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ORIGINAL

EFFECTIVENESS AND PAIN PERCEPTION WITH HOLD-RELAX STRETCHING TECHNIQUE AND ELECTROSTIMULATION

EFICACIA Y PERCEPCIÓN DEL DOLOR EN TÉCNICAS DE ESTIRAMIENTOS HOLD-RELAX Y ELECTROESTIMULACIÓN

López-Bedoya, J.[1]; Vernetta-Santana, M.[2]; Lizaur-Girón, P.[3]: Martínez-Patiño, M.J.[4]; Ariza-Vargas, L.[5]

[1] Department of Physical Education and Sport, Faculty of Physical Activity and Sport Sciences, Granada (Spain) jlopezb@ugr.es
[2] Department of Physical Education and Sport, Faculty of Physical Activity and Sport Sciences, Granada (Spain) vernetta@ugr.es
[3] Department of Physical Education and Sport, Faculty of Physical Activity and Sport Sciences, Granada (Spain) plizaur@ugr.es
[4] Department of Special Didactics, Faculty of Physical Activity and Sport Sciences, University of Vigo (Spain) mjpatino@uvigo.es
[5] Department of Artistic and Corporal Expression Didactics, Faculty of Educational Sciences, University of Córdoba (Spain) eo1arval@uco.es

Spanish-English translators: Rocío Domínguez Castells, rocio@sport-science.net

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ABSTRACT

The aim of this study was to analyse the effect of the hold-relax stretching technique without (HR) and with electrostimulation (HR+ES) on the improvement and maintenance of active (AROM) and passive (PROM) range of movement of hip flexion, as well as pain perception during its application. Forty-two athletes were divided into three groups: control, HR and HR+ES. ROM was

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measured through the straight-leg-rise test before and after the training and two weeks after completing the training. Pain assessment was conducted through the VAS scale. The ANOVA revealed a significant increase in PROM ($p<0.001$) for HR and HR+ES, but not in AROM. There was no significant decrease in PROM in the period after training in either group. Regarding pain, there were no significant differences in VAS values between techniques. Both HR and HR+ES were well tolerated in terms of pain perception.

KEY WORDS: Flexibility, Training, Electrostimulation, Hamstring extensibility, Pain tolerance.

RESUMEN

Se analizó el efecto de la técnica de estiramiento HOLD RELAX sin (HR) y con electroestimulación (HR+EE) sobre la mejora y retención del rango de movimiento (ROM) activo (AROM) y pasivo (PROM) de cadera en flexión, y la percepción del dolor durante su aplicación. 42 deportistas fueron asignados a tres grupos: control, HR y HR+EE. El ROM fue medido con el test Straight-Leg-Raise antes, al finalizar el entrenamiento y trascurridas 2 semanas de su finalización. La valoración del dolor se realizó con la escala EVA. El ANOVA mostró un aumento significativo del PROM ($p<0,001$) en HR y HR+EE, no así del AROM. No se observaron pérdidas significativas del PROM en la retención de sendos grupos. En cuanto al dolor, no existieron diferencias significativas en los valores de EVA al aplicar ambas técnicas. Tanto HR como HR+EE fueron bien toleradas en cuanto a la percepción del dolor.

PALABRAS CLAVE: Flexibilidad, Entrenamiento, Electroestimulación, Extensibilidad isquiotibiales, Tolerancia al dolor.

INTRODUCTION

The role of flexibility on sport performance has been widely researched with the purpose to describe how different techniques affect the range of movement (ROM) improvement, both acute and chronic, since the increase in ROM is generally associated with performance improvement and lower injury incidence (Holt, Holt & Petham, 1996; Schmitt, Pelham & Holt, 1999). Sports like synchronized swimming, figure skating and gymnastic specialities like artistic, rhythmic, acrobatic or aerobic gymnastics, among others, require large ROM, which is associated with technical improvement and movement aesthetics. The development of flexibility in these disciplines is a relevant part of the training that reflects on the competition outcome. Therefore, it is important to understand the effects of the different types of stretching and to determine when each type is most appropriate to maximise human motion and performance (Bernhart, 2013).

Among the three basic stretching techniques defined by Page (2012), static, dynamic and pre-contraction stretching, proprioceptive neuromuscular facilitation (PNF), a type of pre-contraction stretching, has proved to be very

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effective to improve active and/or passive ROM of different joints in athletes (Zajac & Nowak, 1997; Kenric, 2003; Funk, Swank, Mikla, Fagen & Farr, 2003; López-Bedoya, Vernetta, Robles & Ariza, 2013; García-Manso, López-Bedoya, Rodríguez-Matoso, Ariza-Vargas, Rodríguez-Ruiz & Vernetta, 2015).

