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ORIGINAL

COMPARISON OF FLEXIBILITY TRAINING TECHNIQUES (PNF) WITH AND WITHOUT ELECTROSTIMULATION

COMPARACIÓN DE TÉCNICAS DE ENTRENAMIENTO DE FLEXIBILIDAD (FNP) CON Y SIN ELECTROESTIMULACIÓN

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ABSTRACT

The objective of this study was to analyze the effect of the Contract-Relax Agonist Contract stretching technique with (CRAC+EE) and without (CRAC) electrostimulation on the improvement and retention of active movement range (AROM) and passive (PROM) of hip in flexion, in dominant lower extremity. 34 university students were assigned to three groups: control, CRAC+EE and CRAC. AROM and PROM were evaluated before, once completed and after 2 weeks of completion the training. The training lasted 4 weeks, with 3 sessions per week.The ANOVA showed a very significant increase in AROM ($p<0.001$ and $p<0.005$) and PROM ($p<0.001$ and $p<0.01$) in both experimental groups respectively. In the retention, higher values are maintained with respect to the pre-test measurement. In conclusion, the application of CRAC++EE and CRAC improved AROM and PROM, being also effective in the retention of two types of range of motion.

KEY WORDS: Training, Flexibility, Proprioceptive Neuromuscular Facilitation, Electrostimulation.

RESUMEN

El objetivo de este estudio fue analizar el efecto de la técnica de estiramiento Contract-Relax Agonist Contract con (CRAC+EE) y sin (CRAC) electroestimulación sobre la mejora y retención del rango de movimiento activo (AROM) y pasivo (PROM) de cadera en flexión, en extremidad inferior dominante. 34 estudiantes universitarios fueron asignados a tres grupos: control, CRAC+EE y CRAC. AROM y PROM fueron evaluados antes, una vez finalizada y tras dos semanas de la finalización del entrenamiento. El entrenamiento tuvo una duración de cuatro semanas, a razón de tres sesiones semanales. El ANOVA mostró un aumento muy significativo de AROM ($p<0{,}001$ y $p<0{,}005$) y PROM ($p<0{,}001$ y $p<0{,}01$) en ambos grupos experimentales respectivamente. En la retención, se mantienen valores superiores con respecto a la medida pre-test. Como conclusión, la aplicación de CRAC+EE y CRAC mejoró AROM y PROM, siendo además efectivas en la retención de sendos rangos de movimiento.

PALABRAS CLAVE: Flexibilidad, Entrenamiento, Facilitación Neuromuscular Propioceptiva, Electroestimulación.

INTRODUCTION

Flexibility as a physical ability is a decisive quality that enhances and optimizes learning and performance in sports (Alter, 2004). It is the quality that allows human beings to mobilize body segments, allowing great Ranges of Motion (ROM). Flexibility training (maximum demand) can be performed by means of three basic stretching techniques: static, dynamic and pre-contraction stretching (Page, 2012). The latter group involves a contraction prior to muscle stretching, the most common being the proprioceptive neuromuscular facilitation (PNF) technique, which has proven effective in improving both active and passive range of motion within the sport community (Sundquist, 1996; McAtee & Charland, 2000; Kenric, 2003; López-Bedoya, Vernetta, Robles & Ariza, 2013; García- Manso, López-Bedoya, Rodríguez-Matoso, Ariza-Vargas, Rodríguez-Ruiz & Vernetta, 2015).

This is a method that is aimed at promoting or accelerating the neuromuscular mechanism by stimulating proprioceptors (Voss, Ionta & Meyers, 2004). It uses natural reflexes (autogenic inhibition reflex) to inhibit muscle contraction and thus achieve greater ROM (McAtee & Charland, 2000). The effectiveness of PNF is based on the use of mass movement patterns called spiral-diagonal patterns and on specific techniques which sequence the muscular movement during the performance of movement patterns.

According to Barnet (2006), electrostimulation involves the transmission of electrical impulses through surface electrodes in order to stimulate the motor neurons in the peripheral nervous system, causing muscle contractions. There are many authors who used ES in sport in order to achieve various objectives: to improve muscle strength and endurance; to increase muscle mass; to speed up recovery after hard effort; to prevent and improve injury rehabilitation (Maffiuletti, Dugnani, Folz, Di Pierno & Mauro, 2002; Martín, Millet, Lattier & Perrod, 2004; Pombo, Rodríguez, Barnada, Brunet & Requena, 2004; Naffiuletti, Zory, Miotti, Pellegrino, Jubeau & Bottinelli, 2006). However, there are few studies where electrostimulation allows generating a contraction analogous to the physiological one so that the electrical impulse induced could give rise to muscular contraction in order to see its effect on the ROM (Acosta, López-Bedoya & Vernetta, 1998; Pérez & Álamo, 2001; López-Bedoya, Goméz-Landero, Jiménez & Vernetta, 2002; De Hoyo & Sañudo 2006; Espejo, Maya, Cardero & Albornoz, 2012).

