ORIGINAL ARTICLE
TUMOR/INFECTION
http://dx.doi.org/10.1590/S1808-185120222102253908

IMMEDIATE ANALGESIC EFFECT OF 4KHZ AMFS INTERFERENTIAL CURRENT ON CHRONIC LOW BACK PAIN

EFECTO ANALGÉSICO INMEDIATO DE LA CORRIENTE INTERFERENCIAL DE 4 KHZ (AMF) EN EL DOLOR CRÓNICO DE LA REGIÓN LOMBAR

EFEITO ANALGÉSICO IMEDIATO DE CORRENTE INTERFERENCIAL DE 4 KHZ (AMF) SOBRE A DOR LOMBAR CRÔNICA

NICOLE ALMEIDA[1], LUIS HENRIQUE PALADINI[1], LUCAS VINICIUS DIAS[1], RAMON SCHMIDT DE SALES[1], ANA CAROLINA BRANDT DE MACEDO[1]

1. Federal University of Paraná. Department of Prevention and Rehabilitation in Physical Therapy. Curitiba, PR, Brasil.

ABSTRACT

Objective: To analyze the immediate effect of amplitude modulation frequencies (AMFs) of 4kHz interferential current (IFC) on chronic low back pain (CLBP). Method: This is a randomized controlled clinical trial. Sixty-three subjects with CLBP were recruited. The subjects were randomized into 3 groups: the placebo group (PG, n=21) and 2 intervention groups (IG), IG4kHz/2Hz (n=21) and IG4kHz/100Hz (n=21). All groups were submitted to a single session of 30 minutes. Pain was evaluated using a numerical rating scale (NRS), the McGill Pain Questionnaire (MPQ), and pressure algometry. Flexibility was evaluated using the Modified Schober Test (MST), the Sit-and-Reach Test (SRT), the Fingertip-to-Floor Test (FTF), and the Passive Straight-Leg Raise Test (PSLR). Results: Comparing IG4kHz/100Hz with PG, we found a significant difference ($p<0.05$) in NRS in the total and in the MPQ categories, whereas in the comparison between IG4kHz/2Hz and PG, we found a significant difference only in the sensory and evaluative categories of MPQ. Regarding the flexibility tests, we observed a significant difference of both IG4kHz/100Hz and IG4kHz/2Hz in comparison to PG in MST and PSLR, and of IG4kHz/2Hz in comparison to PG in SRT. The 4kHz IFC was effective in immediately reducing CLBP and, consequently, in increasing the flexibility of the lumbar spine and lower limbs. Conclusion: There was a greater number of significant positive outcomes when the 100Hz AMF was adopted. ***Level of Evidence I; High quality randomized clinical trial with or without statistically significant differences, but with narrow confidence intervals.***

Keywords: *Transcutaneous Electrical Nerve Stimulation; Low Back Pain; Pain Measurement.*

RESUMO

Objetivo: Analisar o efeito imediato das frequências de modulação de amplitude (AMF) da corrente interferencial (IFC) de 4 kHz sobre dor lombar crônica (DLC). Métodos: Este é um ensaio clínico controlado randomizado. Foram recrutados 63 participantes com DLC. Esses participantes foram randomizados em três grupos: grupo placebo (PG, n = 21) e dois grupos de intervenção (IG), IG4kHz/2 Hz (n = 21) e IG4kHz/100 Hz (n = 21). Todos os grupos foram submetidos a uma única sessão de 30 minutos. A dor foi avaliada por meio de uma escala numérica de classificação (NRS), o questionário de McGill (MPQ) e algometria de pressão. A flexibilidade foi avaliada pelo Teste de Schober Modificado (MST), Teste de sentar e alcançar (SRT), Teste do terceiro dedo ao solo (FTF) e Teste passivo de Elevação de Perna Reta (PSLR). Resultados: Comparando IG4kHz/100 Hz com PG, encontramos diferença significativa ($p < 0,05$) em NRS nas categorias total e MPQ, enquanto na comparação entre IG4kHz/2Hz e PG, encontramos uma diferença significativa apenas nas categorias sensoriais e de avaliação do MPQ. Com relação aos testes de flexibilidade, observamos diferença significativa tanto do IG4kHz/100 Hz quanto do IG4kHz/2 Hz em comparação com o PG em MST e PSLR, e do IG4kHz/2 Hz em comparação com o PG no SRT. A IFC de 4kHz foi eficaz na redução imediata da DLC e, consequentemente, no aumento da flexibilidade da coluna lombar e dos membros inferiores. Conclusões: Houve maior número de desfechos positivos significativos quando a AMF de 100 Hz foi adotada. ***Nível de Evidência I; Estudo clínico randomizado de alta qualidade com ou sem diferença estatisticamente significante, mas com intervalos de confiança estreitos.***