Its effectiveness is based on using the autogenous inhibition reflex to inhibit muscle contraction and achieve greater ROM. Thus, it is a method with the aim to foster or accelerate the response of the neuromuscular mechanism by stimulating the proprioceptors (Voss, Ionta y Meyers, 2004).

Within these techniques, two are the most frequently used in relation to physical performance: contract-relax (CR) and hold-relax (HR) (Surburg & Schrader, 1997; Adler, Berkers & Buck, 2002; Voss *et al.*, 2004; López Bedoya *et al.*, 2013). Their efficacy to improve active and passive ROM in the long term is sufficiently proved (Zajac & Nowak, 1997). Nevertheless, there is little evidence regarding its effect when electrostimulation is applied to compare ROM improvement (Pérez & Álamo, 2001; Espejo, Maya, Cardero & Albornoz, 2012; López-Bedoya, Vernetta, Lizaur, Martinez-Patiño & Ariza-Vargas, 2017). Besides, one of the factors that often appears when training flexibility is pain, a consequence of maintained tissue elongation.

The International Association for the Study of Pain defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (Merskey y Bogduk, 2005). Nociceptors are peripheral pain receptors that send signals by means of neurotransmitters to the spinal cord. Their function is to keep body integrity and to trigger responses (somatic or vegetative) associated with painful feelings, trying to distinguish between harmless and damaging stimuli. They perform this task by ignoring low-intensity stimuli, coding damaging stimuli within an intensity range and sending this information to the CNS (Besson & Chaouch, 1987).

The mechanisms that support the change in stretch perception or tolerance are not known in detail; only some authors have suggested and studied pain modulation during stretching (Marshall, Cashman & Cheema, 2006; Sharman, Cresswel & Riek, 2006). This scarcity of studies makes it interesting to examine pain perception during muscle stretching in every training session, since it may become a limiting factor of this process. Besides, Sands, Mc Neal, Stone, Haff and Kinser (2008) confirmed in a study on stretching comparing vibration and non-vibration conditions that there were no differences between them regarding post-stretching pressure-to-pain perception measured with an algometer.

AIMS

The main purpose of this study was to assess the long-term effect of flexibility training on passive and active range of movement of hamstring muscles in non-competitive gymnasts using the PNF technique hold-relax alone (HR) or combined with electrostimulation (HR+ES). Likewise, it was aimed to determine what type of training allows for maintenance of the improvement after a two-

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week detraining period, as well as to analyse the pain perceived by the participants during each type of stretching.

MATERIAL AND METHOD

Participants

A total of 42 (22 men, 20 women) students of MSc Sport Sciences specialised on Artistic Gymnastics (age: 22.95 ± 2.03 years; body mass: 67.74 ± 9.60 kg; height: 171.63 ± 9.37 cm) were assigned to one of three groups (control, hold-relax induced by electrostimulation and without electrostimulation) using blocking techniques based on the data obtained in the pre-test. None of them suffered any injury in the involved muscle group, or any other ailment. All participants were fully informed about the procedures and potential risks before they provided written informed consent. The study was approved by the Ethics Committee of the University of Granada.

Experimental design

A factorial repeated-measures design was applied, with three levels in the between-subject factor (control, HR+ES, HR) and three levels in the within-subject factor (pre-, post- and re-test). The dependent variables were passive range of movement (PROM) and active range of movement (AROM) in the hip flexion of the dominant leg, as well as pain perceived by the study participants.

Equipment

A standard digital camera (Nikon, Coolpix S500, Nikon Corporation, Chiyoda-ku, Tokio, Japan, http://www.nikon.com/) was used to take pictures during the straight-leg-raise (SLR) test, which involved active and passive raising of the extended lower limb (ASLR and PSLR, respectively), and to subsequently collect the angle data. During the training phase, seven programmable electrostimulation devices (Cefar Myo4) were used, which delivered asymmetric rectangular biphasic waves, with pulse intensity between 0 and 120 mA in each of their four channels and pulse width or duration measured in microseconds (μs). Pulse frequency could be set between 0 and 120 Hz. The visual analogue scale (VAS) was used to measure pain perception.

