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Inmediate effects of Ultrasound-guided Percutaneous Neuromodulation vs physical exercise in performance Flexor Hallucis Longus Muscle in proffesional dancers: a randomized clinical trial.

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Complete List of Authors:	De la Cruz, Blanca; UNIVIVERSITY OF SEVILLE, PHYSICAL THERAPY BARRERA, IRENE; UNIVERSITY OF SEVILLE, PHYSIOTHERAPY Albornoz-Cabello, Manuel; University of Seville, Physical Therapy
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Authors:

Blanca de la Cruz Torres[1]

[1] Department of Physiotherapy, University of Seville. Avicena Street, 41009, Seville, Spain.

bcruz@us.es

Irene Barrera García-Martín

[1] Department of Physiotherapy, University of Seville. Avicena Street, 41009, Seville, Spain.

irebargar@gmail.com

Manuel Albornoz-Cabello[1]

[1] Department of Physiotherapy, University of Seville. Avicena Street, 41009, Seville, Spain.

malbornoz@us.es

Word count: 2722

CORRESPONDING AUTHOR

Blanca de la Cruz Torres

University of Seville

Avicena street, 41009, Seville (Spain)

bcruz@us.es; Tel: 00 34 666676870

ABSTRACT

Background. Ultrasound-guided Percutaneous Neuromodulation (US-Guided PNM) is a minimally invasive intervention consists in the applicacion of a percutaneous electrical stimulation (PES) through an acupuncture needle-like electrode that is placed in close proximity to the nerve or motor point of the muscle with ultrasound guidance.

Objetive. To examine the immediate effects of a Stretching exercise, an Eccentric exercise and an US-Guided PNM in performance of the Flexor Hallucis Longus muscle in young dancers.

Methods. Randomized clinical trial**.** 45 dancers were divided into three groups: Stretching group, Eccentric group and PNM group. The following performance parameters were assessed: range of motion of first metatarsophalangeal joint, balance test and unilateral heel raise fatigue test.

Results. There were no differences between these groups in the baseline measurements; at the end of the study, mean balance and endurance values were only significantly higher for the PNM group compared to the Stretching ($p=0.007$ and $p<0.001$, respectively) and Eccentric groups ($p=0.003$ and $p<0.001$, respectively). The effect sizes were large for balance ($d=0.8$) and endurance test ($d=1.83$) in PNM group.Both Stretching and Eccentric groups improved ROM compared to their baseline values ($p=0.009$ and $p=0.004$, respectively), whereas there was no significant improvement noted for the PNM group. The effect sizes were moderate for Stretching ($d=0.6$) and Eccentric exercise ($d=0.7$) in ROM value.

Conclusion. An isolated PES intervention provides a greater immediate increase in balance and muscular strength than an active stretching and eccentric exercise of the FHL muscle in young ballet dancers. This technique is complementary to voluntary training.

Key words: percutaneous neuromodulation, Flexor Hallucis Longus, dancer, performance.

TEXT

INTRODUCTION

Ballet dancers are high-performance athletes who are particularly susceptible to a wide variety of musculoskeletal injuries. Several authors found that the most common locations of injury were lower extremities in ballet dancers.[1-3]

Tendinopathy of the flexor hallucis longus (FHL), colloquially referred to as "dancer's tendinitis," is a common condition in dancers and attributed to high demand on this muscle in positions of extreme ankle plantarflexion and metatarsophalangeal (MTP) flexion and extensión.[4,5] In positions of extreme ankle plantarflexion and MTP range of motion (ROM) demanded by dance technique, the FHL stabilizes the foot and contributes significantly to balance;[6] for this reason it is sometimes called the dancer´s Achilles tendon (4). While the FHL tendinopathy also is present in non-dancers, the condition is more severe in dancers, with 3 times longer symptom duration and 71% prevelance of tendon tears (30% in non-dancers).[7]

