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Effects of transcutaneous electrical nerve stimulation and cryotherapy on pain threshold by induced pressure

Efeitos da estimulação elétrica nervosa transcutânea e da crioterapia sobre o limiar de dor induzida por pressão

Efectos de la estimulación eléctrica nerviosa transcutánea y crioterapia en el umbral de dolor inducida por presión

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ABSTRACT | Studies have shown that cryotherapy, transcutaneous electrical nerve stimulation (TENS) and the association of them promotes analgesia, but the effectiveness of this association is unclear. The objective was to evaluate the effects of single and combined application of TENS and cryotherapy on pressure-induced pain threshold in healthy subjects. The sample consisted of 40 subjects, randomly assigned into four groups: (1) cryotherapy group – CG, (2) TENS group – GT; (3) cryotherapy + TENS group – GCT; (4) placebo group – GP. The pain threshold was determined by an algometer before (T1), immediately after (T2) and in the instants 10 (T3), 20 (T4) and 30 (T5) minutes after application of the analgesic techniques. TENS (100 Hz, 40 μs) and cryotherapy (cold compress) were applied for 20 minutes in the GC, GT and GTC, while in the GP was simulated electrical stimulation for the same period of time. Repeated measures ANOVA and Bonferroni post hoc test were employed, considering a significance level of 5%. All experimental groups showed an increase in pain threshold when compared to GP: GC ($p<0.001$), GT ($p<0.009$) and GCT ($p<0.008$). In relation to the time of analgesia, there was an increase in pain threshold in T2 for all experimental groups ($p <0.001$) up T3 to GCT ($p <0.001$) and only in the GC analgesia lasted up to T5. We concluded that under the conditions studied, the three experimental groups had an increase in pain threshold compared to the GP, but cryotherapy had more prolonged effect.

Keywords | Analgesia; Combined Modality Therapy; Algometer.

RESUMO | Estudos têm demonstrado que a crioterapia, a estimulação elétrica nervosa transcutânea (TENS) e a associação destas promovem analgesia, porém a efetividade dessa associação não está clara. Objetivou-se avaliar os efeitos da aplicação isolada e associada da TENS e da crioterapia sobre o limiar de dor induzida por pressão em sujeitos saudáveis. A amostra constou de 40 sujeitos, designados aleatoriamente em quatro grupos: (1) grupo crioterapia – GC; (2) grupo TENS – GT; (3) grupo crioterapia + TENS – GCT; e (4) grupo placebo – GP. O limiar doloroso foi determinado por meio de um algômetro antes (T1), imediatamente após (T2) e nos instantes 10 (T3), 20 (T4) e 30 (T5) minutos após a aplicação das técnicas de analgesia. A TENS (100 Hz, 40 μs) e a crioterapia (compressa fria) foram aplicadas durante 20 minutos em GC, GT e GCT, enquanto no GP foi simulada a eletroestimulação pelo mesmo período de tempo. Uma ANOVA para medidas repetidas e o teste *post hoc* de Bonferroni foram utilizados nas análises, considerando nível de significância de 5%. Todos os grupos experimentais apresentaram aumento no limiar doloroso quando comparados ao GP: GC ($p<0,001$), GT ($p<0,009$), e GCT ($p<0,008$). Em relação ao tempo da analgesia, observou-se aumento do limiar doloroso em T2 para todos os grupos experimentais ($p<0,001$), até T3 para o GCT ($p<0,001$) e apenas no GC a analgesia se prolongou até o T5. Concluiu-se que nas condições estudadas, os três grupos experimentais tiveram um aumento no limiar doloroso comparado ao GP, porém a crioterapia teve o efeito mais prolongado.

Descritores | Analgesia; Terapia Combinada; Algômetro.

