# INFLUENCE OF NEURAL MOBILIZATION OF LOWER LIMBS ON THE FUNCTIONAL PERFORMANCE AND DYNAMIC BALANCE IN ASYMPTOMATIC INDIVIDUALS: A CROSS-OVER RANDOMIZED CONTROLLED TRIAL

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ABSTRACT
**Purpose.** To verify the influence of neural mobilization (NM) applied to the lower limbs on functional performance and dynamic balance in asymptomatic individuals.
**Methods.** The total of 30 asymptomatic participants (15 women and 15 men; age, $30.1 \pm 6.7$ years; height, $1.70 \pm 0.1$ m; body mass, $73.1 \pm 13.4$ kg) were enrolled in this cross-over randomized controlled trial. The participants received NM of the femoral, sciatic, and tibial nerves, as well as static stretching (SS) of the following muscles: hamstring, lumbar, piriformis, hip adductors, hip flexors, quadriceps, and triceps surae. The order of applying NM and SS was randomly decided and the interventions were performed at least 48 hours apart. Functional performance was measured by performance in vertical jump (VJ) and dynamic balance was measured with the Star Excursion Balance Test (SEBT).
**Results.** There were no differences between NM and SS for height (cm) in VJ ($p = 0.16$) or in the distance reached (%) in the SEBT, normalized by lower limb length (dominant limb: anterior, $p = 0.35$; posterolateral, $p = 0.69$; posteromedial, $p = 0.50$ / non-dominant limb: anterior, $p = 0.68$; posterolateral, $p = 1.00$; posteromedial, $p = 0.77$).
**Conclusions.** NM did not exert any influence on functional performance or dynamic balance. Thereby, having no positive or negative impact on performance, NM can be used at any time of treatment.
**Key words:** nervous system, lower limbs, exercise therapy, motor activity, postural balance

## Introduction

Neural mobilization (NM) is a manual technique used to treat and stimulate the nervous system, taking into consideration the tissue's own mobility and its relationship with adjacent structures [1–3]. NM has been recommended for the treatment and prevention of neurodynamic injuries, which are injuries related to the movement and the anatomical path of nerves, such as nerve compressions and adhesions [3]. Because of the movement of the nerve in relation to other structures and its stretching during NM [4–6], it is hypothesized that NM could disperse fluids that are harmful to the nerves and improve the intra-neural circulation and axoplasmic flow [7–9], thus influencing the conduction of nerve impulses.

The randomized clinical trial by Beneciuk et al. [10] showed the effects of NM on nerve conduction of pain in asymptomatic people. The effects of NM were assessed through thermal pain sensation to determine the first identification of pain (A-delta type fibres) and temporal summation (C type fibres) [10]. After the intervention period, no difference was found for perceived pain mediated by A-delta fibres; however, there was significant hypoalgesia in the group that received NM compared with the placebo group in perceived pain mediated by the C fibres. Thus, it can be assumed that NM influences nerve conduction and could potentially impact on the conduction of pain impulses [10].

Therefore, some studies aimed to verify the clinical effects of NM; these were included in the systematic review by Ellis and Hing [3]. In this review, with 11 analysed studies, the authors found that most of the papers reported a positive therapeutic effect with the use of NM. Owing to the moderate methodological quality of the studies, however, the review concluded

that there was limited evidence to support the use of NM. Thus, there is still much to be studied regarding the effects of NM, not only in symptomatic but also in asymptomatic individuals. Among the studies conducted so far, only a few set out to understand the effects of NM on muscles and movements in asymptomatic people [6, 10, 11]. Hypothetically, these people could have neurodynamic alterations [11], and NM could bring some benefits to asymptomatic ones, as a method to prevent injuries or to help improving performance in activities commonly applied in treatment, as strength and sensory-motor training.