Descritores: *Estimulação Elétrica Transcutânea; Dor Lombar; Medição da Dor.*

RESUMEN

Objetivo: Analizar el efecto inmediato de las frecuencias de modulación de amplitud (AMF) de la corriente interferencial (ICF) de 4 kHz sobre el dolor lumbar crónico (DLC). Métodos: Se trata de un ensayo clínico controlad y aleatorizado. Se reclutaron 63 participantes con DLC. Los mismos fueron distribuidos aleatoriamente en 3 grupos: grupo placebo (PG, n=21) y 2 grupos de intervención (IG), IG4kHz/ 2Hz (n=21) e IG4kHz/100 Hz (n=21). Todos los grupos fueron sometidos a una sola sesión de 30 minutos. El dolor se evaluó mediante una escala de clasificación numérica (NRS), el cuestionario de McGill (MPQ) y algometría de presión. La flexibilidad se evaluó mediante el test de Schober modificado (MST), el test de sit-and-reach (SRT), el test de distancia dedos-suelo (FTF) y la prueba pasiva de elevación de la pierna recta (PSLR). Resultados: Al compararIGI4kHz/100 Hz con PG, encontramos una diferencia significativa ($p<0,05$) en el NRS en las categorías total y MPQ, mientras que en la comparación entre IG4kHz/2 Hz y PG, encontramos una diferencia significativa sólo en las categorías sensoriales y evaluativas de MPQ. En cuanto a las pruebas de flexibilidad, observamos una diferencia significativa tanto

Study conducted at the Physiotherapy Laboratory of Universidade Federal do Paraná.
Correspondence: Ana Carolina Brandt de Macedo. Rua Aristides Pereira da Cruz, 21 casa 57. Portão. Curitiba. PR. Brazil. CEP: 80330-290. acbrandtmacedo@gmail.com

Received on 07/04/2021 accepted on 03/07/2022
Reviewed by: Dr. Robert Meves

de IG4kHz /100 Hz como de IG4kHz/2 Hz en comparación con PG en MST y PSLR, y de IG4kHz/2 Hz en comparación con PG en SRT. La ICF de 4kHz fue eficaz en la reducción inmediata del DLC y, en consecuencia, en el aumento de la flexibilidad de la columna lumbar y los miembros inferiores. Conclusión: Hubo un mayor número de resultados positivos significativos cuando se adoptó la AMF de 100 Hz. ***Nivel de Evidencia I; Ensayo clínico aleatorizado de alta calidad con o sin diferencia estadísticamente significativa, pero con intervalos de confianza estrechos.***

Descriptores: *Estimulación Eléctrica Transcutánea; Dolor de la Región Lumbar; Dimensión del Dolor.*

INTRODUCTION

Low back pain (LBP) is a common complaint in all age groups and is the largest cause of disability worldwide, directly influencing quality of life and work absenteeism.[1-3] Located in the lower part of the spine, it is defined as severe or moderate pain in the region, and is related to multifactorial clinical conditions such as biopsychosocial, sociodemographic and economic factors.[4,5]

Approximately 84% of the population will experience acute episodes of LBP at some point in their lives. When the pain lasts for more than 12 weeks, LBP progresses to chronic low back pain (CLBP).[6] Therefore, we emphasize the paramount importance of treatment strategies to minimize this symptomatology.

Studies[7,8] suggest the efficacy of non-invasive and non-pharmacological techniques for the treatment of LBP. Physical therapy uses exercises and electrotherapy, as non-invasive therapies for the management of low back pain, thus providing a good basis for approaches to these cases.[4,9]

Electrotherapy is the application of electrical current as a therapeutic form of pain relief,[10] based on the gate control theory of pain[11] and the release of endorphins.[1-3] Commonly used in clinical practice, electrical currents consist of low frequency (Hz) pulsed currents, such as transcutaneous electrical nerve stimulation (TENS), and medium frequency (kHz) alternating currents, such as interferential current (IFC).[12,13]