Measuring procedure

Measurements were taken at three moments: the pre-test was conducted in a session prior to the first training session; the post-test, immediately after the last training session; and the re-test, after a two-week detraining period. Once the ASLR and PSLR assessments were completed, the angles were measured by digitising the anatomical points with the software ATD 2.0 for Windows (Analysis of Sport Technique, University of Granada, Spain) on the pictures taken during the tests. The angle (α) was obtained by digitising three points: the ankle (malleolus), the hip (greater trochanter) and the ankle of the other leg (malleolus). Every picture was digitised three times in ASLR and PSLR and the mean of each type of test was used for statistical analysis. During the tests, the participants lay on a bench and were requested to keep their head aligned with

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their back and to push the lumbar region against the bench. With their knees in full extension, every participant raised one lower limb slowly by flexing the hip, avoiding internal or external limb rotation or any deviation from the sagittal plane. When the maximum active or passive ROM (depending on the case) was reached as orally indicated by the participant, the position was held and a picture was taken holding the digital camera perpendicular to the participant at a distance of 4 metres, focusing on the hip joint.

Pain intensity and its discomfort component have been assessed by means of various methods, but numerical or verbal scales have been traditionally used, the visual analogue scale (VAS) having been the most frequently used one during the last 15 years (Olesen, Andresen, Staahl & Drewes, 2012).
In the present study, the VAS was chosen and pain perception was assessed immediately after every stretching session. The participants were asked to mark their pain perception on the VAS form on a numerical scale from 0 to 10 points, limited by “no pain” on the left side and “unbearable pain” on the right side. The participants were asked to draw a vertical line across the horizontal line on the point that best described the maximum pain intensity they had experienced during the stretching session.

Training protocol

The participants from both experimental groups followed a flexibility training programme consisting of two sessions per week for four weeks. Prior to every training session, a standardised 10-min warm-up was completed, the same for all training sessions and for both groups. The measurements were performed at the same time and place in the pre-, post- and re-test, with a room temperature of 23º. The stretching exercise chosen was the straight leg raise (SLR). The session was used as first contact and familiarisation with the test and the technique involved.

Experimental group 1 (HR+ES) (14 participants): this group performed the HR technique combined with electrostimulation, consisting of 10 repetitions of the following cycle: passive elongation (PE) of the hamstring muscle group until reaching maximum ROM; isometric concentric contraction (IC) of the stretched muscle (hamstring) with electrostimulation. In order to produce such contraction, a bipolar electrical current (100 mA) was applied between two surface electrodes placed on the proximal and distal ends of the hamstring muscles. The current parameters used were: impulse frequency (IF) 80 Hz; contraction time (CT) 6s; resting time 2s; 10 seconds of passive assisted stretching of the hamstring muscles; 2-second rest in the starting position. The total stretching time per session was 100s and the total working time was 3 min.
Experimental group 2 (HR) (14 participants): the same technique was applied, but the isometric contraction was voluntarily produced against controlled resistance delivered by an assistant and no electrostimulation was applied. A control group (14 participants) did not perform any type of stretching.

Statistical analysis

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Prior to the analysis, normality and homocedasticity assumptions were confirmed by means of Shapiro-Wilk and Levene statistics, respectively.
The differences observed in each of the dependent variables, AROM and PROM, were analysed using a mixed factorial ANOVA or split-plot (treatment x measurement), with three levels in the between-subject factor (control, HR+ES, HR) ad three levels in the within-subject factor (pre-, post-, re-test).
Equality of variance and covariance matrices of the within-subject factor levels was confirmed for every between-subject level using Mauchly's sphericity test. To do so, the univariate F statistic was used and Greenhouse-Geisser's estimation of epsilon correction index for violation of the sphericity assumption was applied.

In the multiple comparisons of the within-subject effects, the thresholds and confidence intervals were adjusted applying Bonferroni's correction. The study of pain with the VAS was conducted using a split-plot design, with two levels (HR+ES, HR) in the between-subject factor (Treatment) and eight levels in the within-subject factor (Measurement). The reliability of the three digitisations of every picture was measured with the intraclass correlation coefficient (ICC). Significance level was set at $p < .05$ for all tests.

RESULTS

The absence of significant differences among the mean values of all dependent variables in the pre-test was confirmed by means of an ANOVA.
All subpopulations resulting from combining the different levels of the factors Measurement and Treatment were found to follow a normal distribution ($p < .05$).

Table 1 shows the mean and standard deviation of all AROM and PROM measurements, as well as the existence or absence of significant differences.

Table 1. Mean (and standard deviation) of the active and passive range of movement in hip flexion, measured in degrees, divided by experimental group and Measurement factor level (pre-, post- and re-test).