Some studies with symptomatic subjects have shown that NM is capable of promoting an increase in strength. Among these is the study by Villafañe et al. [12], which showed that individuals with thumb carpometacarpal osteoarthritis had increased tip pinch and tripod pinch strength compared with the placebo group after treatment with NM. Therefore, it seems that NM could influence nerve conduction and would impact on functional activities and physiological domains, similarly to other manual therapy techniques [13, 14]. Then, it is reasonable to hypothesize that NM could influence the performance of motor actions, such as jumps, by improving the synchronization of muscle fibre recruitment and actions that require balance by enhancing proprioception and reflex reactions. This influence can be either negative, with the reduction of efferent impulses, or positive, with better nerve conduction. Therefore, the present study aimed to verify the influence of NM applied to the lower limbs on functional performance and dynamic balance in asymptomatic individuals.

**Material and methods**

Design

A cross-over randomized controlled trial was performed in which the participants underwent the same assessment protocol under the effect of two different interventions: NM and static stretching (SS). The use of SS was applied as a placebo intervention, therefore the values seen after SS were considered as baseline values. This decision was based on previous studies which showed that short-time SS had no effect on functional performance or dynamic balance [15, 16]. This was done to ensure blinding of the participants. Vertical jump (VJ) was used to assess functional performance, and the Star Excursion Balance Test (SEBT), a unipedal balance test, was applied to assess dynamic balance. Concealed allocation was performed with the use of sealed opaque envelopes prepared by a researcher who was not involved in the recruitment or assessment of the participants (Figure 1).
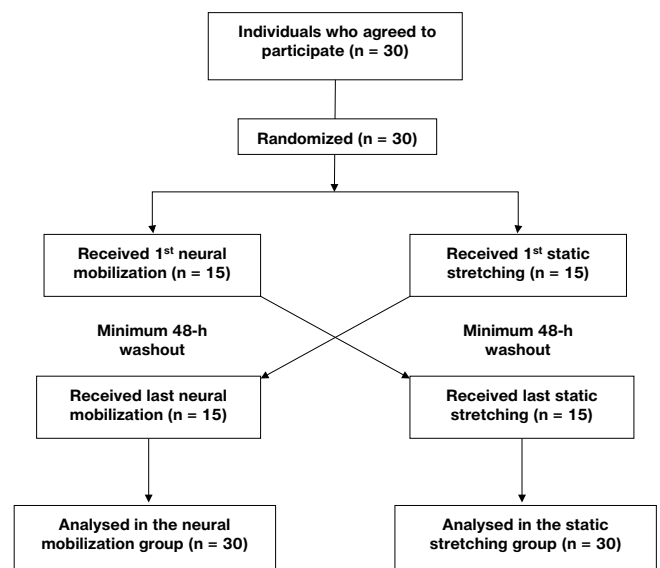


Figure 1. Flow diagram

Participants

A convenience sample of 30 asymptomatic individuals (15 women and 15 men; age, 30.1 [6.7] years; height, 1.70 [0.1] m; body mass, 73.1 [13.4] kg; mean [SD]) were recruited from the community and agreed to take part in the study. To be included, the participants had to be asymptomatic; 18–45 years of age; with no history in the previous year of vestibular or neurological injuries (such as vertigo, regular dizziness, balance disorders, or symptoms of neural compression), musculoskeletal injury (such as fractures, sprains, or low back pain), or any other alterations that would interfere in or contraindicate the measurement procedures of the study. Ethical approval for the study was obtained from the Human Research Ethics Committee of Santa Catarina State University, under the number of 01620812.6.0000.0118; the clinical trial registration number is RBR-3wwt53. Written consent was obtained from all participants prior to data collection.

Procedures

All participants were submitted to two identical assessment batteries, composed of two tests under two different conditions: after the NM of lower limbs and after the placebo technique (SS) of lower limbs. The assessments took place at the Physical Therapy Clinic of the Santa Catarina State University in an isolated room, without external interference. The assessments were conducted at the same time of day, with an interval of at least 48 hours and not more than 1 week between the batteries. This time interval between the test and retest was chosen as it is the time range that would be unlikely to permit a carryover effect from the intervention, with still little chance for major changes in strength and performance due to training or change in life style. The par-

ticipants were instructed to avoid all exercise before the tests, to wear sports clothing, and to have similar amounts of food and water on both assessment days. To reduce bias, the assessor was not involved in the interventions, and the assessment room was not close to the intervention room so that the assessor would not know which intervention the participants received.