Dancers with a reduced ability to generate muscle force[8] or with muscle strength imbalances[9] of selected thigh muscles have problems associated with increased lower body and lower back injuries, respectively. Improving muscular strength has been suggested as a way to prevent these injuries.[10] Nevertheless, research has revealed that certain forms of dance elicit limited stimuli for fitness enhancement[11] and that dancers in general are not as physically well conditioned as equivalent athletes.[12-14]

Techniques involving puncture of the skin are common in physiotherapy. Theses procedures may use a mechanical stimulus, as in acupuncture or dry needling,[15,16] or apply electrical current as in electroacupuncture,[17] stimulation of myofascial trigger point[18] or electrostimulation using galvanic current.[19] Clinically, an invasive technique has appeared, known as Ultrasound-guided Percutaneous Neuromodulation (PNM).[20] This minimally invasive intervention consists in the applicacion of a percutaneous electrical stimulation (PES) through an acupuncture needle-like electrode that is placed in close proximity to the nerve or motor point of the muscle with ultrasound guidance. At the clinical level, the PES is always used with the therapeutic aim of relieving chronic pain[21-24] and neuropathic pain.[25-27] Similarly, in sports, PES is used with the aim of improving muscular activity.[28-30] Therefore, according to the characteristics and the therapeutic benefits of this technique, further research is needed to discover multiple clinical indications.

In dance, strength training has not been generally considered necessary for a successful career. This partly reflects a fear that increased muscular strength would diminish a dancer's aesthetic appearance. However, there are few data that are directly relevant to dancers and strength training. Terefore, the aim of this study was to examine the immediate effects of the different physical procedures in performance of the FHL muscle in professional dancers. Finding from this study may provide further evidence for the relevance of performance dance and to prevent the lower limb injuries.

METHODS

Participants. 45 professioanl ballet dancers were recruited, from the same company volunteered, for the study (Tabla 1), divided randomly into three groups, each comprising 15 dancers: a Stretching group, an Eccentric group and an US-Guided PNM group. Exclusion criteria were: (a) they had sustained an injury to their stance limb in the past year preventing dancing for at least 1 day; (b) a Personal Psychological Apprehension Scale (PPAS) score >37.5;[31] (c) commonly accepted contraindications to invasive phsyiotherapist technique including chronic joint disease, surgery, prosthesis or osteosynthesis in the area of intervention, cardiac disease, neoplasia, coagulopathy, and use of certain drugs (fluoroquinoles, anticoagulants, corticosteroids or non-steroidal anti-inflammatories);[20] (d) any contraindications to needling per se including insurmountable fear of needles, history of adverse reaction to needling, immunocompromise, difficulty expressing feelings appropriately and/or allergy to metals;[20] and (3) epilepsy. All particiants were female in order to eliminate effects of difference in dance technique and training between sexes, becasuse this overuse injury most often affects female ballet dancers and because female dancers work en pointe while male dancers usually do not.[33] Measurements were taken on each participant´s stance limb, defined as the limb contralateral to the preferred kicking limb, because this is also the dancers´ preferred balancing limb while gesturing with the controlateral, and all testing was performed barefoot.

The local ethics committee approved the study, which complied with all the principles set out in the Declaration of Helsinki. Australian New Zealand Clinical Trials Registry ACTRN12617000794303. All subjects signed informed written consent forms to participate in this study. The recruitment period was from July 22 to October 31, 2017. Figure 1 provides a flowchart of subject recruitment during the study.