IFC is a medium frequency current that has is amplitude-modulated at low frequency, according to the desired analgesic mechanism.[14] As it is a medium frequency current (1-10kHz), IFC allows greater penetration depth into the tissues by reducing skin impedance.[14] However, it has not yet been proven that IFC has a superior analgesic effect to that of low-frequency currents.[15]

Despite the widespread use of electrotherapeutic resources in the treatment of low back pain, few studies have evaluated the immediate analgesic effect of IFC. Corrêa et al.[16] observed that IFC provided immediate analgesia using a 1kHz carrier frequency (CF) and a 4kHz CF after the first application; Almeida et al.[17] found a decrease in CLBP using IFC with a 2kHz CF, showing that it may play a key role in preparing the patient to later receive therapies more accepted by the literature, such as kinesiotherapy.

The guidelines[3,5,18] on low back pain mention the therapeutic effects of IFC. On the other hand, they emphasize the low methodological rigor and the lack of randomized clinical trials and adequate blinding in most published studies, which limits a careful interpretation of its effects and results in CLBP. Moreover, a systematic review by Fuentes et al.[19] demonstrates that the heterogeneity of research on the application of IFC in musculoskeletal pain is a factor that limits conclusions about the effectiveness of the analgesic effect of this current. Almeida et al.[17] emphasize that the use of validated assessment instruments, and the participation of patients with real pain, rather than subjects with induced pain, are determining factors for the effectiveness of the studies.

The ideal parameters of IFC are also inconclusive, highlighting the need for further studies[20] to investigate the most appropriate amplitude modulation frequency (AMF) for use in CLBP[7]. Johnson et al.[21] report that determining an AMF between 1 and 250Hz may be the main parameter to generate analgesia, the most commonly used frequencies being 100Hz and 130Hz. Although scarce, research comparing different AMFs[15,21,22] found no differences in pain relief between patients with CLBP and those with knee osteoarthritis.[23]

The primary objective of this study is to compare the immediate analgesic effect of 4kHz IFC, with different amplitude-modulated frequencies, on both objective and subjective perceptions of pain. The secondary objective is to evaluate the effect of 4kHz IFC on the flexibility of the lumbar spine and lower limbs in individuals with CLBP.

METHODS

Study design

This is a double-blind, 3-armed, randomized controlled clinical trial. This study was approved by the Research Ethics Committee of CAEE: 44642615.2.0000.0102.

The project was approved by the Research Ethics Committee of the Federal University of Paraná (CAEE: 44642615.2.0000.0102), under protocol number 1145540, and prospectively registered on ensaiosclinicos.gov.br (RBR-59YGRB).

Participants

We selected participants of both sexes, over 18 years of age, who had chronic nonspecific low back pain (pain duration >3 months),[5] without radiating pain or with pain intensity greater than 3 on the numerical rating scale (NRS).[24] The participants were invited verbally, and were asked to sign an Informed Consent Form (Resolution 466/2012 of the Brazilian National Health Council).

Exclusion criteria were: a diagnosis of disc herniation or any disc pathology; not having low back pain on the day of the evaluation; having taken analgesic medications 24h before the evaluation; and/or a history of any surgical procedure in the abdominal and/or low back region.

The participants were randomized into three groups: the intervention groups (IG) IG4kHz/100Hz and IG4kHz/2Hz, and the placebo group (PG). They were evaluated before and immediately after the intervention, by a previously trained, blinded physical therapist.

The participants were evaluated using a specific form containing identification data, anamnesis, NRS, McGill Pain Questionnaire (MPQ), Start Back Screening Tool (SBST), mechanical pain tolerance (MPTo) by algometry and flexibility tests (Modified Schober Test, Sit-and-Reach Test, Fingertip-to-Floor Test, and Passive Straight-Leg Raise Test).

The numerical rating scale (NRS) consists of a 10cm line, numbered from 0 to 10. The participants were asked to mark the point that represented the intensity of their pain, with 0 indicating absence of pain and 10, maximum pain.[25]

The McGill Pain Questionnaire (MPQ), adapted to Portuguese,[26] was applied to assess several aspects of pain using a total of 78 descriptors (words) that were shown to the participants. These pain qualifiers are divided into 20 groups, each containing two to six words. These groups are still classified into 4 categories: sensory, affective, evaluative, and miscellaneous. The participants were asked to choose either one word or no word in each group. The sum of the number of chosen descriptors corresponded to the total index, with a maximum value of 20; the number of chosen words was also determined in each category.

