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ORIGINAL ARTICLE

Immediate effects of isometric versus isotonic exercise on pain sensitivity and motor performance of ankle plantiflexor muscles

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ABSTRACT

Introduction: This study aimed to quantify the differences on pain sensitivity and motor performance ankle plantiflexor muscles after performing an isometric versus an isotonic exercise task. Method: A parallel experimental trial was carried out at the European University of the Canary Islands. A total of 47 healthy volunteers were recruited and randomly assigned to a group receiving an isometric exercise (n = 23) and a group receiving an isotonic exercise (n = 24). Pain threshold to pressure was measured at four specific points of the triceps surae neurosensory territory in medial gastrocnemius (MG), (2) lateral gastrocnemius (LG), (3) Tendo Achilles osteotendinous unit (TA) and (4) aponeurosis plantar insertion (AP). Furthermore, the two-point discriminatory threshold (2DP) of the osteotendinous junction of the Achilles tendon and maximum voluntary contraction for plantar flexion (MVC-PF) were assessed before and after the intervention. Results: There were no statistically significant intergroup differences for any of the variables PPT-MG (U Mann Whitney = 25; [1.265-0.650], p = .527), PPT-LG (U Mann Whitney = 25; [1.325-0.945]; p = .527) y PPT-TA (U Mann Whitney = 25; [-1.465-0.405] p = .527), D2P (U Mann Whitney = 30.5, IC95% [-0.800-1.300], p = .630) and MVC-PF (U Mann Whitney = 26.5, IC95% [-8.400, 2.900], p = .386). Conclusions: Isometric exercise (Exe_Isom) was the only one able to modify the PPT-AP before and after treatment in a statistically significant way. In contrast, isotonic exercise (Exe_Isot) was the training that demonstrated clinically significant changes in 2PD and MVC-PF before and after treatment. No statistically significant changes were identified between both groups in any of the variables studied.

K**eywords**: Sport Medicine, Ankle, Plantiflexors, Pain, Athletic performance.

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INTRODUCTION

Exercise provides physiological and psychological health benefits. Recent studies show a 13% reduction in the mortality rate, positive changes in psychological aspects such as vitality, mental health, and quality of life. (Carraça et al., 2021; Posadzki et al., 2020) It is usually prescribed in the treatment of musculoskeletal conditions for the improvement of strength and the restoration of function but, without a doubt, one of the main objectives of exercise is the reduction of pain. (Breda et al., 2021) The exercise-induced hypoalgesia (EIH) that can generate a single session of physical activity depends largely on the modalities and intensity with which it is carried out. This response occurs in different modalities of both aerobic and resistance exercise and at different intensities, although some studies indicate that EIH occurs more consistently in healthy subjects after high-intensity exercise. (Naugle et al., 2012).

In any case, these changes are characterized by elevations in thresholds of pain tolerance, as well as as well as a reduction of pain intensity indexes. (Koltyn, 2002; Naugle et al., 2012).

The mechanisms underlying this process are not fully understood, but the hypothesis that acquires more relevance is the one that affirms an activation of the endogenous analgesia system during exercise producing changes in peripheral, spinal, and central sites. (Koltyn, 2002; Rice et al., 2019) Moreover, recent studies show that not only the opioid system is involved in hypoalgesia, but also the endocannabinoid and serotonin systems cooperate in this process. (Crombie et al., 2018; Tour et al., 2017).

Endogenous analgesia system involves the periaqueductal gray matter (PAG), the dorsal horn and the rostral ventromedial medulla (RVM), which constitute a descending pain inhibitory system that facilitates or inhibits non-cerebral stimuli. RVM contains three populations of neurons: ON cells, that enable pain when they are activated, OFF cells, that inhibit nociception by firing, and neutral cells that do not respond to these harmful cells. (Lima et al., 2017).

Physical exercise produces analgesic effects induced by opioids at the central level. In a study where naloxone was administered in MVR and PAG, analgesic effects were blocked. Therefore, when a peripheral antagonist was injected there was not inhibition of analgesia, suggesting that exercise analgesia response depends on central mechanism but not peripheral. (Lesnak & Sluka, 2020; Lima et al., 2017; Sluka et al., 2018). In another study performing water aerobic exercise, it was observed how phosphorylation of the intercellular messenger phospholipase PLCy-1 in the dorsal horn of the medulla leads to a normalization and reversion of hyperactivity of astrocytes and microglia after nerve injury. (Almeida et al., 2015; Lesnak & Sluka, 2020). Apart from the opioids endogenous system, physical exercise also promotes pain relief by increasing the expression of serotonin transporter due to the elevation of serotonin levels (Sluka et al., 2018).

In sedentary conditions, there is less endogenous opioids in the brainstem and, in general, less inhibition. This causes neurons to show greater facilitation after nociceptive input, with increases in phosphorylation of the NR1 subunit of the NMDA (N-Methyl-D-aspartic acid) receptor and increased expression of the serotonin transporter (SERT). Conversely, regular physical activity increases the release of endogenous opioids in the brainstem inhibiting facilitating neurons. This would be associated with a lower phosphorylation of the NR1 subunit of the NMDA receptor and a lower expression of the SERT. In general, in the condition of physical activity there would be more inhibition by opioids, serotonin and less arousal. (Sluka et al., 2018). Another implicated mechanism in EIH is the decreasing in the dorsal horn expression of calcitonin gene related peptide (CGRP). (Ishikawa et al., 2019).