	Stretching Group	Eccentric Group (n=15)	PNM Group (n=15)	p value

	(n=15)			
Age (yrs)	20.53±4.07	19.40±3.07	21.00±3.07	0.43
Height (m)	166.40±5.41	166.73±5.70	163.40±6.05	0.28
Weight (Kg)	53.20±4.91	54.67±4.67	54.63±6.82	0.74
BMI (Kg/cm^2)	17.15±2.91	17.99±2.62	18.43±4.12	0.07
Dance hours/week	27.67±4.58	31.00±6.32	31.00±5.07	0.16
Pointe hours/week	6.73±0.79	7.27±0.42	7.10±0.51	0.05
Dance training (yrs)	9.80±3.51	10.60±3.27	10.00±3.02	0.79

Table 1. Participant characteristics. Data given as mean±SD. p values ($p<0.05$)

Procedures

All subjects filled in the PPAS, the general aim of which was to measure the psychological apprehension of the subjects during electrophysiotherapeutic treatment. This scale evaluates, by means of the opinion and self-positioning of the subjects, an individual´s degree of apprehension to the application of an electrical current.[31] According to Rowley et al.[32] we used three test and the order was: ROM of the first MTP joint, balance and endurence test of the FHL muscle. Before and just after the interventions all volunteers were subjected to the aforementioned assessments.

Subsequently, all physical measurements were obtained by a trained phisiotherapist who were blinded to each subject's group allocation.

- *ROM of the first MTP joint* was evaluated using functional MTP joint extensión with maximal ankle plantarflexion in sitting position. For all measures, the stationary arm of the goniometer was aligned patallel to the support surface with the axis over the medial aspect of the first MTP joint. The moving arm was aligned with the medial midline of the first metatarsal. The participant was seated in a chair with the entire foot flat on the ground. The participant was asked to keep the toes on the floor and extend the first MTP joint by lifting the proximal part of the foot over the toes until maximun range was reached, and the measurement was recorded. The examiner ensured that the entire toe and the base of the first metatarsal remained on the floor during the movement. For each measurement, three trials were recorded and averaged. Within-session intra-rater reliability was established on the first 10 dancers as sufficient for clinical measurement (ICC = 0.92).
- *Balance test*. Participants balanced in unilateral stance heel raised (demi-pointe) and eyes open, until fatigue, defined by the full foot support on the floor.
- *Endurance test*: a modified unilateral heel raise fatigue test was done on a stable block with the participant´s toes off the edge of the block. The purpose of this set-up was to remove any force transmision by the FHL and isolate the larger ankle plantarflexors. Heel raises were performed to a metronome tempo of 30 beats/min. Light touch on a adjacent wall was allowed to assist whith balance. The number of heel raises completed until fatigue, defined by the failure to maintain the tempo or heel height for at least three consecutive raises, was reported.

Interventions

US-Guided Percutaneous Neuromodulation. Dancers in the US-Guided PNM Group received the PES intervention. Specifically, this consisted in the application of a square wave biphasic electrical current, with 10Hz frequency, a 250µs pulse width, and the maximal tolerable intensity to cause an exacerbated muscle contraction for a total of 1.5 mins, according to the protocol by Valera and Minaya.[20] A specifically developed medically certified device (Physio Invasiva®, PRIM Fisioterapia y Rehabilitación, Spain) was used. The subject lay prone with her feet outside the table. The FHL muscle was located at 50% of the distance between the fibular head and inferior border of the lateral malleolus on the posterior aspect of the fibular by ultrasound machine (cross-section) (Logiq, GE Healthcare, USA) and then, a needle (0.30mm x 0.40mm) was inserted, perpendicular to the surface of the skin, into the muscle belly (Figure 2, a-c). Prior to inserting a neddle, the underlying skin was cleaned with isopropyl alcohol. A physiotherapist with years 5of experience in invasive therapy administered the PES intervention.

Static Stretching Group. Dancers in this group performed static stretching exercise of the FHL muscle. These were based on the recognition that the maximal distal excursion of the FHL occurs when both the ankle and first MTP joint are dorsiflexed and the first metatarsal is stabilized in the neutral position. The dancer stood facing the wall while placing a book of appropriate height under the hallux, which places the first MTP into dorsiflexion. With the heel kept on the floor, the ankle was maximally dorsiflexed by bending the knee. The maximally dorsiflexed position was held for 20 seconds, then the patient resumed the starting position. This was repeated 4 times (Figure 2, e). During the 20-second stretching, the therapist supervised the dancers to make sure they did not make any compensation that would alter the stretching position.