	Measurement	Control	HR	HR+ES	Subtotal
AROM	Pre-	94.99(14.35)	97.28(15.12)	93.83(9.68)	95.36(13.02)
	Post-	93.46(13.69)	99.97(13.90)	97.34(10.64)	96.92(12.80)
	Re-test	93.81(16.49)	97.89(14.88)	95.79(10.99)	95.83(14.06)
	Subtotal	94.09(14.54)	98.38(14.33)	95.65(10.30)	
PROM	Pre-	123.60(17.07)	127.78(20.27)	129.04(21.80)	126.81(19.46)
	Post-	122.55(18.55)	137.55(21.65) ††	142.57(12.83)* ††	134.22(19.59)††
	Re-test	127.86(19.85)	137.58(19.34) ††	138.08(12.62) ‡‡	134.51(17.80)††
	Subtotal	124.67(18.21)	134.30(20.47)	136.56(16.91)	

AROM (Active Range of Movement), PROM (Passive Range of Movement)
HR (Proprioceptive Neuromuscular Facilitation – Hold Relax), HR+ES (Proprioceptive Neuromuscular Facilitation – Hold Relax combined with isometric contraction induced by electrostimulation)
* = $p < .05$; significantly different from the control group
†† = $p < .001$; significantly different from the pre-test measurement
‡‡ = $p < .01$; significantly different from the post-test measurement

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Analysis of the effect of HR+ES or HR application on active and passive ROM

The mixed factorial analysis yielded uneven results for active and passive ranges of movement. AROM did not show significant differences considering either the three measurements $F(2, 78) = 1.499$, $p = .230$, $\eta_p^2 = .037$, or the interaction among the variables Measurement * Treatment $F(4, 78) = 1.482$, $p = .216$, $\eta_p^2 = .071$. No significant differences were found between subjects in the different levels of Treatment $F(2, 39)= .389$, $p = .680$, $\eta_p^2 = .020$ (see Figure 1A).

In PROM, a significant main effect of the variable Measurement was observed $F(2, 78) = 15.457$, $p = .000$, $\eta_p^2 = .284$, as well as of the interaction Measurement * Treatment $F(4, 78) = 4.068$, $p = .005$, $\eta_p^2 = .173$ (Figure 1B). The mean value in the pre-test ($M = 126.81$, $SD = 19.46$) was significantly lower ($p < .001$ in both cases) than after the treatment ($M = 134.22$, $SD = 19.59$) and two weeks after finishing the treatment ($M = 134.51$, $SD = 17.80$). As regards the interaction Measurement * Treatment, the univariate contrast yielded significant differences in the post-test, $F(2, 39) = 4.663$, $p = .015$, $\eta_p^2 = .193$, between the control group ($M = 122.55$, $SD = 18.55$) and the group treated with HR+ES ($M = 142.57$, $SD = 12.83$), $p = .017$, 95% CI (2.954 – 37.084).

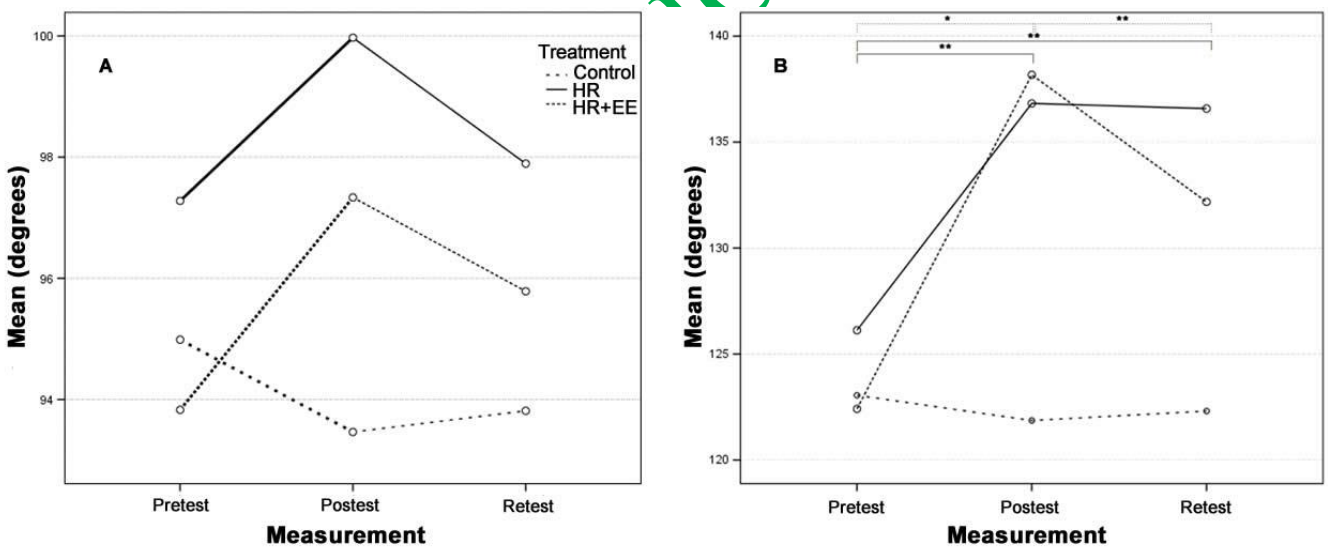

Figure 1. Mean value of active (A) and passive (B) range of movement in the dominant hip, according to the experimental group (Control, HR, HR + ES) and measurement.
* = p < .001; ** p < .05