Peripheral nervous system (PNS) may play a critical role regading to EIH. Some studies conducted in animals showed changes in PNS that can be responsible of the EIH. For example, in injuries of peripheral nerves of the lower limb, running on the treadmill promotes reinnervation and attenuates pain by up-regulating adipokines releasing. In another study, daily exercise increased the number of cells in the nucleus pulposus and annulus fibrosus, as well as increased markers of cell proliferation in the intervertebral disc and adjacent epiphyseal cartilage, compared to sedentary controls. All these results indicate that a peripheral damage may be eased or eliminated by exercise through pronociceptive changes in these remote locations. (Lesnak & Sluka, 2020).

Some authors point out that the intensity and duration which the exercise is performed may act as relevant factors in EIH. However, to date no blinded controlled intervention study has been performed comparing the immediate effect of isotonic versus isometric exercise on pain tolerance and motor performance in healthy subjects. In addition, the results that we can obtain would demonstrate which intervention generates more analgesia in the short term and would allow us to open lines of study on subclinical populations that suffer from pain of musculoskeletal origin in the plantar flexor region. The main objectives of our work were to compare the clinical efficacy of an isotonic versus an isometric exercise programme on pain sensitivity and motor output of triceps surae.

METHODS

Study design

A parallel experimental trial was conducted from 11 February 2022 to 1 June 2022 following CONSORT declaration. Researchers P.L.R, and E.C.C. were responsible for administering the written informed consents of all participants included in the study before starting the experiment. The procedure was conducted in accordance with the *Declaration of Helsinki* on Experimentation on Human Subjects.

Participants

Healthy volunteers belonging to the community of students and workers of the European University of the Canary Islands (Santa Cruz de Tenerife, Spain) were selected using a consecutive non-probability sampling technique from May 12, 2022 to May 24, 2022. Patients were contacted using word-of-mouth technique and publication on bulletin boards and social networks of the study researchers, inclusion criteria and main objectives. See Figure 1.

Inclusion criteria

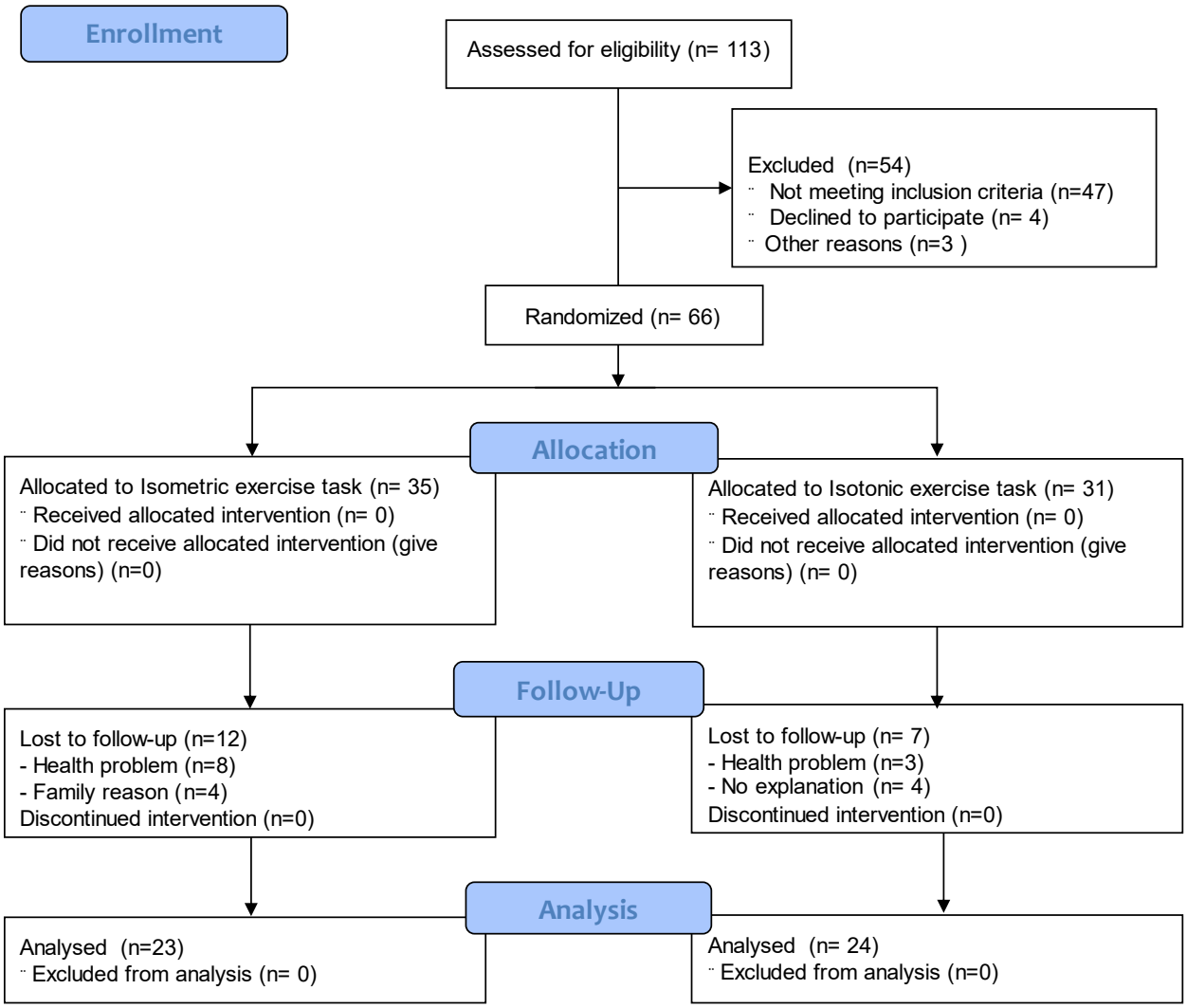
Inclusion criteria were: (1) aged between 18 and 30 years old, (2) no pain or altered sensation in the lower limb or lumbosacral spine at the time of the study, (3) no history of traumatic illness in the lower limb or lumbosacral spine, (4) no presentation of psychological or psychiatric illness, (5) no have being treated by *anti-inflammatory drugs* (NSAIDs), *analgesics*, *antidepressants*, *anti-inflammatory drugs*, *contraceptives*, and *calcium channel blockers* during the study period, (6) no have being surgically treated for a musculoskeletal disease in the lower limb or lumbosacral spine, (7) no presents toxic habits (alcohol intake, smoking, etc…).