Eccentric Group. Dancers in this group performed eccentric exercise of the FHL muscle. The dancer placed the foot the same way as the Stretching Group. The dancer performed 4 sets of flexion-extension 20 repetitions of hip, knee, ankle and first toe (Figure 2, d). These exercises perform the stretching-shortening cycle, using their own bodyweight.

The three interventions were performed 1.5 minutes, to homogenize the applications, on stance limb.

Statistical analysis.

Descriptive statistics (mean, stan- dard deviation, 95% CI) were calculated for pretest and posttest ROM, balance and endurance averaged values for the 3 groups. ROM responsiveness data were calculated using the between-session ICC established in this study (ICC=0.92).[34] The normality of the data distribution was evaluated using the Shapiro-Wilk test. Data was first analyzed using a two-factor repeated measures analysis of variance (ANOVA) with three between-group factor (Stretching group versus Eccentric group, Stretching group versus PNM group, Eccentric group versus versus PNM group) and one within-group factor (baseline versus intervention). The Bonferroni post-hoc test was used for multiple comparisons. Within-group size effect was calculated using Cohen d coefficient.[35] An effect size greater than 0.8 was considered large, around 0.5 was moderate, and less than 0.2 was small. All statistical analyses were performed using SPSS version 21 and significance levels were set at $p<0.05$.

RESULTS

There were no significant baseline differences between the Stretching group, Eccentric group and PNM group in any participant characteristics variables including age (20.53±4.07 vs. 19.40±3.07 vs. 21.00±3.07 years), weight (53.20±4.91 vs. 54.67±4.67 vs. 54.63±6.82 kg), height (166.40±5.41 vs. 166.73±5.70 vs. 163.40±6.05 cm), body mass index (17.15±2.91 vs. 17.99±2.62 vs 18.43±4.12), dance hours a week (27.67±4.58 vs. 31.00±6.32 vs. 31.00±5.07 hours), pointe hours a week (6.73±0.79 vs. 7.27±0.42 vs. 7.10±0.51 hours) and dance training (9.80±3.51 vs. 10.60±3.27 vs. 10.00±3.02 years). On the PPAS scale, the Stretching, Eccentric and PES groups scored 20.13±4.00, 21.20±4.83 and 22.47±5.63 ($p>0.05$ for all comparisons).

Descriptive statistics are provided in Table 2. The Stretching group had a pretest mean range of 103.40º for the ROM (95% CI: 101.02–105.77), 24.34 s for the balance (95% CI:20.55-28.13) and 16.87 rep for the endurance (95% CI:14.93-18.81) and posttest mean range of 104.73º for the ROM (95% CI: 101.87-107.60), 25.38 s for the balance (95% CI:19.87-30.89) and 18.20 rep for the endurance (95% CI: 16.17-20.23). The Eccentric group had a pretest mean range of 104.73º for the ROM (95% CI: 102.81-106.66), 21.27s for the balance (95% CI: 14.42-28.11) and 19.67 rep for the endurance (95% CI:16.80-22.53) and posttest mean range of 106.20º for the ROM (95% CI:104.08-108.32), 23.48 s or the balance (95% CI:17.98-28.99) and 18.13 rep for the endurance (15.06-21.21). Finally, the PNM group had a pretest mean range of 104.00º for the ROM (95% CI:102.05-105.95), 26.92 s for the balance (95% CI: 16.64-37.21) and 19.67 rep for the endurence (95%CI:16.78-22.54) and posttest mean range of

104.07º for the ROM (95% CI: 102.47-105.67), 41.96 s for the balance (95%CI:30.93-53.00) and 33.40 rep for the endurance (95% CI:28.30-38.50).