The repeated measures ANOVA on the three levels of the variable Measurement and all levels of the variable Treatment yielded significant differences in HR, $F(2, 26) = 13.191$, $p = .000$, $\eta_p^2 = .504$, and HR+ES, $F(2, 26) = 6.27$, $p = .006$, $\eta_p^2 = .325$ (Figure 2). In the first case, the mean PROM value in the pre-test ($M = 127.78$, $SD = 20.27$) was significantly lower than in the post-test ($M = 137.55$, $SD = 21.65$), $p = .006$, 95%CI (2.839, 16.691) and the re-test ($M = 137.58$, $SD = 19.34$), $p = .001$, 95%CI (4.512, 15.081). In the case of

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HR+ES, these differences appeared between the mean values of the pre- (M = 129.04, SD = 21.80) and the post-test (M = 142.57, SD = 12.83), p = .032, 95%CI (1.06, 25.997), and between the post- and the re-test (M = 142.57, SD = 12.83), p = .004, 95%CI (1.458 – 7.512) (Table 1).

No significant differences were observed among the mean values obtained for the between-subject factor Treatment: $F(2, 39) = 1.815$, $p = .176$, $\eta_p^2 = .085$.

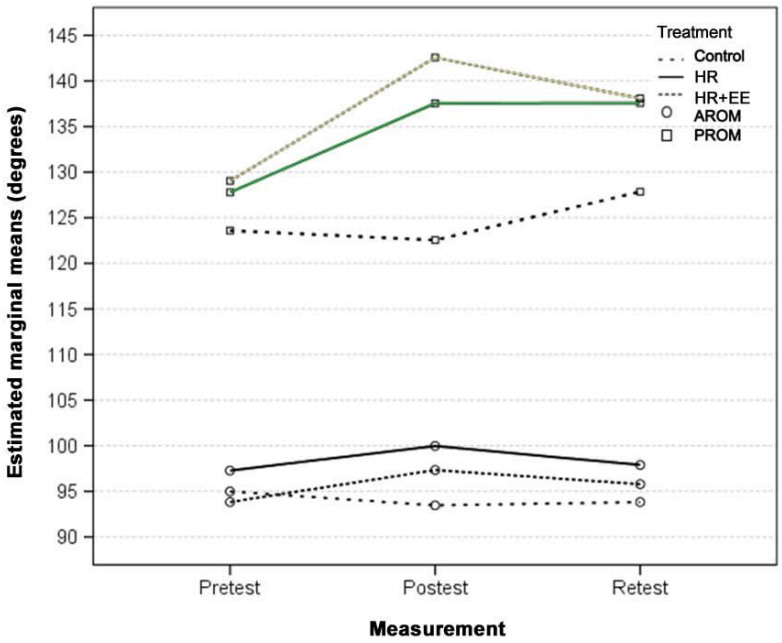

Figure 2. Mean value of active and passive range of movement in the dominant hip, according to the experimental group (Control, HR, HR + ES) and measurement.

Statistical analysis of VAS

Tables 2 and 3 display the results of the normality test using Shapiro-Wilk statistic as well as mean and standard deviation values. The repeated measures ANOVA revealed the absence of statistically significant fixed effects of the factor Measurement, $F(7, 108, 288) = .924$, $p = .455$, $\eta_p^2 = .034$. Conversely, significant differences were found in the interaction Measurement * Group, $F(7, 108, 288) = 3.091$, $p = .017$, $\eta_p^2 = .106$. More specifically, the mean VAS value was significantly different between HR and HR+ES treatments in measurement 1 (M = 57.66, SD = 13.30 for HR and M = 38.3, SD = 17.29 for HR+ES), p = .003, 95%IC (7.374 – 31.341). Significant differences between pairs of measurements were only observed in the group who underwent HR+ES, in pair 1 (M = 38.30, SD = 17.29) – 4 (M = 57.73, SD = 16.10), p = .035, 95%IC (0.7742 – 38.083). With regard to the between-subject factor, no significant differences were detected based on the method applied (HR *vs.* HR+ES), $F(1, 26) = .232$, $p = .634$, $\eta_p^2 = .009$ (Figure 3).