Among the numerous PNF techniques for improving the ROM, the most common in the scientific literature related to sport training are called Contract-Relax (CR) and Hold-Relax (HR) (Surburg & Schrader, 1997; Acosta *et al.*, 1998; Adler, Berkers & Buck, 2002; Voss *et al.*, 2004; López Bedoya *et al.*, 2013), the technique called *Contract-Relax-Agonist Contract* (CRAC) being less studied (Etnyre & Abraham, 1986; McAtee & Charland, 2000). The latter is executed very similarly to CR, that is, in its first part, a concentric isotonic contraction of the muscle to be stretched is performed, followed by a relaxation phase and subsequently an isometric contraction of the opposing muscle, followed by an active stretch towards the new range of motion (McAtee & Charland, 2000; Norris, 2007; Ayala, Sainz de Baranda & Cejudo, 2012). It is believed that this active contraction of the stretch opposing muscle stimulates the reciprocal inhibition of the target muscle, thereby allowing a deeper stretch.

There are several studies that proved its efficiency over the long-term increase of active and passive range of motion (Etnyre & Abraham, 1986; Sundquist 1996; McAtee & Charland, 2000). However, there is very little literature conceptualizing its effect when the agonist contraction is induced by electrostimulation (Acosta *et al.*, 1988; Pérez & Álamo, 2001; López Bedoya *et al.*, 2002).

AIMS

The fundamental objective of the study is to evaluate the long-term effect of flexibility training through the PNF CRAC technique with and without induction of the last contraction phase by means of electrostimulation, on the passive and active range of motion in the hamstring of young athletes. Moreover, another objective is to detect which of the two training modalities allows maintaining the improvement obtained after a two-week period of inactivity.

MATERIALS AND METHODS

Participants

A total of 34 young athletes, university students in Sports Science, specialty Artistic Gymnastics (20 males and 14 females) with an age range of between 20 and 23 years (age = 21.80 ± 1.20 years, body mass = 66.81 ± 9.60 kg, height = 170.52 ± 8.22 cm) were divided into 3 groups: control, Contract-Relax Agonist Contract induced by electrostimulation (CRAC+EE) and CRAC by blocking techniques based on the data obtained in the pre-test. All participants were fully informed of the procedures and risks involved before written consent was obtained. None of them suffered injuries of the mentioned muscle group or other ailment.
The study was performed according to the Declaration of Helsinki and was approved by the Ethics Committee of the University of Granada.

Experimental design

A repeated-measure factorial design was used, with three levels in the inter-group factor (control, CRAC+EE, CRAC) and three levels in the intra-group factor (pre-, post and re-test measurements). The dependent variables are the passive range of motion (PROM) and the active range of motion (AROM) of the flexed hip.

Instruments and equipment

A standard digital photo camera (Nikon, Coolpix S500, Nikon Corporation, Chiyoda-ku, Tokyo, Japan, http://www.nikon.com/) was used to capture the ASLRT and PSLRT evaluation tests, and subsequently to collect the angle data. Furthermore, the training phase involved 7 devices for programmable electrostimulation Cefar Myo4, with an asymmetric biphasic rectangular pulse waveform, a pulse intensity ranging from 0 to 120 mA in each of its four channels, and a pulse-width or pulse-duration set in microseconds (μs). The pulse frequency is programmable in a range from 0 to 120 Hz.

Procedure of measurement

The assessment tests were conducted in three stages: the pre-test was performed prior to the first training session; the post-test 1 immediately after the last training session, and the re-test after two weeks of inactivity to check the loss in each of the training groups. In the assessment of active and passive flexibility, the active straight leg raise test (ASLRT) and the passive straight leg raise test (PSLRT) were used. The angles were measured through the digitalization of the anatomical points using ATD 2.0 for Windows (Analysis of Sport Techniques, program Granada University, Spain) on the photographs taken during the tests. The angle (α) was obtained by digitalizing 3 points: ankle (malleolus), hip (greater trochanter) and the ankle of the other leg (malleolus). Each photograph was digitalized 3 times in ASLRT and PSLRT and the average was considered in each case. During the tests, the participant lay prone on a bench and is told to keep the head and back in a straight line and the lumbar area pressed against the bench. Keeping the knees fully extended, the participant slowly proceeded to raise the leg straight up by flexing the hip, avoiding internal and external rotations of the leg or deviations from the sagittal plane. When the maximum active or passive ROM was reached (as appropriate), as expressed verbally by the subject, the position was maintained and a photograph was taken with the camera perpendicular to the participant at a distance of 4 meters and with the center of focus on the hip joint. The photographs had a resolution of 1024x768 pixels.

Training Protocol

The participants from the two experimental groups undertook flexibility training consisting of 3 sessions per week for 4 weeks. Before each training session, they performed a standardized warm-up for 20 minutes, which was the same for all training sessions and for both groups. The evaluation tests in pre-test, post-test 1 and 2, and re-test, as well as the training sessions, took place at the same time in the morning (11 a.m.) and place and at a temperature of 23º C. The stretching exercise used was SLR (Straight Leg Raise). Before the training period, the subjects participated in a session where they were instructed about the application of the CRAC-PNF stretching technique used. The session was used as a first contact and familiarization with the evaluation test and the technique employed.