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RESUMEN | Estudios tienen demostrado que la crioterapia, la estimulación eléctrica nerviosa transcutánea (TENS) y la asociación de ellas promueven analgesia, pero la efectividad de esa asociación no está clara. Se objetivó evaluar los efectos de la aplicación aislada y asociada de la TENS y de la crioterapia sobre el umbral doloroso inducido por presión en sujetos saludables. La muestra incluyó 40 sujetos aleatoriamente separados en cuatro grupos.: (1) grupo crioterapia – GC; (2) grupo TENS – GT; (3) grupo crioterapia + TENS – GCT; y (4) grupo placebo – GP. El umbral doloroso fue determinado por medio de un algómetro antes (T1), luego después (T2) y en los instantes 10 (T3), 20 (T4) y 30 (T5) minutos después de la aplicación de las técnicas de analgesia. La TENS (100 Hz, 40 μs) y la crioterapia (compresa fría) fueron aplicadas durante 20 minutos en el GC, GT y GCT, mientras que en el GP fue simulada la electroestimulación por el mismo período. Un ANOVA para medidas repetidas y el test *post hoc* de Bonferroni fueron utilizados en los analices, considerando un 5% de nivel de significancia. Todos los grupos experimentales presentaron aumento en el umbral doloroso al compararlos al GP: GC (p<0,001), GT (p<0,009) y GCT (p<0,008). Con relación al tiempo de analgesia, se observó un aumento del umbral doloroso en T2 para todos los grupos experimentales (p<0,001) hasta T3 para el GCT (p<0,001) y solamente en el GC la analgesia prosiguió hasta T5. Se concluyó que en las condiciones estudiadas, los tres grupos experimentales tuvieron un aumento en el umbral doloroso comparado al GP, pero la crioterapia tuvo un efecto más longo.

Palabras clave | Analgesia; Terapia Combinada; Algómetro.

INTRODUCTION

Pain is a multifactorial phenomenon that is considered a mechanism of alert and defense of the organism[1,2]. Painful symptoms are part of complex sensations that require a deep analysis on the physiological and psychic mechanisms involved in their production and perception, as well as on their types of treatment[3,4]. This phenomenon has not been completely understood yet, probably because it represents an individually subjective feeling of difficult characterization and generalization[5].

A[6], and the adverse effects from the clinical and/or surgical analgesic methods can be minimized or prevented when they are associated or replaced with an analgesic therapy based on noninvasive physical means[7]. Several procedures and techniques have been used in the analgesic physiotherapeutic practice and amongst the most common we can mention cryotherapy and transcutaneous electrical nerve stimulation (TENS).

TENS is a current that produces electrical pulses with a frequency of up to 200 Hz able to influence the processes of pain neuro-conduction[8], and its analgesia physiological mechanism depends on the modulation of the current applied in the affected area. Low-frequency (4 Hz) and high intensity TENS produces analgesia through the activation of opioid receptors, releasing endogenous analgesic substances through the brain or spinal cord[9,10], while TENS with a frequency higher than 100 Hz and applied with low intensity promotes analgesia through the mechanism of pain barrier. According to this last theory, the electrical current activates the Aβ nerve fibers afferent, which are melanized, of thick caliber and fast conduction, inhibiting in the medulla the passage of painful stimuli taken by Aδ and C fibers, both of small diameters, non-melanized and of slow conduction[11]. Thus, TENS in this modulation promotes an analgesia immediately or after ten minutes of use, which can continue for 20 to 30 minutes or until two hours later[12].

Cryotherapy includes a wide quantity of specific techniques that use cold sources in the solid, liquid and gaseous forms with the therapeutic aim of removing heat from the body and inducing the tissues to decrease metabolism and inflammatory effects, thus reducing the pain[13]. In the nerve fibers, the cold action mechanism happens by decreasing the excitability of the free nerve terminations and the speed of the conduction of the nerve fibers, through the asynchrony transmission in the pain fibers, the release of endorphins and the inhibition of spine neurons and by an increase in the refractory period[14]. After a 20-minute application of such technique, the nerve transmission can be reduced in up to 29.4% with its conduction remaining deteriorated until a certain point for 30 minutes after the cold modality had been removed[15].

Lately, some professionals have been using TENS and cryotherapy simultaneously (CRIOTENS-CT) because they believe that by doing this they will raise the analgesic effect of these resources, since they will achieve a sum of physiologic actions promoted by both treatments[16].

However, the analgesic effects and mechanism of action of the association of the abovementioned techniques have not been very well clarified in the literature. It is known that the pain neurotransmitter promoted by cryotherapy involves the lateral spinal thalamic axis, while TENS uses the anterior spinal thalamic axis and both veins become one only in the bridge's height, forming the medial lemniscus that is directed to the thalamus[17]. Therefore, it is assumed that the association of these two therapeutic modalities creates a paradox between the physiological mechanism of pain reduction, because while one of them reduces the speed of the nerve conduction, the other stimulates the nerve fibers[18].

Facing this controversy, this study aimed at assessing the influence of TENS and cryotherapy used alone or together on the pressure-induced pain threshold in healthy subjects. It took into consideration the hypothesis that CRIOTENS could not present an improvement in the pain threshold of the individuals, because the TENS and cryotherapy neurophysiological mechanisms of pain regulation act paradoxically.