Table 2. Results of the Shapiro-Wilk normality test for every measurement conducted on the dominant hip.

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Measurement	Statistic	df	Sig.
1	.974	28	.679
2	.958	28	.306
3	.971	28	.604
4	.971	28	.599
5	.975	28	.732
6	.979	28	.826
7	.969	28	.542
8	.983	28	.906

Table 3. Descriptive analysis (mean and standard deviation) of the VAS in the dominant hip, divided by experimental group.

Measure ment	HR			HR+ES			TOTAL		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
1	14	57.66	13.30	14	38.30	17.29	28	47.98	18.06
2	14	50.38	14.20	14	48.32	11.76	28	49.35	12.83
3	14	55.12	19.01	14	52.98	16.58	28	54.05	17.54
4	14	48.33	19.08	14	57.73	16.11	28	53.03	17.97
5	14	52.07	16.31	14	53.86	19.85	28	52.96	17.85
6	14	52.07	17.91	14	51.93	21.36	28	52.00	19.35
7	14	53.54	19.34	14	52.00	22.83	28	52.77	20.77
8	14	57.07	16.18	14	51.21	20.19	28	54.14	18.20

HR = Proprioceptive Neuromuscular Facilitation – Hold Relax; HR+ES = Proprioceptive Neuromuscular Facilitation – Hold Relax combined with isometric contraction induced by electrostimulation.

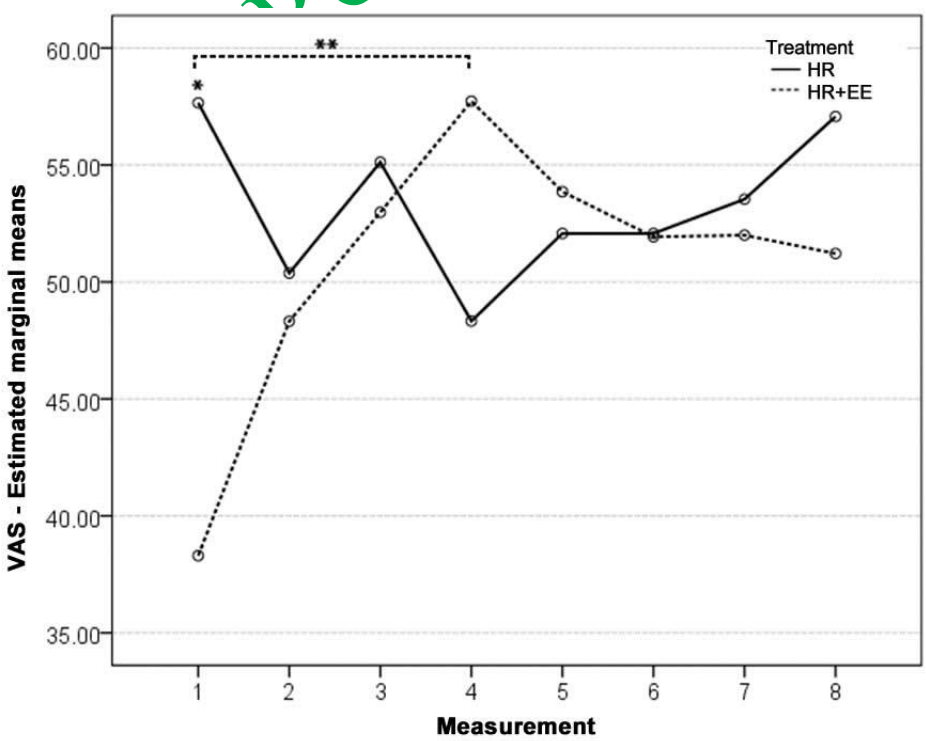

Figure 3. Mean VAS values in the eight measurements (dominant hip) according

to the experimental group.
HR = Proprioceptive Neuromuscular Facilitation – Hold Relax; HR+ES = Proprioceptive Neuromuscular Facilitation – Hold Relax combined with isometric contraction induced by electrostimulation.
*= p < .05; ** = p < .01