Sample size determination

Sample size and power calculations were performed with SPSS Statistic v.28 software. The calculations were based on the minimum classically detectable difference (MCID) of PPT in healthy subjects which is 0.806 Kg/cm^2 assuming a standard deviation of 0.150 Kg/cm^2, a 2-tailed test, an alpha level of .05 and a desired power of 80%. (Gatz et al., 2020) The estimated sample size for each of the arms was n = 23 individuals.

Randomized assignment

Participants were randomly assigned to the isometric exercise intervention group (*Exe_ISOM*) and to the control the isotonic exercise (*Exe_ISOT*) with a sequence of random numbers generated by an investigator (P.L.R.) who was not involved in the recruitment of subjects. Randomization was performed using a random sequence generator (http://www.random.org) program.



Note. Participants were randomly assigned to the isometric exercise (Exe_ISOM) intervention group and isotonic exercise control (Exe_ISOT) with a sequence of random numbers generated by an investigator (P.L.R.) who was not involved in the recruitment of subjects. Randomization was performed using a random sequence generator (http://www.random.org) program.

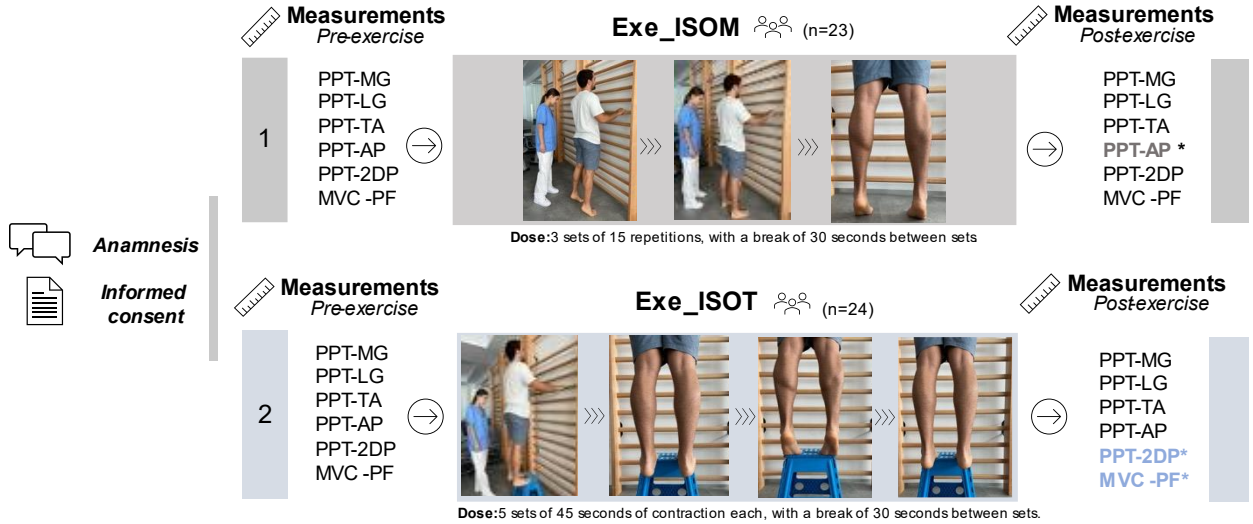
Figure 1. *CONSORT diagram of the participant selection process.*

Concealment

A blinded evaluator (A.R.P.T) was responsible for obtaining measurements at baseline (Pre-Exe) and immediately after the treatment period (Post-Exe). The interventions in both groups were applied by the same physiotherapist (S.M.) with 10 years of experience in manual therapy and management of musculoskeletal pain disorders. Both groups received the same instructions and information about the effectiveness of the treatment.