METHODOLOGY

Sample

A cross-sectional study with an almost experimental outline was carried out, with approval of the Ethics and Research Committee in Human Beings of the institution (protocol number 002/2009), and all the participants signed the free informed consent according to Resolution number 196/96 from the Brazilian Health National Counsel.

Forty subjects from both genders (19.9±1.4 years old; 63.9±13.4 kg; 1.67±0.07 m), 20 men and 20 women, were chosen through non-probabilistic criteria. In order to take part in the study, subjects had to be healthy, do not have history of injury, pain or deficit of sensitivity in the non-dominant forearm region. Individuals who had ingested painkillers 24 hours before the beginning of the study were excluded and also those with any kind of allergies to ice and hypersensitivity to electrical current, which were checked before each technique was applied.

Every other day, all subjects underwent three protocols of analgesia (cryotherapy, TENS, CRIOTENS) and one placebo, which was randomly assigned. The flowchart of the experimental design is described in Figure 1.

Procedures

Protocol to assess painful threshold

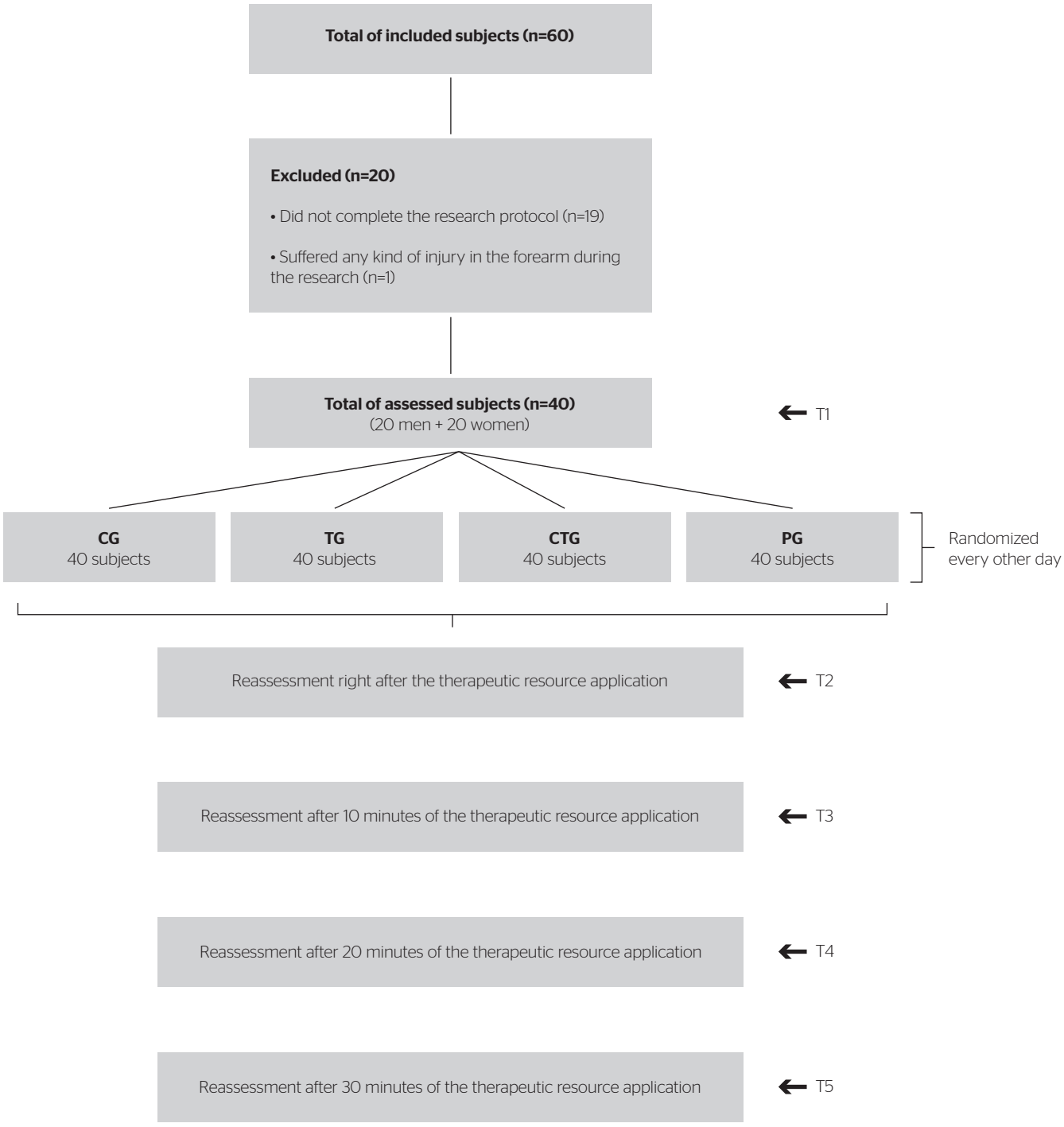
In order to assess the painful threshold, the medium point of the anterior part of the non-dominant forearm was standardized, signalized with a dermographic marker, obtained by the trace of the medium line between the elbow and the wrist. Individuals were sat with their forearms in anatomical position and elbows extended, and the painful threshold (lower pressure needed for the subject to feel pain) was checked before and after the research protocols through pressure stimuli measured in kfg/cm^2 using a digital algometer (Kratos, Brasil)[19-21]. The instrument, whose contact probe had a plane format and measured 1 cm^2 of area[22], was positioned in 90º compared to the forearm.