ROM (º)	Time	Mean±SD	Difference between before and after ±SD	95% CI of the difference	
				Lower bound	Upper bound
Stretching Group	Basal	103.40±4.29	-1.33±1.72	-2.28	-3.82
	Post	104.73±5.18			
Eccentric Group	Basal	104.73±3.47	-1.47±1.64	-2.37	-5.57
	Post	106.20±3.82			
PNM Group	Basal	104.00±3.53	-0.07±1.43	-0.86	0.73
	Post	104.00±4.07			

Balance test (s)	Time	Mean±SD	Difference between before and after ±SD	95% CI of the difference	
				Lower bound	Upper bound
Stretching Group	Basal	24.34±6.84	-1.04±8.61	-5.81	3.73
	Post	25.38±9.95			
Eccentric Group	Basal	21.27±12.36	-2.22±8.88	-7.14	2.70
	Post	23.48±9.95			
PNM Group	Basal	26.92±18.58	-15.04±10.52	-20.86	-9.21
	Post	41.96±19.93			

Endurance test (rep)	Time	Mean±SD	Difference between before and after ±SD	95% CI of the difference	
				Lower bound	Upper bound
Stretching Group	Basal	16.87±3.50	-1.33±3.01	-3.00	3.37
	Post	18.20±3.67			
Eccentric Group	Basal	17.73±5.06	-0.40±3.04	-2.08	1.28
	Post	18.13±5.55			
PNM Group	Basal	19.67±5.18	-13.73±6.43	-17.29	-10.17
	Post	33.40±9.21			

Table 2: Mean ROM, balance and endurance test values pre- and post-intervention for each of the 3 groups with associated standard deviations (SD), mean differences over time, and associated 95% con dence intervals (CI).

There were no differences between these groups in the baseline measurements (all p>0.05); however, at the end of the study, the groups were significantly different. Mean balance and endurance values were only significantly higher for the PNM group compared to the Stretching (p=0.007 and p<0.001, respectively) and Eccentric groups (p=0.003 and p<0.001, respectively) (figure 3). The effect sizes were large for balance (d=0.8) and endurance test (d=1.83) in PNM group. Both Stretching and Eccentric groups improved ROM compared to their baseline values (p=0.009 and p=0.004, respectively), whereas there was no significant improvement noted for the PNM group (p>0.5). The effect sizes were moderate for Stretching (d=0.6) and Eccentric exercise (d=0.7) in ROM value.

DISCUSSION

The main finding of this study was that an isolated PES intervention provides a greater immediate increase in balance and muscular strenght than static stretching exercise and eccentric exercise of the FHL muscle in ballet dancers. We think that: (a) according to

Rowley et al,[32] dancers performed worse on the endurance test than non-dancers. PES intervention caused that our dancers obtained similar values compared to the non-dancer (33.40±9.21 vs 28.20±7.30); (b) PES intervention decreased muscle fatigue because dancers increased the balance in unilateral stance heel raised (demi-pointe); (c) both Stretching and Eccentric groups improved ROM compared to their baseline values, although there were no significant differences between three groups after the interventions. This was because the degrees of ROM that our dancers reached was very high (104.00±3.53), compared to the non-dancers (91.15±9.50), and within the normality, according to Rowley et al.[32] It would be interesting to study these techniques in dancers with a low ROM by any pathology.

Strength may be defined as the capacity to exert force under a particular set of biomechanical conditions. Empirical and objective data suggest that muscles can undergo adaptations to physical training, resulting in increased maximal tensile strength. Improvements in the muscle's ability to generate force seem to be a way for dancers to enhance their performance.[14] However, although many research articles have been published on muscular strength, there are few that are directly relevant to dance. Koutedakis and Sharp[36] assess the effects of 12 weeks of quadriceps and hamstring strength training on torque levels after a dance exercise and on selected anthropometric parameters and their results suggested that supplementary strength training for hamstring and quadriceps muscles is beneficial to professional ballerinas and their dancing.