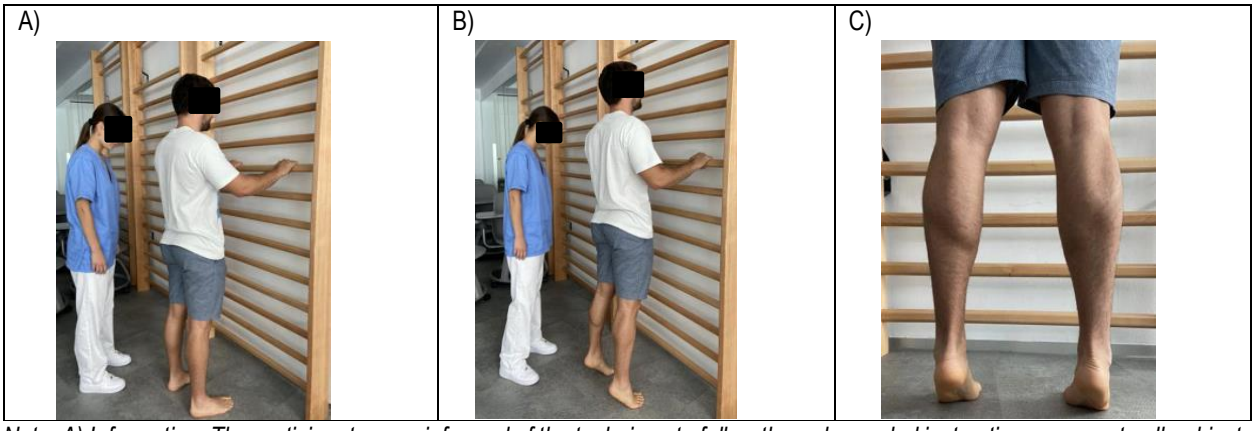
Intervention

The intervention was performed in consultation 1 of the Simulated Hospital of the European University of the Canary Islands (Santa Cruz de Tenerife, Spain) from March 12, 2022 to June 24, 2022. See Figure 2. The participants were divided into two groups that were treated:



Note. The participants were previously interviewed to assess whether they met the inclusion criteria and were subsequently given voluntary consent to participate in the study. They were randomly assigned to isometric exercise intervention (Exe_Isom) and isotonic exercise control (Exe_Isot) groups with a random number sequence generated by an investigator (P.L.R.) who was not involved in subject recruitment. A measurement was made before and after the intervention with the aim of evaluating intra-group changes as well as inter-group changes in the indicated variables. It was observed that isometric exercise (Exe_Isom) was the only method able to modify PPT-AP in a statistically significant manner before and after treatment. In contrast, isotonic exercise (Exe_Isot) was the exercise that showed clinically significant changes in 2PD and MVC-PF before and after treatment.

Figure 2. Study protocol.

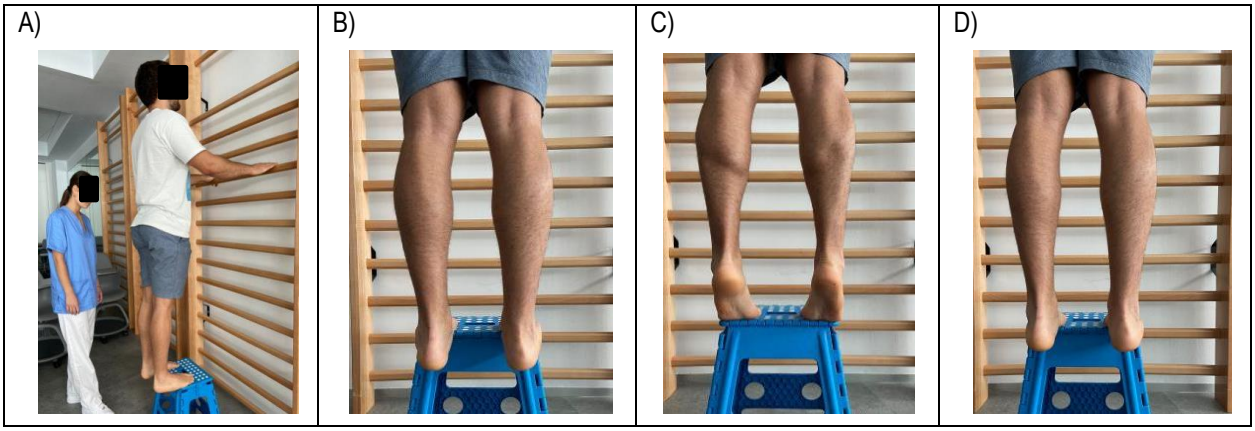


Note. A) Information. The participants were informed of the technique to follow through a verbal instruction common to all subjects who participated in the experiment, B) Patient Location. The starting position of the participant was standing, with his hands resting on the trellises to maintain stability, C) Development of the test. Task description: A maximum heel lift was performed while maintaining the support on the fingers. Then, we proceeded to make the complete support of the sole of the foot on the ground and the contraction will be repeated. Dose: 5 sets of 45 seconds of contraction each, with a break of 30 seconds between sets. Speed and amplitude: They were adjusted so that there was no pain.

Figure 3. Isometric exercise group intervention.

Group 1. Isometric exercise (Exe_ISOM)
The participants had to perform an isometric exercise based on the Rio *et al.* (2015) protocol. The starting position was standing and with the hands resting on the wall to maintain stability. The exercise was developed in a single session of 5 sets of 45 seconds of contraction with a rest between sets of 30 seconds. These movements were recorded through a metronome (Korg, MA-1, USA). The speed and range of motion were adjusted so that there was no pain. See Figure 3.