The subject was requested to inform the evaluator when did the pressure start bothering him/her, proportionally to a painful perception of level three in the analogical visual scale (AVS)[23,24]. At this moment, subjects should communicate this sensation by using the word "done", so then the pressure stimulus was removed and the maximum pressure peak marked in the device was registered.

With the aim of familiarizing the subject to the stimulus, the measure protocol was previously explained to him/her and a test with three stimuli in the counterlateral limb (dominant) was carried out with the purpose of ensuring more reliability of the measures[25,26]. In total, five evaluations in the non-dominant limb were performed: the first, before the experimental protocol application (T1); the second, right after (T2); the third, 10 minutes later (T3); the fourth, 20 minutes later (T4); and the fifth, 30 minutes later (T5).

In the TENS group (TG), before the therapy application, skin cleaning was done with 70% alcohol in the non-dominant forearm, and subjects were sat with their forearms in anatomic position and elbow at a 90º flexion. TENS was applied for 20 minutes at 100 Hz frequency, 40 μs pulse duration and intensity in the sensorial limit, using Endomen 582 ID device (*Enraff Nonius*, Netherlands) with silicone/carbon rectangular electrodes measuring 8x6 cm, longitudinally positioned on the forearm anterior region.

In the cryotherapy group (CG), subjects adopted the same position as in TG and cryotherapy was then applied through cold compress using 1.0 kg of pulverized ice wrapped by a thin wet tissue, fixed with velcro strips in the anterior region of all the forearm, during 20 minutes.



CG: cryotherapy group; TG: TENS group; CTG: cryotherapy group + TENS; PG: placebo group

Figure 1. Flowchart of the experimental outline

In the CRIOTENS group (CG), subjects were in the same position as TG and GC. TENS was applied with the same parameters used in TG and, simultaneously, the cold compress was applied identically as in CG for 20 minutes.

In the placebo group (PG), the same TG protocol was used; however, the device was connected with zero stimulation amplitude during a 20-minute period.

Statistical analysis

The analyzed dependent variable was the pressure measured by the algometer in kgf/cm^2. Data were tabulated by time (T1 to T5) and group, and descriptive statistics was calculated (mean±standard deviation). Initially, data normality (Kolmogorov-Smirnov) and variance homogeneity (Levene) tests were performed, followed by the

variance analysis (ANOVA) for repeated measures with Bonferroni's post hoc to compare the means of pressures in the different time intervals and experimental groups, as well as to analyze the interaction between time *versus* group variables. For the statistical analysis, the Statistical Package for the Social Sciences was used (SPSS version 16), considering a 5% level of significance.

RESULTS

The ANOVA with repeated measures provided significant differences in the mean values of the pressures through time intervals of the experiment regardless the experimental group [F(4.153)=43.476; p<0.001]. It was seen that only in T2 and T3 the pressures were statistically higher than in T1 (p<0.001). Pressures means and standard deviations compared to time, as well as differences of pressures obtained in every time interval with regard to T1 are presented in Table 1.

The analysis of the pressure values concerning the groups also showed significant differences [F(3.156)=6.786; p<0.001]. All the experimental groups had an increase in the painful threshold (a higher pressure difference) compared to the PG (p<0.01). Painful threshold mean and standard deviation of each group by time measurement, as well as values of pressure differences per group, are presented in Table 2.