Interventions

Firstly, the subjects warmed up on a cycle ergometer for approximately 5 minutes. After that, the envelope with the intervention sequence was opened. The interventions were conducted by therapists who were not involved in the assessments. They had previous clinical experience in manual therapy and received training in NM techniques before the beginning of the study.

*Neural mobilization*

All participants received 2 techniques (slider and tensioner) of NM of the femoral, sciatic, and tibial nerves in the following order: (1) NM of the femoral nerve in the right limb followed by the left limb, 3 sets with a 1-min interval between them; (2) NM of the sciatic nerve in the right limb followed by the left limb, 3 sets with a 1-min interval between them; (3) NM of the tibial nerve in the right limb followed by the left limb, 3 sets with a 1-min interval between them. The NM dose used here was based on previous studies and adapted to attenuate any possible discomfort felt by the participant [3, 17, 18]. NM was applied in a passive manner, and the nerve slides (described below) were performed with small range movements of approximately 10°. This range of motion was selected because even though there is no consensus about the adequate range for sliders, the range of 10° is likely to be sufficient for the technique to be applied, especially when implemented in a pragmatic way. The techniques were used in accordance with the guidelines of the Neuro Orthopaedic Institute with some adaptations; they were performed in a sitting position instead of supine for both the NM of the sciatic nerve and of the tibial nerve [19]:

– NM of the femoral nerve: with the participant in lateral decubitus with underneath hip and knee flexed to 90°, the therapist was positioned behind the participant and extended and adducted their top hip until the level of lumbar lordosis increased and the foot touched the floor. Next, the therapist performed 15 neural slides toward hip extension (Figure 2A). After that, the participant maintained the position and simultaneously flexed the spine and trunk with the therapist's help, holding the stance for 6 seconds (Figure 2B). This NM technique also stimulated the lateral femoral cutaneous nerve.

– NM of the sciatic nerve: with the participant seated with hands on the lumbar region and maintaining lum-

bar lordosis as close as possible to normal, the therapist extended the participant's knee and flexed the hip, while adducting and internally rotating the hip until the maximum tolerated stretch of the back thigh muscles. In this position, the therapist performed 15 neural slides toward hip flexion (Figure 2C). After that, the participant maintained the position and simultaneously flexed the spine and trunk with the therapist's help, holding the stance for 6 seconds (Figure 2D).

– NM of the tibial nerve: with the participant seated with hands on the lumbar region and maintaining lumbar lordosis as close as possible to normal, the therapist passively extended the participant's knee and flexed the hip, while adducting and internally rotating the hip until the maximum tolerated stretch of the back thigh muscles. In this position, the therapist performed 15 neural slides toward ankle dorsiflexion with pressure on the lateral side of the foot to also perform ankle ever-
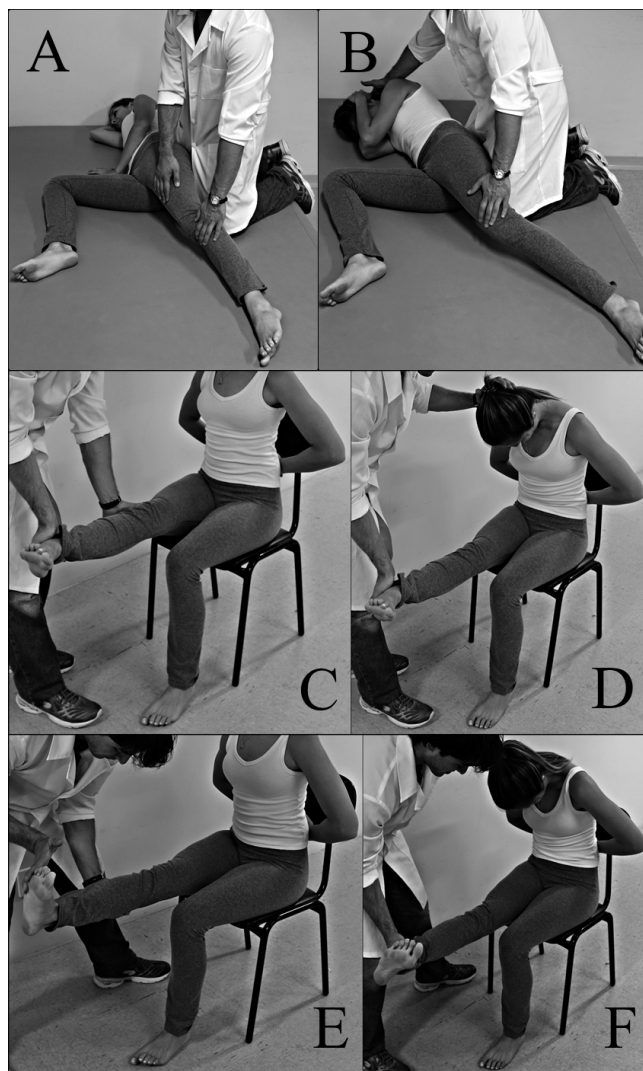