The relevance of this finding to clinical practice lies in the benefit of the PES technique to improve the FHL muslce performance and to increase the dance performance. Lower extremity injuries are a common occurrence among dancers of all genres, especially ballet dancers. Selecting effective treatments which may minimize time away from training and performing are important to dancers. Although a full understanding of the exact physiological mechanism of action is not complete, there is evidence to suggest favorable local biomechanical changes may occur. Pain relief from PES as sensed through paresthesia is mediated by Aß fibers; however, the mechanism of segmental pain relief may share similar pathways spinal cord stimulation (SCS) as the same by Aß fibers traverse the dorsal columns.[37] It has been hypothesized that PES may affect local concentrations of biochemical mediators that enhance the pain response. Biochemical mediators of pain such as neurotransmitters an endorphins lead to increased local blood flow that may contribute to the development of chronic pain. Studies have suggested that PES may directly inhibit pain neurotransmission, possibly, through alteration of local inflammatory mediators, as demonstrated by studies in healthy human volunteers, whereby elevated pain thresholds were observed during direct peripheral nerve stimulation.[38]

In conclusión, an isolated PES intervention provides a greater immediate increase in balance and muscular strength than an active stretching and eccentric exercise of the FHL muscle in young ballet dancers.

Limitations. This study only examined immediate effects of a single episode and the lack of longer term follow-up should be considered. It is not known how long the observed increase in balance and muscular fatigue might have lasted. It would also be interesting to study the influence of this invasive technique in the improvement of the relevé o pointe tecchique or in the treatment of the FHL tendinopathy in dancers.

Clinical applications

The present data have shown that an isolated PES intervention provides a greater immediate increase in balance and muscular strenght than active stretching and eccentric exercise of the FHL muscle in young ballet dancers. It practically is the first study that shows different tools for the FHL muscle-tendon unit seems to enhance mobility in the first MTP joint and on dance performance and hopefully helps to prevent a FHL tendinopathy. Physical therapies of dancers, apart from their technical training in dance, should be encouraged, with special attention to the core and to the musculature specific to the demands. The PES treatment is complementary to voluntary training and in addition, the method does not specifically develop elasticity in skeletal muscle, and it must be accompanied by a technical workout.

Contributorship statement BdlCT and MAC conceived the study, supervised its design and drafted the manuscript. BdlCT and IBGM contributed to the execution of the study. MAC performed data management and statistical analysis. All authors read and approved the final version of the manuscript.

Competing Interests None declared.

Patient consent Obtained

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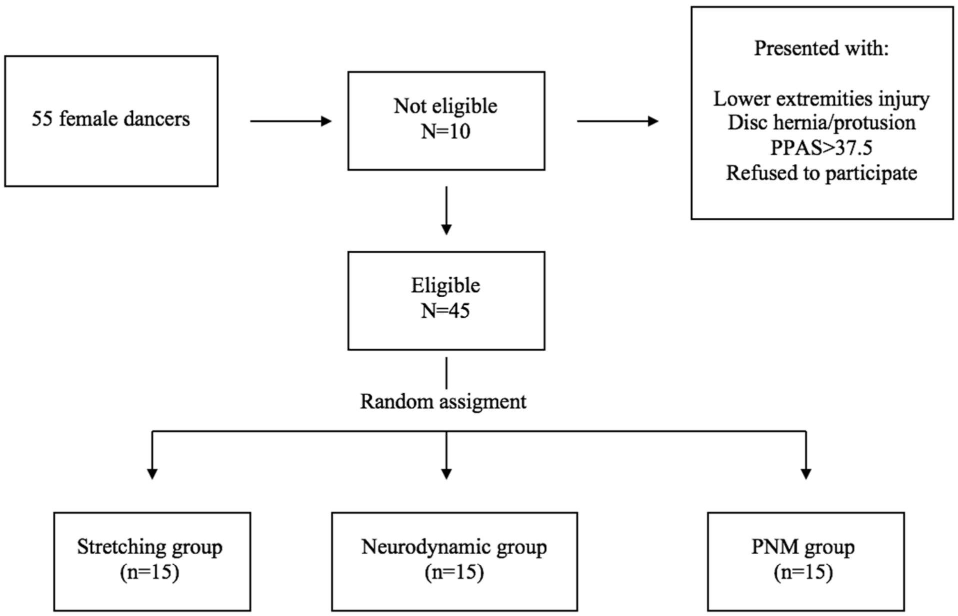

Figure 1: CONSORT flow diagram of dancer recruitment and retention.