Experimental Group 1 (CRAC+EE) (11 participants): in this case, the CRAC technique was applied, using electrostimulation consisting of one series of 10 repetitions of the following cycle: active elongation (AE) of the hamstring muscle group to the maximum ROM; maximum concentric contraction (CC) of the muscle to be stretched (hamstring muscle group). To perform this contraction, a bipolar electrical current (100 *mA*) was applied, using two surface electrodes located in the proximal and distal ends of the hamstring muscle group. The electrical current parameters used were: electrical impulse frequency of 80 Hz, with a contraction time (CT) of 6 s, whilst their partner tried to maintain the position of the leg; relaxation of the contraction for 2 s and contraction of the opposing muscles (quadriceps and psoas) while exhaling, and extending the stretching of the hamstring muscle group actively through the new ROM and the position was maintained for 10 seconds; relaxation of the muscle group in the initial position for 2 s. In the stretch there is no traction performed by the assistant. The summary of the cycle was: 6 s contraction, 10 s stretch, 2 s rest. Thus, the training was: 1x10x (6 s CC + 10 s ES) taking 2 s rest between repetitions, giving a total stretching time of 100 s per session and a total work time of 3 min.

Experimental Group 2 (CRAC) (11 participants): the technique applied was the same, but without electrostimulation during the concentric contraction (CC) for 6 s of the muscle to be stretched (hamstring muscle group).

Statistical analyses

Prior to analysis, the assumptions of normality were tested using Shapiro-Wilks normality test for samples of 50 or fewer participants and then Levene’s test for homoscedasticity. Next, the differences in each of the dependent variables AROM and PROM were analyzed through a mixed factorial ANOVA or ‘split-plot’ (measurement-treatment), with three levels in the between-subject factor (control, CRAC+EE, CRAC) and three levels in the within-subject factor (pre-, post-, and re-test).

The equality of variance and covariance matrices of the within-subject factor levels was checked in each of the levels of between-subject factors using Mauchly's sphericity test, the univariate F statistic, by applying the Greenhouse-Geisser correction of the Epsilon index in case of violation of the sphericity assumption.

In the multiple comparisons regarding the within-subject effects, the critical levels and confidence intervals were adjusted by Bonferroni's correction.

To evaluate the differences between the gain scores obtained between the pre- and post-test measurements, and the post- and re-test measurements, in each of the applied treatment, a one-way ANOVA was used. *Post-hoc* comparisons were made using the Bonferroni statistics. The significance level used in all tests was $p < .05$. Data were analyzed using the IBM SPSS Statistics software, V.22.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

All the distributions of the values corresponding to the subpopulations resulting from combining different levels of the measurement-treatment factor showed normal behavior, $p <.05$.

Table 1 shows the mean values and standard deviations of the various AROM and PROM measurements.

Table 1. Mean (standard deviation) values of the ranges of hip flexion, active and passive, measured in degrees, according to the different experimental groups and levels of Measure factor (pre-, post- and retest).

		Control	CRAC+EE	CRAC	Total
ROM Active	N	10	12	12	34
	Pre-	94.70 (12.06)	91.00 (10.26)	90.83 (6.58)	92.03 (9.60)
	Post-	95.60 (11.82)	98.83 (8.26)***	96.17 (5.44)***	96.94 (8.53)***
	Re-test	95.40 (11.91)	94.42 (8.97)** †††	93.58 (5.38)* †	94.41 (8.70)*** †††
	Improvements (Post-Pretest)	.90 (3.51)	7.83 (.04) ‡‡	5.33 (4.29) ‡	4.91 (4.79)
	Improvements (Post-Retest)	-.2 (2.78)	-4.41 (2.47) ‡‡	-2.58 (3.26)	2.53 (3.26)
ROM Passive	N	10	12	12	34
	Pre-	118.40 (24.57)	120.17 (20.40)	116.50 (9.95)	118.35 (18.41)
	Post-	124.00 (20.89)	136.33 (12.52)***	127.92 (12.01)**	129.74 (15.69)***
	Re-test	119.50 (23.26)	132.17 (13.32)***	122.25 (7.75)* †	124.94 (16.04)*** ††
	Improvements (Post-Pretest)	5.60 (10.20)	16.17 (10.51)	11.42 (9.24)	11.38 (10.59)
	Improvements (Post-Retest)	4.50 (10.30)	4.17 (1.59)	5.67 (6.76)	4.79 (6.74)

*** = $p < .001$; ** = $p < .01$; * = $p < .05$; statistically significant differences as Pretest
††† = p < .001; †† = p < .01; † = p < .05; Statistically significant differences as Post-test
‡‡ = p < .01; ‡ = p < .05; statistically significant differences with Control Group
CRAC+EE = Contract-Relax Antagonist Contract with Electrostimulation.
CRAC = Contract-Relax Antagonist Contract
CRAC+EE = Contract-Relax Antagonist Contract with Electrostimulation
CRAC = Contract-Relax Antagonist Contract

The mixed factorial analysis showed similar trends for active and passive ranges of motion.

Active range of motion (AROM)

Regarding AROM, the repeated measures ANOVA showed a statistically significant main effect of the Measurement factor, $F(2.62) = 32.255$, $p = .000$, $\eta_p^2 = .510$, and the measurement-treatment interaction, $F(4.62) = 5.872$, $p = .000$, $\eta_p^2 = .275$.

The mean values of AROM (see Table 1) were statistically higher in the post- and re-test measurements compared to the pre-test measurement ($p < .001$, 95% CI [2.951, 6.427] and $p = .001$, 95% CI [.882, 3.696], respectively), and the post-test measurement was higher than the re-test measurement (p = 0.000, 95% CI [1.154, 3.646]).