DISCUSSION

Changes produced in passive and active ROM between the pre- and the post-test

The ANOVA revealed significant differences in PROM, p < .001, with both training techniques, HR and HR+ES, between the pre- and the post-test. Both experimental groups experienced significant improvements in PROM (p < .001) after the training programme. Similar studies have reported significant improvements using HR techniques in two training sessions per week, but for a longer period (Rowlands, Marginson & Lee, 2003; González-Ravé, Sánchez-Gómez & Sánchez-García, 2012; López-Bedoya *et al.*, 2013). López-Bedoya, Robles, Vernetta, Piedra and Núñez (2007) assessed PROM in abduction comparing HR techniques and Active Isolated Stretching (AIS) and concluded that both techniques were effective, with no differences between them. In a later study, López-Bedoya *et al.* (2013) compared the same techniques and observed greater improvements in the PROM of the hamstring muscles (18.42º with AIS and 17.18º with HR) than of the adductors (10.44º with AIS and 6.52º with HR). With the same number of sessions, duration and protocol, the training seems to be more effective on the hamstring than on the adductor muscles, so the increase in PROM may be associated with the technique applied but also with the architecture of the muscle involved. In the present study, both HR and HR+ES treatments produced significant improvements in PROM from the pre- to the post-test (9.77º and 13.53º, respectively, p < .001). This confirms the effectiveness of the HR technique to improve PROM, as shown in the study by López-Bedoya *et al.* (2013), where a significant enhancement (p < .001) of 17.18º was found between the pre- and the post-test. This 17.18º improvement, compared with 9.77º for HR and 13.53º for HR+ES, may be related with a longer training period (9 vs. 4 weeks). Furthermore, a six-week study reported the largest increase in the first three weeks, i.e. similar to our study (Rowlands *et al.,* 2003). Likewise, Kenric (2003) compared PNF, AIS and PSS (n=38) on hip flexion after training for four weeks, four sessions per week, and obtained significant improvements in the three groups with no significant differences among them. One training session per week, with a total training time that was three times as much as in our study, produced significant increases in ROM (Burke *et al.*, 2001; Rowlands *et al.,* 2003; Feland & Marín, 2004). Some authors reported that one single PNF session was sufficient to increase ROM (Feland, Myrer & Merrill 2001), the improvement ranging between 3 and 9 degrees, depending on the joint (Feland *et al.*, 2001).

As regards the isometric contraction, a large number of studies involving PNF used contraction times between 3 (Bonnar, Deivert & Gould, 2004) and 15 seconds (Schuback, Hooper & Salisbury, 2004). ROM increased in most studies in which contraction time was between 3 and 15 seconds (Feland *et al.,* 2001;

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Ferber, Osternig & Gravelle, 2002; Bonnar *et al.*, 2004; Feland & Marín, 2004). In some cases, longer duration of the isometric contraction was positively associated with an increase in ROM. The application of a PNF stretching protocol for six weeks produced a mean change of 28º in the group that maintained the contraction for 5 s and 33º in the group that maintained it for 10 s (Rowlands *et al.,* 2003). Other studies found that the increase in ROM was independent from the isometric contraction duration (Schmitt *et al.*, 1999; Feland *et al.,* 2001; Bonnard *et al.*, 2004). Studies in which 3-s isometric contractions were used also reported to be effective (Nelson & Cornelius, 1991; Bonnard *et al.*, 2004; González- Ravé *et al.*, 2012).

In the present study, the isometric contraction lasted for 6 s in both techniques and significant improvements were obtained. This duration falls within the range of the majority of studies that reported increases in ROM (Schmitt *et al.*, 1999; López-Bedoya *et al.,* 2007; López-Bedoya *et al.*, 2013). Both techniques produced significant improvements in PROM between the pre- and the post-test, them being slightly higher with HR+ES. Therefore, the effectiveness of electrostimulation to improve ROM was confirmed, in line with some previous studies (Pérez & Álamo, 2001; Basas, 2001; Maciel & Câmara, 2008; Espejo, Maya & Cardero, 2012; López-Bedoya *et al.* 2017). Nevertheless, despite them being long-term studies like this one, different electrostimulation techniques or programmes were applied.

The results obtained in this study were less favourable for AROM than for PROM. Several studies (López-Bedoya *et al.*, 2013; López-Bedoya *et al.*, 2017) also reported greater improvements for PROM. Slight gains were obtained in AROM, with no significant differences between the pre- and the post-test in HR or HR+ES. These results seem to confirm other studies that concluded that PNF hold relax technique and others using passive stretching were not the most appropriate ones to improve AROM (Meroni *et al.,* 2010; López-Bedoya *et al.*, 2013), unlike it occurs with PROM.

Changes produced in passive and active ROM between the post- and the re-test

Contradicting results were found in the literature regarding the duration of the effects of PNF stretching techniques on ROM. McCarthy, Olsen and Smeby (1997) stated that gains in ROM lasted for approximately seven days after one week stretching twice a day. Other studies reported that increases in ROM dropped rapidly once the intervention stopped (McCarthy *et al.,* 1997; Spernoga, Uhl, Arnold & Gansneder, 2001), so they recommended performing PNF stretching once or twice a week in order to stabilise ROM in the long term. This was also confirmed by studies where 3 sessions per week for 30 days were conducted (Spernoga *et al.*, 2001).