Group 2. Isotonic exercise (Exe_ISOT)
The participants had to perform an isotonic exercise based on Alfredson *et al.* (1998) protocol in which the participant must perform an eccentric exercise that consists of placing the subject on a step, performing an elevation with both legs, and finally descending slowly for 5 seconds to the position of maximum ankle flexion with the leg that will be measured. The exercise was developed in a single session of a total of 3 sets of 15 repetitions considering a total of 30 seconds of rest. (Stasinopoulos & Manias, 2013) These movements were recorded through a metronome (Korg, MA-1, USA). The speed and range of motion were adjusted so that there was no pain. See Figure 4.



Note. A) Information. The participants were informed of the technique to follow through a verbal instruction common to all subjects who participated in the experiment, B) Patient Location. The starting position of the participants was standing on a step with the heels outside it, leaving the base of the metatarsals supported, C) Development of the test. Task description: Held on a step, you must perform an elevation of both legs and then D) descend slowly for 5 seconds to the position of maximum ankle flexion. Dose: 3 sets of 15 repetitions, with a break of 30 seconds between sets. Speed and amplitude: They were adjusted so that there was no pain.

Figure 4. Isotonic exercise group intervention.

Study variables
Pre-treatment measurements were collected by a blinded blinded (E.C.C.) to the subjects' intervention assignment. To reduce the error of measurement procedure, a random evaluation order was generated among the participants taking three measurements with a pause of 1 min between measurements. Before, the intervention a questionnaire of affiliation was carried out as well as the taking of anthropometric measurements such as weight and height. Next, the measurement sites were identified and the Pre-ExeISOM and Pre-ExeISOT pre-treatment measurement protocol was developed, which contributes to define the baseline before the intervention. After the test, the Post-ExeISOT and Post-ExeISOM after-treatment measures were performed 5 minutes after the application of the procedure. The following outcome variables were evaluated:

Pain pressure threshold (PPT)

Mechanosensitivity was measured through the threshold of pain to pressure (PPT) using a digital Pain Tester (FPX™ Algometer, Wagner) with a unit of measurement of kg/cm^2 at four specific points of the neurosensory territory of the triceps surae: (*1) Medial gastrocnemius (MG), (2*) *lateral gastrocnemius (LG), (3*) *Tendo Achilles osteotendinous unit (TA) and (4) aponeurosis plantar insertion (AP).* The measurements were made just before and after the intervention, taking the average of 3 measurements for the main analysis. This procedure has reported a good inter-examiner reliability with a mean intra-class correlation coefficient (ICC) of 0.75 and an excellent intra-examiner reproducibility(mean ICC = 0.84). (Antonaci et al. 1998).

Two-point discrimination threshold (PPT-2DP)

The threshold of discrimination of two points was measured with an aesthesiometer (Aesthesiometer Baseline 12-1480) calibrated and graduated to perform minimum measurements of 0.1 cm using as a starting point the osteotendinous junction of the Achilles tendon, understanding the measurement in the direction proximal to the myotendinous junction between gastrocnemius and Achilles tendon. The instrument consists of two movable (sliding) vinyl-coated tips. Vinyl coatings help minimize the impact of temperature on contact perception. To check the minimum distance between two points perceived, the patient was asked to confirm when he began to perceive two different points. The measurements were made just before and after the intervention, taking the average of 3 measurements for the main analysis. This procedure has reported moderate to good inter-examiner reliability 0.83-0.96(Dellon et al., 1987; Levin et al., 1978).

Maximal voluntary contraction in plantar flexion (MVC-PF)

The maximum voluntary contraction of plantar flexion was measured with the BIOFET dynamometer (V3, MuscTec). The measurements were made just before and after the intervention taking the average of 3 measurements for the main analysis. The participant was measured supine with the hip, knee and ankle in a neutral position, with the foot on the edge of the examination table. The therapist placed the hand in the posterior region of the foot, locating the dynamometer in the plantar region (metatarsal bases) requiring the realization of a maximum plantar flexion for 5 seconds. The measurements were made just before and after the intervention taking the average of 3 measurements for the main analysis. This procedure has reported moderate to good interexaminer reliability 0.65-0.87 and moderate to good intraexaminer 0.77-0.97. (Kelln et al., 2008).

Statistical analysis

Statistical analysis was carried out using SPSS Statistic v.28 software. for the analysis and representation of data. First, the researcher E.C.C. performed a record in an electronic database of the results of the evaluation instruments used to measure each study variable while A.R.P.T. verified the accuracy of the data by completing the double data entry. Secondly, the researcher S.E.M.P. performed the calculation of the descriptive statistics of centralization (mean, and median), dispersion (standard deviation) and position (minimum, maximum) to describe the study variables. Thirdly, the Shapiro-Wilk test was carried out for quantitative variables to determine the normality of the data obtained. The variables that met the assumptions of normality ($p > .05$) were analyzed with an analysis of the intragroup (T-student for paired samples) and intergroup (T-student for independent means) mean differences. If they did not meet the assumptions of normality, it was decided to perform an analysis with non-parametric techniques to determine the intragroup (Wilcoxon sign range test) and intergroup (Mann-Whitney U test) differences comparing the data before (Pre) and after treatment (Post). Finally, the effect size (Cohen's d or biserial's correlation coefficient) was calculated to quantify the size of the difference between two groups. The statistical significance was set at a value of $p < .05$.