Regarding the measurement-treatment interaction, the statistical analysis highlighted the fact that the active range of motion was significantly different among the different measurements according to whether CRAC+EE or CRAC were administered.

Applying the CRAC+EE technique, the mean values of the pre-test measurements were significantly lower than those obtained in the post- and re-test measurements (p < .001, 95% CI [4.919, 10.748] and p = .003, 95% CI [1.057, 5.776], respectively). Moreover, the mean value of the post-test measurement was significantly higher than that obtained for re-test (p < .001, 95% CI [2.328, 6.506]).

The same dynamics was observed when the CRAC technique was applied. The mean value of the post-test measurement was significantly higher than those obtained in the pre- and re-test (p < .001, 95% CI [2.419, 8.248] and p = .011, 95% CI [.494, 4.672], in the same order) and the latter is also higher than in the pre-test measurement (p = .011, 95% CI [.494, 4.672]) (see Figure 1).

Regarding the intra-group 'Treatment' factor, no statistically significant differences were observed between total mean values of the active range of motion, regardless of the pairs of contrasting levels, $F(1,31) = .109$, $p = .897$, $\eta_p^2 = .007$.

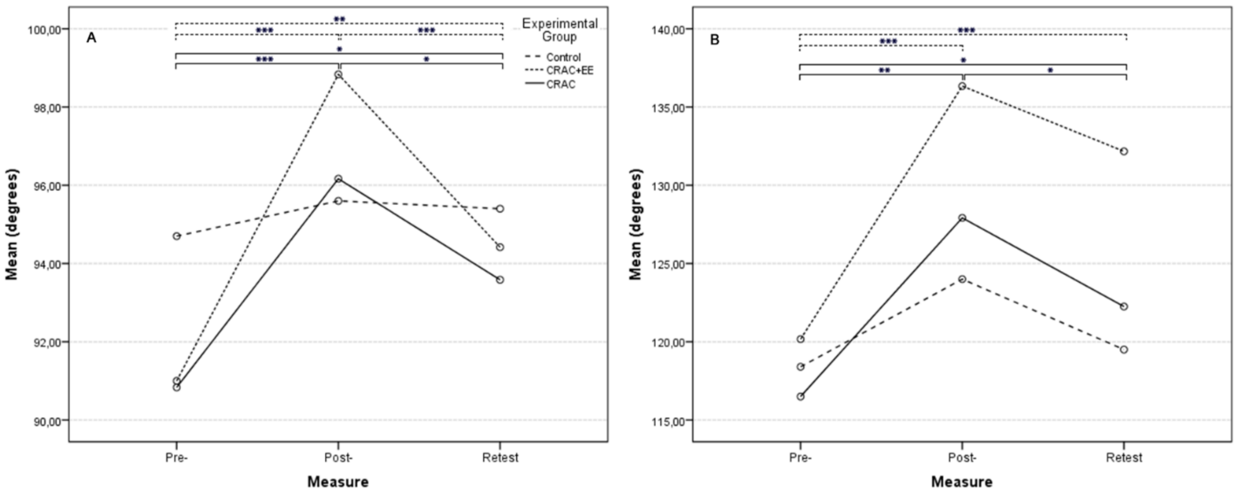


Figure 1. Mean values of AROM (A) and PROM (B) according to the different measures carried out, in each experimental group (Control, Contract-Relax Antagonist-Contract with electrostimulation - CRAC+EE and Contract-Relax Antagonist-Contract - CRAC). *** = P <.001; ** = P <0.01; * = P <0.05

Passive Range of Motion (PROM)

Split-Plot ANOVA indicated a significant main effect of the Measurement factor, $F(1.622, 50.287) = 30.818$, $p = .000$, $\eta_p^2 = .499$. Specifically, the mean values of the pre-test measurement were significantly lower than those obtained for the post- and re-test measurements (p = .000, 95% CI [6.711, 15.411] and p = .000, 95% CI [3.064, 9.503], respectively). The mean value for the post-test measurement was significantly higher than that for the re-test measurement (p = .001, 95% CI [1.763, 7.793]) (see Table 1).

In addition, a significant effect of the measurement-treatment interaction was observed, $F(3.244, 50.287) = 3.177$, $p = .029$, $\eta_p^2 = .170$), the detected differences focusing on the CRAC+EE and CRAC treatments (see Figure 1).