Figure 2. Neural mobilization techniques.
A. Neural slide of femoral nerve. B. Neural stretching of femoral nerve. C. Neural slide of sciatic nerve.
D. Neural stretching of sciatic nerve. E. Neural slide of tibial nerve. F. Neural stretching of tibial nerve

sion (Figure 2E). After that, the participant maintained the position and simultaneously flexed the spine and trunk with the therapist's help, holding the stance for 6 seconds (Figure 2F).

*Static stretching*

SS was intended to be used as a placebo treatment given that, in some studies, short-time stretching did not influence performance in jumps or balance [15, 20]. All participants received the same type of stretching in the order described below, twice in each muscle group of both lower limbs, and maintained for 30 seconds in each repetition [15, 21]:

– SS of the hamstring muscles: in supine position with fully extended lower limbs, the participant used a band placed on the heel to raise one limb while maintaining knee extension until the hamstrings felt stretched [22].

– SS of the lumbar muscles: in supine position with knees slightly bent, the participant flexed the hip and knee of one lower limb, bringing it toward the chest [22].

– SS of the piriformis muscle: in supine position with one ankle over the opposite knee, the participant pulled the opposite knee toward the chest [22].

– SS of hip adductors: seated on the floor with lower limbs flexed, hip abducted and externally rotated, and soles of feet touching each other, the participant pushed the knees down toward the ground [22].

– SS of hip flexors: in the lunge position, the participant extended the hip until the iliopsoas and rectus femoris felt stretched [22].

– SS of quadriceps: standing up, the participant flexed one knee, reached for the forefoot and held it, bringing the heel as close as possible to the gluteus until the quadriceps felt stretched [22].

– SS of triceps surae: the participant performed a lunge movement, pressing the heel of the back limb toward the ground and keeping its knee straight until the triceps surae felt stretched [22].

Tests

Immediately after the interventions, the participants were taken to another room for the tests, which were applied by a single investigator to assess dynamic balance (SEBT) and functional performance (VJ height). The subjects received instructions as described below and were allowed to perform as many attempts as necessary until they felt comfortable with the procedure. No participant performed the familiarization procedure more than twice.

*Functional performance*

It was assessed with the estimation of VJ height, by measuring flight time with the use of a force platform (EMG System do Brazil Ltda, the Biomec 400 model). This measure has high reliability (intra-class correlation coefficients [ICC] ranging from 0.82 to 0.97) [23]. The participant maintained the bipedal stance on the platform with hands on hips and performed the highest possible jump with countermovement (countermovement jump). During the trials, the subject was verbally encouraged to jump as high as possible. Three valid jumps were recorded, with a minimum 1-min rest allowed between them. The jumps were considered invalid if the participants used the upper limbs to perform the jump, if they landed outside the platform, or if they flexed the hip and/or knee during the flight phase of the jump. To calculate the jump height, the following formula was used:

$$h = 0.5 \ (t/2)^2 \ g$$

where h is the jump height in meters, t is the flight time in seconds, and g is the acceleration of gravity, considered as 9.81 m/s$^2$ [24].