RESULTS

Demographic description of the sample

First, we included a total of 47 patients (23 women and 24 men) aged 18 to 37 years who were randomly chosen and assigned to the two study groups. See Figure 1. Secondly, the experimental group, which participated in an *isometric exercise* task (*Exe_Isom)* included a total of 23 subjects (Women, n = 12; Men, n = 11) had a mean age of 25.25 years (SD = 5.97) with a BMI of 24.42 Kg/m^2 (SD = 5.63) while the control group that was treated with an isotonic exercise task (*Exe_Isot*) consisted of a total of 24 subjects (Women, n = 11; Men, n = 13) had a mean age of 23.56 (SD = 3.04) years with a BMI of 22.79 kg/m^2 (SD = 2.19). On the other hand, most of the subjects who were finally included in this study turned out to be students (n = 30, 63.8%) and were considered active (n = 17, 36.2%). See Table 1.

Table 1. Anthropometric characteristics of the study population (n = 47).

		Descriptive											
			95% C. I.									Shapiro-Wilk	
	Group	Mean	Lower	Upper	Median	SD	Var.	IQR	Range	Min.	Max.	W	*p*
Age, (yrs.)	Exe_Isom	25.25	21.11	29.39	23.00	5.97	35.64	5.2500	0.19	0.18	0.37	0.907	.334
	Exe_Isot	23.56	21.57	25.55	23	3.04	9.27	2.0000	0.11	0.20	0.31	0.762	.7
Height, (m)	Exe_Isom	1.65	1.58	1.71	1.61	0.09	0.00871	0.0900	0.270	1.51	1.78	0.873	.163
	Exe_Isot	1.75	1.70	1.79	1.76	0.06	0.00473	0.0500	0.250	1.61	1.86	0.955	.746
Weigh, (Kg)	Exe_Isom	66.38	55.18	77.57	68.50	16.15	260.83	17.2500	49.000	43.00	92.00	0,952	.733
	Exe_Isot	69.44	62.84	76.05	68.00	10.11	102.27	13.0000	32.000	57.00	89.00	0.946	.646
BMI (Kg/m^2)	Exe_Isom	24.42	20.51	28.32	23.80	5.63	31.77	2.0453	19.349	16.59	35.94	0.889	.228
	Exe_Isot	22.79	20.74	24.85	22.34	3.14	9.916	0.8451	10.734	19.35	30.08	0.823	.37

Note. C. I. = Confidence Interval. SD = Standart Deviation. Var = Variance. IQR = Interquartilic Range. Min = Minimum. Max = Maximum.

Table 2. Description of variables of the study (n = 47).

	Descriptive								
								Shapiro-Wilk	
	Mean	Median	SD	Var.	IQR	Min.	Max.	W	p
Pre_PPT-MG	2.13	1.67	1.29	1.667	1.620	0.860	4.84	0.81	.003
Pre_PPT-MG	2.08	1.75	1.20	1.450	0.850	0.710	5.36	0.83	.005
Pre_PPT-LG	2.25	2.20	1.17	1.368	1.785	1.000	4.90	0.90	.072
Post_PPT-LG	2.29	1.74	1.10	1.226	1.355	1.100	5.00	0.87	.024
Pre_PPT-TA	2.55	2.17	1.01	1.023	1.440	1.145	4.29	0.93	.266
Post_PPT-TA	2.38	2.32	0.85	0.724	0.855	1.120	4.10	0.95	.536
Pre_PPT-AP	2.79	2.50	0.99	0.983	1.315	1.705	4.62	0.87	.026
Post_PPT-AP	2.97	3.10	1.040	1.081	1.105	1.445	4.92	0.93	.279
Pre_2PD	3.70	3.40	1.93	3.757	1.100	0.600	10.10	0.76	< .001
Post_*2PD*	3.65	3.40	1.26	1.598	1.200	2.200	7.70	0.80	.002
Pre_MVC-PF	26.77	25.20	5.33	28.415	4.400	20.900	42.20	0.85	.014
Post_MVC-PF	28.12	28.60	5.60	31.397	6.500	20.200	43.00	0.92	.195

Note. SD = Standart Deviation. Var = Variance. IQR = Interquartilic Range. Min = Minimum. Max = Maximum.

Key findings

Pain Pressure Threshold (PPT)

First, in relation to the group that received isotonic exercise (Exe_Isot), statistically significant intragroup increases in PPT-AP were detected with a difference between the threshold measured before 2.92 (1,028) Kg/cm^2 and after treatment 3.13 (1,054) Kg/cm^2 (Δ = 0.235 Kg/cm^2, Wilcoxon W = 8, 95% CI [0-.020)]; *p* =

.048). In relation to the rest of the variables, there was in general a response of decrease of the thresholds studied as is the case of PPT-MG, PPT-LG and PPT-TA in which a decrease in the thresholds of pain to pressure was demonstrated without reaching statistical significance.

Secondly, in the group that received isometric exercise (*Exe_Isom*) no statistically significant changes were detected although an immediate decrease in the thresholds was recorded in the variables PPT-MG, PPT-LE and PPT-AP. The same does not happen with the clinical change detected in the PPT-TA variables that increased from 1.94 Kg/cm^2 to 2.01 Kg/cm^2 (Δ = 0.213 Kg/cm^2, Wilcoxon W =25; p = .527).

Finally, if we look at the comparison between the groups, the analysis showed that there were no statistically significant differences between the intervention groups for any of the variables studied PPT-MG (U Mann Whitney = 25; [1.265-0.650], p = .527), PPT-LG (U Mann Whitney = 25; [1.325-0.945]; p = .527) and PPT-AT (U-Mann Whitney = 25; [-1.465-0.405]; p = .527).