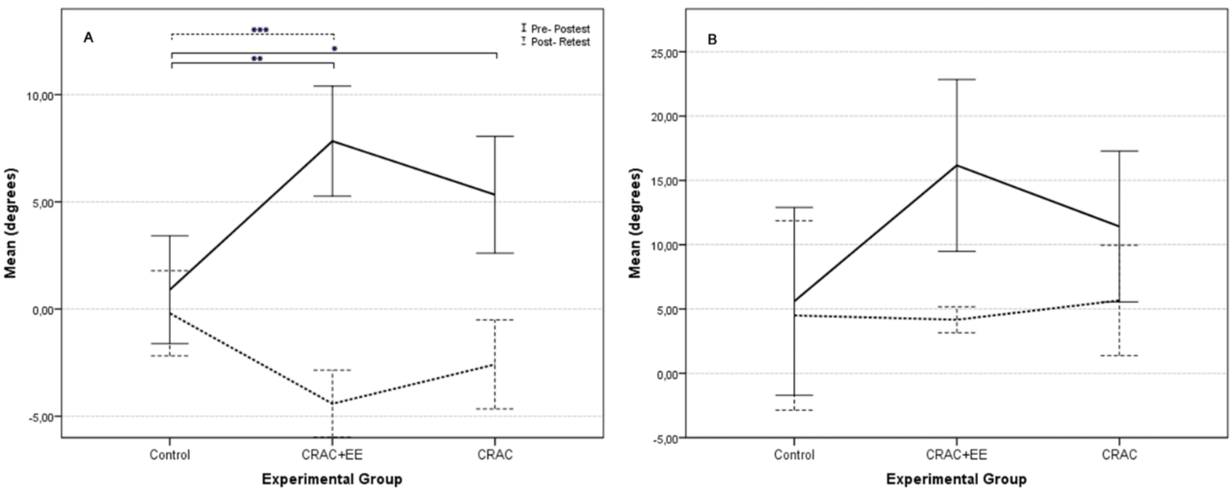
In the case of CRAC+EE, the differences between pairs showed mean values lower than the pre-test measurement with respect to the post- and re-test measurements ($p = .000$, 95%IC [8.871, 23.462] and $p = .000$, 95%IC [6.600, 17.400], in the same order). Applying CRAC led to higher mean values of ROM in the post- and re-test measurements compared to the pre-test measurement ($p = .001$, 95% CI [4.121, 18.712] and $p = .034$, 95% CI [.350, 11.150], respectively), as well as higher mean values of the post-test measurement with respect to the re-test measurement ($p = .024$, 95% CI [.610, 10.723]).

No statistically significant differences were observed between the total mean values of the various measurements associated with the intra-group treatment factor, $F(2,31) = 1.014$, $p = .374$, $\eta_p^2 = .061$.

Gain scores obtained between pre-/post-test measurements, and post-/re-test measurements

Considering the active range of motion, the analysis of one-way variance detected statistically significant differences in gain scores obtained between the pre-/post-test measurements, $F(2, 31) = 8.343$, $p = .001$, and the post-/re-test measurements, $F(2, 31) = 5.935$, $p = .007$ (see Figure 2).

In the first case, the *post hoc* tests indicated that the difference obtained between the pre- and post-test measurements in the Control group was significantly lower than that obtained in the CRAC+EE, $p = .001$, 95% CI[2.6107, 11.2559] and CRAC treatments, $p = .043$, 95% CI [.1107, 8.7559]. Regarding the gain score obtained between the post- and re-test measurements, the only significant difference was observed between the Control and CRAC+EE treatments , $p = .005$, 95% CI [1.1182, 7.3152], the absolute values of the mean differences being higher in the CRAC+EE group. (see Table 1).



*** = $P < .001$; ** = $P < 0.01$; * = $P < 0.05$; Error bars 95% CI

DISCUSSION

The major findings of this study included a significant improvement of passive and active ROM in the two experimental groups with and without induction of contraction through electrostimulation, while the control group basically maintained its initial conditions.

The improvements in the CRAC+EE and CRAC groups were 16.17º and 11.42º respectively for PROM and 7.83º and 5.33º for AROM, after an intervention of 3 sessions per week for 4 weeks (Table 1). These results confirm those found in other studies (Etnyre & Abraham, 1986; McAtee & Charland, 2000) in relation to the training using the CRAC technique, which, after a period of training, obtained improvements in both passive and active ROM.

The research studies conducted by Etnyre & Abraham (1986) and Sundquist (1996), after having compared the technique of Static Stretching and different PNF, CR and CRAC techniques, concluded that the CRAC technique generated the biggest inhibitory neuronal influence of the motor activity during stretching, reducing contractility of the muscles to stretch, which allowed greater muscular obedience, and a better increase in ROM.

The study carried out by Etnyre and Abraham (1986) showed mean results of 26º of improvement in the range of motion of the hip after a 12-week training period with the CRAC technique. These values refer to passive manifestations and although they are above those obtained by both experimental groups of our study, they were obtained over a training period three times longer. In the above-mentioned study, the contraction times were equal to ours (6 s), but stretches were performed for 3 seconds over a period of 12 weeks; this may be the reason why the achieved margins are not comparable to ours (12 weeks vs. 4 in our study).

Moreover, the effectiveness of electrostimulation to improve the ROM is also confirmed, as well as in long-term studies which employed different techniques and applied various electrical current frequencies (Acosta *et al.*, 1998; Pérez & Álamo, 2001; Basas, 2001; López-Bedoya *et al.*, 2002; Maciel & Câmara, 2008; Espejo *et al.*, 2012).

The effectiveness of the CRAC technique should be pointed out when combined with electrostimulation, in accordance with the study conducted by Lopez-Bedoya *et al.* (2002). This work also compared two protocols with and without induction of muscle contraction by electrostimulation using the CRAC technique, finding better results for the technique with electrostimulation in the post-test, both in the passive and active manifestations, with no statistically significant differences between the two, as it occurs in our study.

Maciel and Câmara (2008) evaluated the electrostimulation effect associated with passive stretching (PS) in order to achieve flexibility gains for the hamstring muscle group. The results showed that groups of PS and PS&ES with the

TENS program increased their range of motion compared to the control group, but there was no difference between the two groups, as in our study.