*Dynamic balance*

It was assessed by the SEBT [25]. This test has high reliability (ICC ranging from 0.84 to 0.92) [26]. Initially, the participant maintained a single leg stance on the assessed lower limb at the intersection of three lines drawn on the floor extending in 3 directions relative to the participant: anterior (SEBT Ant), posterolateral (SEBT PL), and posteromedial (SEBT PM). The position of the supporting foot was controlled by keeping the third toe aligned with the anterior line drawn on the floor and the projection of the fifth metatarsal over the intersection. The participant was instructed to touch each line as far as possible with the hallux of the opposite foot, and the distance they reached was recorded. The procedure was repeated 3 times in each direction for each limb. For data analysis, the distance reached was normalized by dividing it by the length of the lower limb and multiplying by 100. Lower limb length was considered as the distance between the anterior superior iliac spine and the medial malleolus. This measure was performed with the participants lying in supine position [27].

Statistical analyses

The size of the paired sample was predetermined on the basis of the difference of 2 cm in the VJ between the groups. The power calculation proved that a sample of 26 participants per group was necessary for an 80% probability of detecting the difference of 2 cm in the VJ, assuming a standard deviation of 3.5 cm, with alpha of 5% [28].

For data analysis, the mean of 3 valid trials was considered in each assessment. Descriptive statistics were

used to calculate the mean and standard deviation of the collected data. Analysis of variance for repeated measures was utilized to determine the specific impact of the order of interventions on results. The Student t-test for dependent samples was applied to analyse the results. The significance level was set at 0.05 (5%). The analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 17.0 (SPSS Inc., Chicago, IL, USA).

## Ethical approval

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

## Results

All participants completed both assessments in accordance with the randomization (Figure 1). The analysis of variance showed no carryover effect (no interaction) at any moment of the interventions.

The results of the main statistical analysis revealed that NM applied to lower limbs had no influence on functional performance or dynamic balance. The comparison between NM and SS did not present significant differences in the performance of VJ or SEBT (Table 1). NM was bound with 1.2% lower flight time and 2.6% lower height of VJ compared with SS. For all directions of SEBT, the differences between conditions were lower than 0.8% (Table 1).

## Discussion

The present study investigated the influence of NM applied to the lower limbs of asymptomatic individuals. The results showed that NM did not exert any influence on functional performance or dynamic balance as compared with the method used in the placebo group. It did not increase VJ height or performance in the SEBT, nor did it hinder performance in the VJ or the SEBT.

The performance of any motor action requires integrity of the entire nervous system, not only in terms of continuity for the conduction of nerve impulses, but also mechanical integrity with the surrounding tissues, allowing mobility in relation to adjacent structures [1]. The structures of the nervous system cross several bodily interfaces that can compromise adaptations to movement, such as tunnels, inflexible interfaces, and tension points. That may leave the nervous system vulnerable to trauma due to friction, compression, and stretching, hampering nerve impulse conduction and compromising function.

Therefore, applying NM to treat or prevent these alterations could have some influence on motor performance, as it could reduce compressions and adhesions that compromise nerve conduction, thus improving muscle recruitment. One of the main reasons for an improved performance of a motor action is the recruitment of additional motor units through neural adaptations to the stimuli of the imposed loads [29]. Increased motor unit recruitment may result from synchronization of nerve impulses, reaching the necessary threshold, facilitating contraction, and increasing the muscle's force-generating capacity [29]. NM may help in this synchronization of nerve impulses. The study by Legakis and Boyd [30] revealed that the depression of the scapula during upper limb neurodynamic testing (ULNT) increased the neural tension during the test and raised the muscle activity of the superior fibres of the trapezius in asymptomatic participants.