In the intragroup analysis there was a significant increase in the painful threshold in all times after application (T2, T3, T4, T5; p<0.005) for CG, only in T2 (p<0.001) for

Table 1. Means and standard deviations of pressures in different times and differences of pressures compared to T1 for all the experimental groups

Times	Mean±SD	Differences (kgf/cm²)	p-value
T1	4.99±0.08	-	-
T2	5.69±0.09	T2-T1=0.70	0.001
T3	5.22±0.09	T3-T1=0.23	0.001
T4	5.11±0.08	T4-T1=0.12	0.263
T5	5.04±0.08	T5-T1=0.04	1.000

SD: standard deviation.

Table 2. Means and standard deviations of pressures in the groups in each measurement time and differences of general means per group

Groups	Mean per time±SD	Mean±SD	Difference (kgf/cm²)	p-value
Cryotherapy	T1=4.97±0.17 T2=6.31±0.18 T3=5.63±0.17 T4=5.49±0.17 T5=5.38±0.17	5.56±0.16	CG-TG=0.22 CG-CTG=0.21 CG-PG=0.94	1.000 1.000 0.001
TENS	T1= 4.99±0.17 T2=5.87±0.18 T3=5.36±0.17 T4=5.27±0.17 T5=5.19±0.17	5.34±0.16	TG-CG=-0.22 TG-CTG=-0.01 TG-PG=-0.71	1.000 1.000 0.009
CRIOTENS	T1= 4.97±0.17 T2=5.99±0.18 T3=5.32±0.17 T4=5.29±0.17 T5= 5.15±0.17	5.34±0.16	CTG-CG=-0.21 CTG-TG=-0.01 CTG-PG=-0.72	1.000 1.000 0.008
Placebo	T1=5.06±0.17 T2=4.62±0.18 T3=4.59±0.17 T4=4.41±0.17 T5=4.43±0.17	4.621±0.16	PG-CG=-0.94 PG-TG=-0.72 PG-CTG=-0.72	0.001 0.009 0.008

CG: cryotherapy group; TG: TENS group; CTG: cryotherapy group + TENS; PC: placebo group

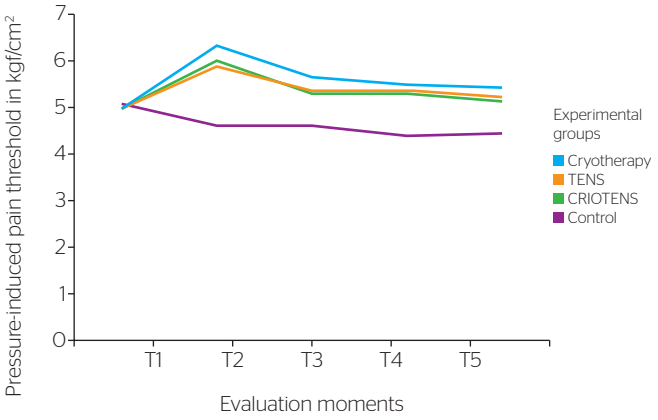


Figure 2. Modifications in the pressure-induced pain threshold (kgf/cm^2) of the experimental groups with regard to evaluations (T1 to T5)

TG, and in T2 ($p<0.001$), T3 and T4 ($p<0.05$) for CTG. Figure 2 allows the visualization of modifications done in the means of the pressure-induced pain threshold of groups due to evaluation time.

It was also verified an interaction between time *versus* group variables [$F(12.405)=10.722$; $p<0.001$]. Thus, it has been observed that means of the four groups did not have a significant difference in the T1 instant ($p>0.05$). However, all the experimental groups were different from the PG in all times ($p<0.001$).

DISCUSSION

In this study, cryotherapy, TENS and CRIOTENS effects analysis in an experimental condition of pressure-induced pain induced allows emphasizing two important findings: (1) all the techniques were effective in increasing the painful threshold, with the exception of placebo; and (2) cryotherapy presented a longer analgesia effect.

Painful threshold decrease in the placebo group was expected due to the non-application of an analgesic resource and of painful tactile stimulation several repeated times, promoting the irritation of the tissue, with release of neurotransmitters, and reducing the threshold of nociceptive excitement[27]. It was also expected the analgesic effectiveness of cryotherapy[16-18] and TENS[16,17,28,29] alone, because they are resources that have already been proved to increase painful threshold.