However, it should be noted that although TENS obtained improvements in both experimental groups, as in our study, one of the most important aspects of the effectiveness of the protocols used when working on muscle extensibility with electrostimulation, is the choice of suitable electrical current waveforms, i.e. those which, as the ones used in our study, and unlike TENS, have frequencies able to stimulate skeletal muscle realistically (Plaja 1999; Linares, Escalante & LaTouche, 2004).

On the other hand, it is also confirmed, as in other research studies, that the improvements in the PROM are always higher than those in AROM (Roberts & Wilson, 1999; López Bedoya *et al.*, 2013).

In this sense, it is of major importance to note that AROM improvements in our study may be due to the use of the CRAC technique, since there are several studies showing that improvements in active manifestations are associated with PNF techniques such as CRAC, used in the present study (Etnyre & Abraham, 1986; Sundquist, 1996; McAtee & Charland, 2000; Rowlands, Marginson & Lee, 2003; Sharman, Cresswell & Riek, 2006).

Many of these previous studies explain these gains by the mechanism of reciprocal innervation. In the CRAC technique, the contracting muscle, which is opposed to the stretching muscle, causes this reflex and inhibits the muscle group to be stretched (MS). This inhibition of MS, along with the contraction - shortening of the opposing muscle - allows the muscle fibers of the MS to be extended even more, because of a greater inhibitory influence on that muscle (Etnyre & Abraham, 1986; Sharman *et al.*, 2006). The interneurons which innervate the alpha motor neurons, which synapse in the MS, reduce the neural activity in the above-mentioned muscle group, leading to a greater stretch thereof (Rowlands *et al.*, 2003).

With regard to the re-test results, in relation to the PROM, the gain scores obtained between the post- and re-test measurements were significantly different between the CRAC+EE and CRAC treatments. The data showed that subjects from both experimental groups who used the CRAC-PNF technique with and without electrostimulation, lost little of the improvement obtained in the range of motion of the hip joint compared to the pre-test, two weeks after the treatment was suspended. In other words, none of the experimental groups experienced a complete loss, where the values maintained between pre-test and re-test were 5.76º for the CRAC group and 12º for the CRAC+EE group (see Figure 2).

The recorded data confirm the results obtained in the studies performed by Zamora and Salazar (2001), who claimed that the PNF technique allowed maintaining the improvement in the range of motion of the hip joint for a longer period of time, compared to the use of static stretching techniques.

However, the review found that there were contrary results regarding the duration of the effects of PNF stretching techniques over ROM stretching techniques. McCarthy, Olsen & Smeby (1997), pointed out that the gain scores in the ROM lasted about seven days after a week of stretching exercises twice a day; other studies showed that ROM increases diminish relatively quickly after cessation of the intervention (Wallin, Ekblom, Grahn & Nordenborg, 1985; Spernoga, Uhl, Arnold & Gansneder, 2001; Funk, Swank, Mikla, Fagen & Farr, 2003). Thus, it is advisable to work on the PNF stretching at least once or twice a week in order to stabilize the long-term ROM.

The duration of these effects may vary due to stretching time and duration of the contraction during the PNF stretching (Feland & Marín, 2004; Rowlands *et al.*, 2003). It was shown that this type of contraction produced better effects when maintained between 3 and 10 s, a time of 6 s being considered preferable (Feland & Marín, 2004).

Under the conditions of our study, with a contraction of 6 s, it was found that none of the experimental groups experienced a complete loss after two weeks without applying the stretching techniques (see Figures 1 and 2). These results contradict the ones obtained by McCarthy *et al.* (1997), in relation to maintaining the ROM gain scores; the authors mentioned that they were lost after seven days.

However, it is important to note that this was not the case for AROM, where slight losses were also found, of 2.58º between post-test (96.17º) and re-test (93.58º), and of 2.75º between pre-test (90.83º) and re-test (93.º58) in CRAC (see Figure 1), significantly lower than those obtained for the group who was applied the CRAC+EE technique, with a loss of 4.41º between the post-test group (93.83º) and the re-test group (94.42º). Note that in this group a very slight gain of 3.42º is maintained between pre-test (91º) and re-test (94.42º). These AROM results lead us to the idea that the application of the CRAC+EE flexibility training technique, although produces a temporary increase of the active range of motion, within two weeks of cessation has an adverse effect, which leads to a reduction of that lower value that would have been obtained if the participants had not been subjected to any treatment (control group). This adverse effect was not recorded when the subjects were submitted to the CRAC technique, and the gain scores obtained were similar to those obtained by the CRAC+EE group, the reduction of the range of motion involved remaining similar to the control group.

CONCLUSIONS

This study shows how to stretching training protocol in young athletes using the PNF-CRAC stretching technique with and without contraction induced by electrostimulation (Three sessions per week for four weeks, with a total stretching time of 100 seconds per session) on the hamstring muscle group was proven effective in improving the active and passive range of motion. Although no significant differences were found between the two techniques, the results showed that there was a slight trend toward greater ROM gain scores in

CRAC+EE over CRAC. Similarly, both techniques allow maintaining the improvement of AROM and PROM with a slight decline after two weeks of inactivity.