In the present study, when using the HR technique, almost no PROM loss (0.03º) occurred after two weeks of detraining between the post- and the re-test. Actually, a significant improvement in ROM of 9.80º was maintained between the pre- and the re-test (Table 1). The group that underwent HR+ES

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experienced a significantly higher loss (4.49º) between the post- and the re-test. However, a significant increase in ROM of 9.04º was maintained between the pre- and the re-test.

These results are in keeping with Rubley, Brucker, Ricard and Draper (2001), who suggested that the gains in ROM achieved were maintained for at least three weeks after finishing the training programme. By contrast, McCarthy *et al.* (1997) reported that improvements in ROM lasted for approximately seven days after one week stretching twice a day. Other studies stated that the effect duration may vary depending on the stretching time and the contraction duration during stretching. It has been proved that greater effects are achieved when the contraction is maintained between 3 and 10 seconds, 6 s being considered as the optimal duration (Rowlands *et al.*, 2003; Feland *et al.*, 2004).

Tolerance to stretching and pain sensation with the visual analogue scale

In this study, we have intended to provide some initial answers to underlying questions regarding flexibility training and intrinsic pain sensation. It seems difficult to establish a comparison with other studies, since PNF techniques have been generally applied as therapy to reduce pain in patients with myofascial pain syndrome or painful pathologies in the shoulder joint. These studies have obtained positive effects, measured by means of digital analogue scales (Lee, Park & Na, 2013; Kim, Lee & Ha, 2015).

Only Marsall *et al.* (2006) measured pain intensity during maximal stretching using the VAS. They reported an increase of 20.9% in hamstring ROM measured through the straight-leg-raise test after four weeks of stretching, but did not find any significant change between the pre- and the post-test in pain intensity.

However, the mean value of the VAS in our study was significantly different between HR and HR+ES groups in the first session (p = .003). This suggests that perceived pain levels during HR+ES technique were very low compared to HR.

It is surprising that the lower levels of pain sensation are registered in the HR+ES group in this session. This result may be due to negative predisposition towards a technique that includes an element that is perceived as painful because of the electric current: electrostimulation. This negative predisposition to pain may lead to lower values on the VAS, after trying the technique and experiencing it as less painful. Along the eight sessions of HR+ES in which perceived pain was assessed, it stabilised at medium levels from the first to the fourth session and decreased progressively from the fourth to the last session. In HR sessions, it stayed at medium levels until the last two sessions, in which perceived pain increased slightly to higher levels than for HR+ES.
Since no significant differences were found in VAS values in our study between HR and HR+ES, we must discard the effect of pain on the PROM gains occurred between the pre- and the post-test with both treatments. That is, the improvement does not depend on the pain produced by either technique. The

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mean VAS value for all sessions was almost the same for both groups: 53.28 for HR and 50.79 for HR+ES, suggesting that both techniques were well tolerated.

Nevertheless, further studies are needed in order to provide answers to the numerous questions that are inherent to flexibility training and the pain sensation it produces.

CONCLUSIONS

Flexibility training based on the PNF techniques hold relax and hold relax with isometric contraction induced by electrostimulation increases passive ROM significantly, with no significant differences between techniques.

Active ROM has not improved significantly in any of the groups, what suggests that these techniques are not appropriate for this purpose.

There was no significant decrease in passive range of movement in the period after training.

The application of HR and HR+ES techniques led to similar mean VAS values, showing high tolerance regarding pain perception.

Practical applications

The previous conclusions suggest that flexibility training using PNF techniques that involve passive stretching, like HR with or without isometric contraction induced by electrostimulation, are advisable to improve PROM, but not AROM, in young and adult athletes.

Consequently, the use of these techniques seems appropriate in gymnastics, especially artistic, rhythmic and acrobatic gymnastics, which require high levels of passive ROM in order to execute specific static positions with maximum technical quality (Harvey & Mansfield, 2000; Sands, McNeal, Stone, Russell & Jemni, 2006; Douda, Toubekis, Avloniti & Tokmakidis, 2008). Nevertheless, in order to improve AROM, which is a relevant variable in these gymnastic disciplines, as well as in combat sports, figure skating or synchronised swimming, other PNF techniques like CRAC, verified in several studies, would be advisable due to the reciprocal innervation mechanism (Sharman *et al.*, 2006; López Bedoya *et al.*, 2007).

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