194x136mm (144 x 144 DPI)

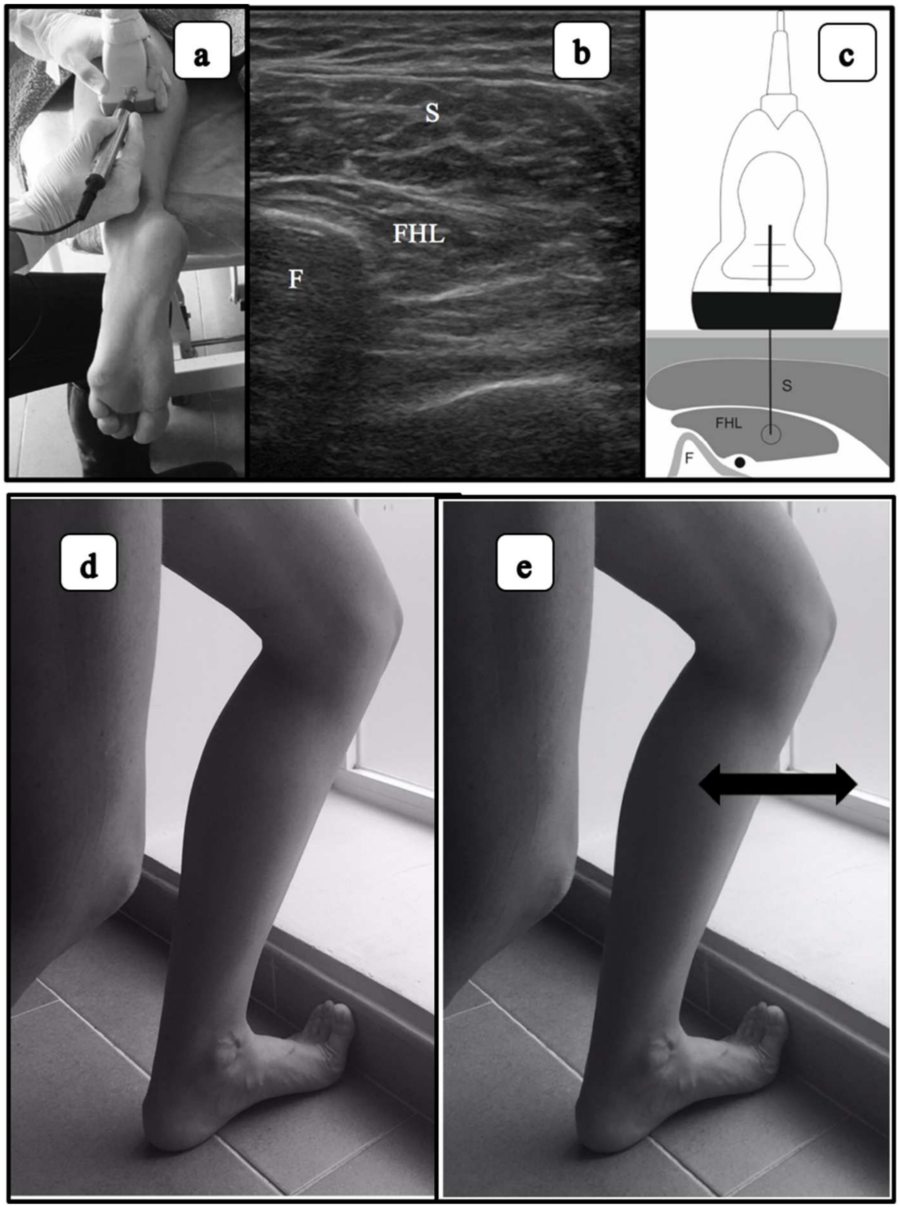

Figure 2: a) Ultrasound-guided PNM intervention in FHL muscle; b) ultrsound image of the intervention. FHL: Flexor Hallucis Longus muscle; S: soleus muscle, F: Fibula; and c) ultrasound-guided of invasive approach of FHL