Table 3. Intragroup analysis of isometric exercise (n = 23).

Paired Samples T-Test									
							95% Confidence Interval		
			Statistic	*p*	Mean difference	SE difference	Lower	Upper	Effect Size
Pre_PPT-MG	Post_PPT-MG	Wilcoxon W	19.0	.578	0.02875	0.136	-Inf	0.320	0.0556
Pre_PPT-LG	Post_PPT-LG	Wilcoxon W	12.0	.230	-0.14250	0.158	-Inf	0.252	-0.3333
Pre_PPT-TA	Post_PPT-TA	Wilcoxon W	25.0	.844	0.21375	0.166	-Inf	0.525	0.3889
Pre_PPT-AP	Post_PPT-AP	Wilcoxon W	18.0	.527	0.00500	0.127	-Inf	0.313	0.0000
Pre_2PD	Post_2PD	Wilcoxon W	15.5	.389	-0.10004	0.443	-Inf	0.900	-0.1389
Pre_MVC-PF	Post_MVC-PF	Wilcoxon W	10.5	.163	-1.24996	0.818	-Inf	1.000	-0.4167

Table 4. Intragroup analysis of isotonic exercise (n = 24).

Paired Samples T-Test									
							95% Confidence Interval		
			Statistic	*p*	Mean difference	SE difference	Lower	Upper	Effect Size
Pre_PPT-MG	Post_PPT-MG	Wilcoxon W	18.00	.318	-0.1950	0.2867	-Inf	0.6450	-0.2000
Pre_PPT-LG	Post_PPT-LG	Wilcoxon W	24.00	.594	0.0324	0.0950	-Inf	0.2051	0.0667
Pre_PPT-TA	Post_PPT-TA	Wilcoxon W	15.00	.363	-0.1752	0.3205	-Inf	0.8500	-0.1667
Pre_PPT-AP	Post_PPT-AP	Wilcoxon W	8.00	.48	-0.2350	0.1113	-Inf	-0.0200	-0.6444
Pre_2PD	Post_2PD	Wilcoxon W	31.00	.857	0.5501	0.5325	-Inf	1.2500	0.3778
Pre_MVC-PF	Post_MVC-PF	Wilcoxon W	8.00	.48	-1.8501	0.8905	-Inf	-0.1500	-0.6444

Table 5. Intergroup analysis of isometric exercise versus isotonic exercise (n = 47).

Independent Samples T-Test							
					95% Confidence Interval		
		Statistic	*p*	Mean difference	Lower	Upper	Effect Size
Post_PPT-MG	Mann-Whitney U	31.0	.673	-0.188	-1.265	0.650	0.139
Post_PPT-LG	Mann-Whitney U	30.0	.606	-0.170	-1.325	0.945	0.167
Post_PPT-TA	Mann-Whitney U	24.0	.277	-0.530	-1.465	0.405	0.333
Post_PPT-AP	Mann-Whitney U	31.5	.699	0.155	-1.030	1.530	0.125
Post_2PD	Mann-Whitney U	30.5	.630	0.229	-0.800	1.300	0.153
Post_MVC-PF	Mann-Whitney U	26.5	.386	-2.600	-8.400	2.900	0.264

Two-point discrimination (PPT-2PD)

In subjects participating in the isotonic task (*Exe_Isot*), there was a clinical decrease in the discriminating threshold of two points from 3.66 cm (SE 0.436) to 3.38 cm (SE 0.209) after activity without reaching statistical

significance (Wilcoxon W = 31, 95% CI [0-1.25], *p* = .857). Secondly, unlike the isotonic task, the isometric achieved slight clinical increases of the discriminatory threshold from two points 3.91 cm (SE 0.903) to 3.95 cm (SE 0.613) (Wilcoxon W = 15.5, 95% CI [0-0.900], *p* = .389). If we made a comparison between both groups, the analysis showed that there were no statistically significant differences between the intervention groups for this variable (U Mann Whitney = 30.5, 95% CI [-0.800-1.300], *p* = .630).

Maximal voluntary contraction in plantar flexion (MVC-PF)
Statistically significant changes in MVC-PF were detected in the isotonic exercise group (*Exe_Isot*) with a difference between before treatment 29.28 (2,550) Kg/f and after treatment 31.11 (2.52) Kg/F (Δ = 1.85 Kg/f, Wilcoxon W = 8, 95% CI [0-.015)]; *p* = .048). In relation to the group that received isometric exercise (*Exe_Isom*) clinical changes were detected before 25.40 (SE 1.571) Kg/f and after treatment 26.32 (SE 1.663) Kg/f (Δ = 0.90 Kg/f, Wilcoxon W = 10.5, 95% CI [0-1)]; *p* = .163). Finally, if we look at the comparison between the groups, the analysis showed that there were no statistical differences for both the experimental group and the control at the end of treatment for any of the study variables (U Mann Whitney = 26.5, 95% CI [-8,400, 2,900], *p* = .386). See Table 3 and Table 4. Intragroup analysis of *isometric exercise* (n = 23) and isotonic exercise (n = 24).

DISCUSSION

This is one of the few randomized clinical studies comparing the efficacy of isometric exercise versus isotonic exercise at PPT, PPT-2PD threshold and MVC of triceps surae.