In short, the flexibility training using PNF-CRAC stretching techniques with and without muscle contraction induced by electrostimulation, has beneficial effects in improving hamstring muscle group extensibility. Further research is necessary to continue testing with larger samples, of different age ranges and different characteristics (elite athletes, in the initiation phase, etc.) representing the rest of the population and using methodological designs that include medium- and long- term follow-up periods.

It is necessary to emphasize the prudence in the generalization of the results of this study for other groups of subjects with different characteristics of age, gender, physical activity level or initial level of ROM; they cannot be extrapolated to other muscle groups or different joint points, environmental conditions, which implies the need to continue the study with new investigations.

Practical applications

As a result of its findings, it could be considered that the techniques including active stretching, such as CRAC, with and without electrostimulation, are recommended for improving both active and passive range of motion.

On the other hand, considering the effectiveness of these techniques, its use in artistic-expressive sports such as rhythmic and artistic gymnastics, synchronized swimming, figure skating, etc., could provide beneficial effects, since having large ranges of movement in unusual postures is a key factor in their performance (Sands, 2002).

REFERENCES

Acosta, J.; López Bedoya, J. & Vernetta, M. (1998). Mejora del Spagat frontal aplicando métodos de *Facilitación Neuromuscular Propioceptiva y técnicas de Electroestimulación y Biofeedback.* En M. Vernetta, J. López-Bedoya & P. Panadero (eds.) *Novedades en Actividades Gimnásticas* (pp. 127-130). Granada: Editores.

Adler, S. S.; Berkers, D. & Buck, M. (2002). *La Facilitación Neuromuscular Propioceptiva en la práctica. Guía ilustrada.* Buenos Aires: Editorial Panamericana.

Alter, M. J. (2004). Science of Flexibility (3ª Ed.). Champaign: Human Kinetics.

Ayala, F., Sainz de Baranda, P. & Cejudo, A. (2012). Flexibility training: Stretching techniques. *Revista Andaluza de Medicina del Deporte, 5*, 105-112. https://doi.org/10.1016/S1888-7546(12)70016-3

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes: does it help? *Sports Medicine,* 36(9), 781-796. https://doi.org/10.2165/00007256-200636090-00005

Basas, G. A. (2001). *Metodología de la electroestimulación en el deporte. Fisioterapia*, 23, 36-47. https://doi.org/10.1016/S0211-5638(01)72971-9

De Hoyo, M. & y Sañudo, B. (2006). La electroestimulación como mejora de la flexibilidad. http://www.efdeportes.com/ Revista Digital - Buenos Aires, 11 (101).

Etnyre, B.R. & Abraham, L.D. (1986). H-reflex changes during static stretching and two variations of proprioceptive neuromuscular facilitation techniques. *Electroencephalography and Clinical Neurophysiology,* 63, 174-179. https://doi.org/10.1016/0013-4694(86)90010-6

Espejo, L., Maya, J., Cardero, M.A., & Albornoz, M. (2012). Aumento de la extensibilidad isquiotibial tras aplicar elongación muscular eléctrica. *Fisioterapia. 34*(3*)*, 112–117. https://doi.org/10.1016/j.ft.2012.01.001

Feland, J.B., & Marin, H.N. (2004). Effect of submaximal contraction intensity in contract-relax proprioceptive neuromuscular facilitation stretching. *British Journal of Sports Medicine, 38*(4):e18. https://doi.org/10.1136/bjsm.2003.010967

Funk, D.C., Swank, A.M., Mikla, B.M., Fagen, T.A., & Farr, B.K. (2003). Impact of Prior Exercise on Hamstring Flexibility: A Comparison of Proprioceptive Neuromuscular Facilitation and Static Stretching. *National Strength & Conditioning Association Journal*. 17(3), 489–492. https://doi.org/10.1519/00124278-200308000-00010

García-Manso, J.M., López-Bedoya, J., Rodríguez-Matoso, D., Ariza, L., Rodríguez-Ruiz, D. & Vernetta, M. (2015). Static-stretching vs. contract-relax - proprioceptive neuromuscular facilitation stretching: study the effect on muscle response using tensiomyography. *European Journal of Human Movement*, *34*, 96-108.

Kenric, L. (2003). *A Comparison of Different Methods for Improving Hamstring Flexibility*. Tesis Doctoral. Florida Atlantic University.

Linares, M.; Escalante, K., & LaTouche, R. (2004).Revisión bibliográfica de las corrientes y parámetros más efectivos en la electroestimulación del cuádriceps. *Fisioterapia, 26*(4), 235-244. https://doi.org/10.1016/S0211-5638(04)73108-9

López-Bedoya, J.; Goméz-Landero, A.; Jiménez, J. & Vernetta, M. (2002). Estudio comparativo entre técnicas de Facilitación Neuromuscular Propioceptiva mediante electroestimulación (FNP-EEM) y secuencia estiramiento facilitado Contracción, Relajación, Contracción Antagonista (CRCA) en la musculatura isquiotibial. En *Enseñanza y entrenamiento de la Gimnasia y la Acrobacia. Actas del I Simposium Internacional de*