muscle; d) Static stretching exercise of FHL muscle; e) Eccentric exercise of FHL muscle.

149x200mm (144 x 144 DPI)

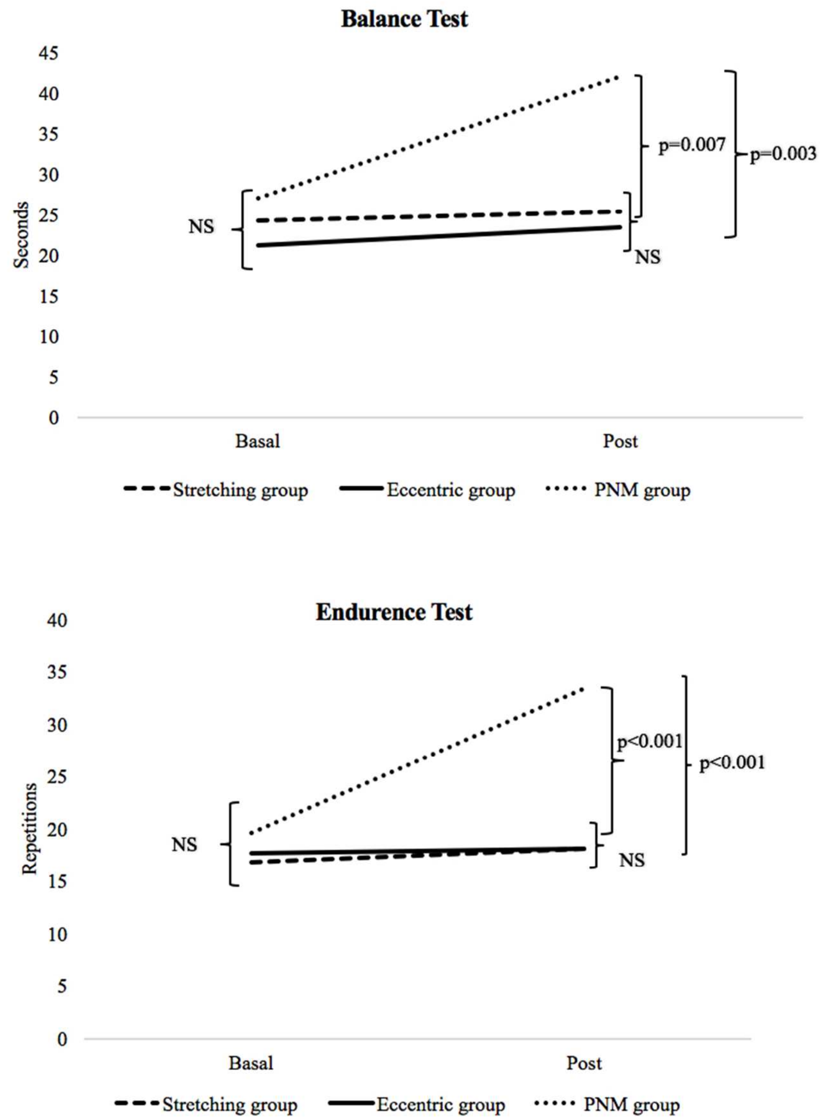

Figure 3: Baseline and post-intervention mean balance and endurence values for the three groups. NS: no significant.

142x188mm (144 x 144 DPI)