As to the immediate analgesic effect, results reported herein are in agreement with those presented by Abreu *et al.*[16], who assessed the analgesic efficiency of cryotherapy, TENS and its association, through AVS, in people with chronic lower back pain. These authors found that there was no significant difference between the groups, so none of the analgesia techniques overcame the others. In addition, in a study carried out with healthy subjects and pressure-induced pain using a plicometer, Farias *et al.*[30] also did not see a significant difference in the effect of analgesic techniques. However, none of these studies point to a higher durability of the analgesic effect of the cryotherapy technique, as it was found here.

On the other hand, Ribeiro *et al.*[17], in a study that assessed the effects of using cryotherapy and TENS simultaneously to treat low back pain in women, verified some different results from what was achieved in this study. Their results showed that the pain mentioned through AVS presented a significant reduction in patients treated with TENS and with CRIOTENS, which was not seen in the group treated with cryotherapy alone. We must emphasize that the sample used by Ribeiro *et al.*[17] was composed by women with chronic pain, which includes different processes from the acute pain created by a characteristic mechanical stimulus in the method used in this investigation.

In another study, Schulz *et al.*[31], assessing the effect of TENS Burst on the pressure-induce pain threshold, verified no significant difference in the painful threshold when the different moments of evaluation were compared for the PG and TG. Nevertheless, there is an important methodological difference of this experimental protocol with regard to what was done in our study. TENS Burst has a known indication for chronic pain, while the conventional TENS (100 Hz, 40 μs) is more effective for the promotion of analgesia in acute pain like it was induced in both studies[32].

Even though CRIOTENS did not overcome the other analgesia modalities, it showed to be more effective in promoting an increase in the perception pain threshold, like in other studies[16,17,30]; however, it is believed that cryotherapy was the most responsible for increasing the pressure-induced pain threshold. This questioning is supported in the analgesia duration, since CTG had a similar behavior with increase of the painful threshold longer than the TG. Furthermore, CTG presented a painful threshold increase even after 20 minutes of the application (T4), while this duration lasted 30 minutes (T5) for CG, which leads us to believe that the nerve stimulation promoted by TENS may have decreased the cryotherapy action to reduce the nerve conduction speed to acute pains, like the case of this sample.

In this aspect, although it is said that in CRIOTENS, cryotherapy inhibits TENS action by reducing the speed of sensitive and motor nerve conduction[33-35], there is a possibility that the inhibitory mechanism may be reciprocal, since TENS performs the nerve stimulation opposed to cryotherapy that promotes a decrease of this excitement activity.

The cryotherapy inhibitory effect on TENS may seem to be more clarified as to the nerve conduction peripheral pathways. An experimental study performed in rats that assessed the electrical activity of the femoral nerve (EAFN) before, during and after the individual and associated application of TENS and cryotherapy, evidenced that TENS increased EAFN and cryotherapy did not change this variable. In the associated therapy, there was an attenuation in the EAFN, previously raised by isolated TENS, therefore the association of cryotherapy with TENS opposes the stimulation effect and reduces TENS therapeutic actions when applied isolatedly[18].

An important methodological aspect needs to be registered: the area of the contact probe between the device and skin is an important factor in pain perception. Probes with larger area of contact seem more useful to detect pressure-induced muscular pain[36], whereas the smaller ones cause skin pain[37]. Since the objective of our study was to induce superficial pain, it was used a probe with an area of 1 cm^2, which was enough to produce a superficial acute pain.

Results provided in this paper show that, in experimental conditions of pressure-induced acute pain, cryotherapy presents longer effects than TENS and CRIOTENS, which is probably the most economic and effective resource to treat acute pains. In addition, studies like this one support the physical therapy practice that may help in choosing the needed analgesic modalities both to perform the treatment and to reduce the clinical symptoms. Furthermore, based on the results presented here, CRIOTENS does not raise analgesia, because in the present sample neither it showed a totality result increasing the pain threshold nor it increased analgesia time.

However, despite the pressure-induced pain methodology be wide used in experimental protocols, it is believed that it does not reliably replicate what happens in the physiopathological process of secondary pain to pathologies or traumas, which is considered a limitation of this study. Therefore, in order that these findings may be used in the physiotherapeutic practice, more studies including patients with acute and chronic pains should be carried out.

CONCLUSION

Results from this study show that cryotherapy, TENS and CRIOTENS are effective techniques to increase the pressure-induced painful threshold in healthy subjects; however, cryotherapy presented a longer analgesic effect. These findings improve knowledge on non-drug analgesic methods and point out for the use of cryotherapy alone as a preferential method to treat superficial acute pains.

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