Actividades Gimnásticas y Acrobáticas (pp 160-165). Cáceres: Universidad de Extremadura.
López-Bedoya, J., Vernetta, M., Robles, A & Ariza, L. (2013). Effect of three types of flexibility training on active and passive hip range of motion. *The Journal of Sports Medicine and Physical Fitness*, 53(3), 304-11.
Maciel, A.C.C. & Câmara, S.M.A. (2008). Influência da estimulação elétrica nervosa transcutânea (TENS) associada ao19.alongamento muscular no ganho de flexibilidade. *Revista Brasileira de Fisioterapia, 5*(12), 373-378. https://doi.org/10.1590/S1413-35552008000500006
Maffiuletti, N.; Dugnani, S.; Folz, M.; Di Pierno, E., y Mauro, F. (2002). Effects of combined electrostimulation and plyometric training of vertical jump height. *Medicine and Science in Sports and Exercise, 34*(10), 1638-1644. https://doi.org/10.1097/00005768-200210000-00016
Martin, V.G., Millet, G.Y., Lattier, G. & Perrod, L. (2004). Effects of recovery modes after knee extensor muscles eccentric contractions. *Medicine and Science in Sports and Exercise,* 36(11), 1907-1915. https://doi.org/10.1249/01.MSS.0000145526.43208.08
McAtee, R.E. & Charland, J. (2000). *Estiramientos Facilitados. Los estiramientos de FNP con y sin asistencia*. Barcelona: Paidotribo.
McCarthy P.W., Olsen J.P. & Smeby I.H. (1997). Effects of contract-relax stretching procedures on active range of motion of the cervical spine in the transverse plane. *Clinical Biomechanics, 12* (2), 136-138. https://doi.org/10.1016/S0268-0033(96)00060-5
Naffiuletti, N.A., Zory, R., Miotti, D., Pellegrino, M.A, Jubeau, M., Bottinelli, R. (2006). Neuromusuclar adaptations to electrostimulation resistance training. *American Journal of Physical Medicine & Rehabilitation, 85*(2), 167-75. https://doi.org/10.1097/01.phm.0000197570.03343.18
Norris, C.M. (2007). La Guía completa de los estiramientos. 2ª ed. Barcelona: Paidotribo.
Page, P. (2012).Current concepts in muscle stretching for exercise and rehabilitation. *The International Journal of Sports Physical Therapy, 7*(1), 109-119.
Pérez, M.J. & Álamo, A.D. (2001). Comparative study between muscular stretching by active tension and electrostimulation*. Fisioterapia,* 23, 10-14. https://doi.org/10.1016/S0211-5638(01)72924-0
Plaja, J. (1999) *Guía práctica de electroterapia*. Barcelona: Carin Electromedicarin, SA.
Pombo, M., Rodríguez, J., Bruñe, X. & Requena, B. (2004) *La electroestimulación entrenamiento y periodización.* Barcelona: Paidotribo.
Roberts, J.M. & Wilson, K. (1999). Effect of stretching duration on active and passive range of motion in the lower extremity. *British Journal of Sports Medicine*, *33*(4):259-63. https://doi.org/10.1136/bjsm.33.4.259

Rowlands, A.V., Marginson, V. & Lee, J. (2003). Chronic flexibility gains: effect of isometric contraction duration during proprioceptive neuromuscular facilitation stretching techniques. *Research Quarterly for Exercise and Sport, 74*(1), 47-52. https://doi.org/10.1080/02701367.2003.10609063

Sands, WA. (2002). Physiology. In W.A. Sands, D.J. Caine & J. Borms, (eds.) *Scientific Aspects of Women's Gymnastics* (pp.128–161). Switzerland: Karger Publisher. https://doi.org/10.1159/000067490

Sharman, M.J., Cresswell, A.G. & Riek, S. (2006). Proprioceptive Neuromuscular Facilitation Stretching Mechanisms and Clinical Implications. *Sports Medicine, 36*(11), 929-939. https://doi.org/10.2165/00007256-200636110-00002

Spernoga, S.G., Uhl, T.L., Arnold, B.L. & Gansneder, B.M. Duration of Maintained Hamstring Flexibility After a One-Time, Modified Hold-Relax Stretching. *Protocol. Journal of Athletic Training, 36*(1), 44–48.

Sundquist, R.D. (1996).The comparative effectiveness of static stretching and propioceptive neuromuscular facilitation stretching techniques in increasing hip flexion range of motion. *Microform publications, for Sport & Human Performance, Universidad de Oregon.*

Surburg, P. R. & Schrader, J. W. (1997). Proprioceptive Neuromuscular Facilitation Thechniques in Sports Medicine: A Reassessment. *Journal of Athletic Training, 31*(1), 34-39.

Voss, D. E., Ionta, M. K. & Meyers, B. J. (2004). *Facilitación Neuromuscular Propioceptiva. Patrones y técnicas*. Buenos Aires: Editorial Panamericana.

Wallin, D., Ekblom, B., Grahn, R., & Nordenborg, T. (1985). Improvement of muscle flexibility: A comparison between two techniques. *The American Journal of Sports Medicine*, *13*(4), 263-268. https://doi.org/10.1177/036354658501300409

Zamora, J.D. & Salazar W. (2001). Efecto del método de estiramiento PNF y estático en la mejora de la flexibilidad de la articulación de la cadera en practicantes de kung Fu. *Revista de Ciencias del Ejercicio y la Salud, 1(2), 43-50.* https://doi.org/10.15517/pensarmov.v1i2.430

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