Even though it is usually applied to people with symptomatic neurodynamic changes, in the present study it was hypothesized that NM could bring some functional benefit in asymptomatic people. This technique was not applied as treatment, but as an intervention that could perhaps improve performance and as a method to possibly prevent neural shortening and tension. However, the study did not indicate that NM improved motor function as compared with the method used in the placebo group. The results might be related to the characteristics of the applied tests. VJ encompasses great muscular

Table 1. Comparison between neural mobilization and static stretching; data shown as means (*SD*)

|  | NM | SS | Mean difference | 95% CI of the difference | *p* Values |
|---|---|---|---|---|---|
| Flight time (ms) | 421.5 (75.0) | 426.8 (79.6) | –5.27 | –11.66 to 1.13 | 0.15 |
| Vertical jump (cm) | 22.5 (8.4) | 23.1 (9.0) | –0.63 | –1.32 to 0.07 | 0.16 |
| DB in SEBT Ant (dominant, %) | 81.5 (7.2) | 82.1 (6.6) | –0.66 | –2.09 to 0.77 | 0.35 |
| DB in SEBT Ant (non-dominant, %) | 81.9 (6.8) | 82.3 (7.0) | –0.37 | –2.19 to 1.44 | 0.68 |
| DB in SEBT PM (dominant, %) | 87.6 (8.1) | 88.3 (10.0) | –0.73 | –2.92 to 1.47 | 0.50 |
| DB in SEBT PM (non-dominant, %) | 87.2 (8.9) | 87.6 (9.3) | –0.35 | –2.75 to 2.05 | 0.77 |
| DB in SEBT PL (dominant, %) | 82.4 (8.2) | 81.8 (10.3) | 0.54 | –2.19 to 3.27 | 0.69 |
| DB in SEBT PL (non-dominant, %) | 82.4 (8.6) | 82.4 (9.3) | 0.009 | –2.89 to 2.91 | 1.00 |

NM – neural mobilization, SS – static stretching, DB – dynamic balance, SEBT – Star Excursion Balance Test,
Ant – anterior, PM – posteromedial, PL – posterolateral

action, which demands muscle power, strength, and contraction coordination of many muscles, such as quadriceps, hamstring, and triceps surae [29]. SEBT, as a balance test, depends on complex reflex responses, as well as requires action from many muscles to recover or maintain postural control [27]. Perhaps the possible effects of NM are limited to single muscles or actions with less complexity, such as improving fingers strength [12] or decreasing delayed onset muscle soreness in the biceps brachii muscle [31]. Furthermore, the isolated application of NM in asymptomatic individuals might not be enough to provide benefits. The association of NM and other techniques could be an option, as Sharma et al. [32] have reported. In their study, NM associated with SS turned out more effective than SS alone to increase hamstring flexibility of healthy individuals [32]. Nevertheless, there is still no evidence that NM has any effect on motor control in asymptomatic individuals, mostly because there are very few studies investigating such possibility.

According to recent studies, the NM technique is able to influence physiological parameters. Studies that analysed dosages of the technique similar to that used in the current study (5 series of 10 sliders [18] and 5 seconds of tension hold [17]) showed positive results on pain and sensitivity. However, the applications were performed more than once and that difference between the studies could help to explain the lack of positive results observed in the present study. It is possible that a single treatment session is not enough to cause any alteration to the nervous system; however, to see whether a single session was enough to cause any functional change was one of the study objectives. Another possibility is that there were physiological changes, but not large enough to be reflected in a functional change.

A probable explanation for the lack of significant differences in the present study could come from the technique used in the placebo group; however, we based our choice on previous results that showed no effect of short-time stretching with regard to activities involving balance or jumps [15, 16]. Another possible explanation for the present study results is related to the assessments. More sensitive and specific methods, such as isokinetic and EMG tests, might be able to detect changes resulting from NM. However, the study is probably the first one to investigate whether NM can increase performance and balance, and even though we found no effect from NM, further investigations in this field might improve the knowledge about the impact of NM on motor control.

## Conclusions

The results of our study showed that NM did not have any influence on functional performance or dynamic balance in asymptomatic individuals as compared with the method used in the placebo group. The lack of significant differences between the two groups does not endorse the use of NM when the objective is to improve motor function and postural control in asymptomatic individuals. However, NM can be applied in order to prevent neural shortening and tension prior to physical activities or treatment, particularly the ones involving jumps and balance activities, as NM does not influence these performances. Therefore, future studies should investigate the effects of NM on injury prevention and treatment of musculoskeletal affections.

## Conflict of interest

Authors state no conflict of interest.

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