According to our results, the performance of isotonic exercise was the intervention that produced the greatest changes in the mechanical threshold and motor performance. On the one hand, mechanical pain threshold could be modified in remote regions such as aponeurosis plantar (PPT-AP) immediately. On the other hand, discriminative threshold of the Achilles tendon (PPT-2DP) increased in the group that performed an isotonic exercise task. Moreover, there was a statistically significant difference in MVC of ankle plantiflexor muscles (MVC-PF) were also detected in the isotonic exercise group.

However, it should be noted that, despite the results obtained, it has not been possible to demonstrate the superiority of one mode of contraction over the other. Unlike other studies made on clinical populations if we perform a comparative analysis between both treatments, the absence of statistically significant changes leads us to state that the type of contraction and neither doses are ultimately responsible of the observed changes in pain sensitivity tolerance and motor performance triceps surae muscles.

Abounding in the above, the absence of superiority or inferiority of both treatment modalities is a controversial issue and widely discussed in the literature. In fact, a clinical study by Kanniappan and Sathosh (2020) concluded that there is a significant improvement in Achilles tendonitis when pain and functionality are evaluated for both eccentric and isometric exercise with no significant differences between them. In another work by van der Vlist et al. (2020) they also found no difference when isometric exercise was added in patients with tendinopathy to chronic pain, so they do not recommend isometric exercises if the goal is to provide immediate pain relief. Even when program exposure reaches 3 months, Gatz et al. (2020) demonstrated that isometric exercises have no additional benefit when combined with eccentric exercises. Despite these studies, we are struck by the fact that other high methodological quality clinical studies support the idea that isometric exercise is better than isotonic exercise on reducing pain tolerance and increasing motor output. In this regard, Rabusin et al. (2021) noted that isometric heel lift exercise was more effective than eccentric exercise in reducing pain and improving function at 12 weeks. Also, supporting its use but in other type of

tendinopathies of the lower limb, Rio et al. (2017) defends the superiority of the isometric over the isotonic in the relief of immediate pain of subjects suffering from patellar tendon pain. Despite these controversies, we identified well made reviews such as those carried out by Lim and Wong (2018) and Vang and Niznik (2021) that conclude that isometric exercises would be more effective in relieving pain in the short term, while isotonic eccentric exercises would be better for long-term pain reduction and improvement of knee function.

Strengths

As strengths of this study, we have identified some advantages that can improve the internal validity of the study.

First, the use of blinding in the treatment assignment sequence in each group reduced selection bias. In addition, blinded allocation sequence allocation by the investigators reduced the likelihood of participants being screened for prognostic criteria or potential benefit or harm of the intervention.

Secondly, all participants received the same instructions throughout the protocol, except for using the same treatment room and wearing the same therapist. Through this aforethought procedure avoids the possible contextual interactions that have been described by other authors as responsible for modifying outcome measures that might alter comparisons between the same group of subjects.

Thirdly, it should be noted that the this study was conducted with the masked raters, meaning that at no point did the raters have any information about which group of participants was assigned during the intervention protocol. In this sense, we argue that this procedure reduces detection bias, that is, the influence of the fact that participants would know detailed information about the treatment they received, on the results.

Limitations

Several limitations were detected in this study.

First, regarding the sample, recruitment was conducted using a non-probabilistic consecutive sampling technique which may implies the extraction of biased samples. However, given the possible impact of this participant selection technique, we believe that this is the easiest recruitment system from an organizational perspective during project implementation, as it allows us to achieve a significant sample size, ultimately allow data collection to be comparable.

Secondly, we argue that a large proportion of participants recruited primarily in the university education community on the list of recruiting subjects have both theoretical and practical knowledge of the expected impact of the intervention.

Thirdly, the study protocol did not include familiarity with the instruments used to measure the outcome variable, so the variability obtained in the sample could be a bias due to the participants' inexperience at the time of measurement.

Fourthly, regarding interventions, we believe that the lack of a control group and/or placebo group may be a limitation, as this design may not allow us to determine the nonspecific effects of interventions and whether they exist without considering treatment.

Finally, the short duration of this design or pre-experimental protocol hinders the understanding of clinical changes that may occur during mid- to long-term follow-up. In this same sense, we can assume that the lack

of cumulative training dose, only one training session, can usually explain the few clinical changes noted not only between groups but also within the same experimental protocol.This question compels us to emphasize the need for studies with extended follow-up of outcome variables, as our results suggest that the use of changes measured immediately after exercise in healthy subjects is not sufficient to justify their use in the population with musculoskeletal pain.

CONCLUSIONS

Isometric exercise (*Exe_Isom*) was the only one able to modify the PPT-AP before and after treatment in a statistically significant way. In contrast, isotonic exercise (*Exe_Isot*) was the training that demonstrated clinically significant changes in PPT-2PD and MVC-PF before and after treatment. No statistically significant changes were identified between both groups in any of the variables studied.

AUTHOR CONTRIBUTIONS

Theoretical conceptualization, S.E.M.P., E.A.S.R., J.L.A.P.; literature searching, P.L.R., A.R.P.T., E.C.C.; conducted data collection P.L.R., A.R.P.T. and E.C.C.; statistical analysis, I.M.P., E.A.S.R. and S.E.M.P.; elaboration of draft S.M.P., I.M.P.; review E.A.S.R., S.E.M.P., M.D.S.R., J.H.V, J.F.C.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained by an internal committee and informed consent was requested from all participants in the study.

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