The Start Back Screening Tool (SBST), adapted to Portuguese by Pilz et al.,[27] is an instrument for screening patients at risk of poor prognosis for the treatment of LBP based on the presence of physical or psychosocial risk factors. This instrument consists of nine questions divided into two subscales. The first subscale has 4 items addressing pain, dysfunctions, and comorbidities; the second has 5 items addressing biopsychosocial aspects. Each question is

scored either 0 or 1 point, depending on the participants' responses. The sum represents the score of each subscale; therefore, the score ranges from 0 to 9. The participant's prognosis was defined as low risk if the total score ranged from 0 to 3 points. If the second subscale scored ≤3 points, the participant was classified as medium risk and for scores>3 points, high risk.[27,28] The participants answered the questions once only, before the application of the IFC, to assess the influence of biopsychosocial factors in response to IFC.

The mechanical pain tolerance (MPTo) was assessed using an algometer (EMG System of Brazil) before and immediately after the application of the IFC. For data analysis purposes, the MPTo was analyzed in kilogram-force (kgf). A previously trained physical therapist conducted a reliability study for the application of the algometer. A previously trained physical therapist conducted a preliminary intra-examiner reliability study for the application of the algometer. In order to conduct this study, the professional evaluated ten individuals within a 48h interval. The intra-examiner reliability for measuring PPT was estimated by calculating the intraclass correlation coefficients (ICC-0.95). MPTo was measured bilaterally at points previously marked with a dermatograph pencil: two points in the anterior tibial region for control purposes (one on each leg) and four points in the low back region (5 cm from the third and fifth lumbar vertebrae, on both right and left sides). The tip of the algometer (area of 1 cm^2) was pressed at each point perpendicularly to the participants' skin. They were asked instructed to say "stop" when they felt the maximum pressure they could endure. The constant rate of the algometer application was 0.3 kgf/s.[16] Three readings were taken for each point with a 1 min interval between them, and the respective averages were calculated.

The Modified Schober Test (MST) was conducted to check the flexibility of the lumbar spine. This test has strong validity (r=0.97) and an excellent interclass correlation coefficient (r=92).[29] For the test, the participants remained in a relaxed, standing position, and the transverse process of the first sacral vertebra (S1) was marked. From this point, two other points were marked: 10 cm above and 5 cm below. We instructed the participants to bend forward as though touching their toes, while keeping their knees straight; we then measured the distance between the points above and below the S1.[30] The data collected through this test before and after the intervention were compared.

The Sit-and-Reach Test (SRT), described by Wells and Dillon[31] and validated by Lemnink et al.,[32] was used to assess the flexibility of the trunk and lower limbs. For this test, we used a box, positioned against the wall, measuring 30.5x30.5x30.5 cm with a 23 cm extension to support the upper limbs. With the participants seated, their bare feet resting on the box and their knees extended, they were asked to flex their trunks forward as far as they could without flexing their knees, and to hold this position for 3s, touching the furthest point of the equipment that they could reach. We registered the distances reached by the participants' fingertips. Three measurements were taken, but only the best (i.e. furthest) distance was recorded.[33] We checked the difference between the results obtained before and after the application of the interferential current.

The Fingertip-to-Floor Test (FTF), validated by Perret et al.,[33] was used to evaluate the mobility of the entire spine and pelvis in a general forward-leaning movement.[34] The participants stood upright and barefoot on a 20 cm platform, with their feet together and aligned with their shoulders and knees. They were instructed to lean their trunks forward as far as possible while keeping the knees, arms and fingers fully extended. We measured the distance between the tip of the participants' middle fingers and the ground with a measuring tape and recorded this distance in centimeters; we then compared the pre-and post-treatment values.[34]

The Passive Straight-Leg Raise Test (pSLR)[34] was used to assess the flexibility of the hamstring muscles. The participants were positioned in the supine position with a fleximeter fixed to the side of the leg being assessed, while the other leg remained in a neutral position, stabilized by a belt. The physical therapist flexed the participants' hips with their knees extended.[35] We compared the values obtained before and after the treatment.

Sample calculation

The sample calculation was performed using Gpower 3.0. We considered the mean difference of 1 point in the NRS [36] with a standard deviation of 1.47[37] statistical power of 0.95, α equal 0.05, totaling 63 participants, 21 per group.

Randomization

We carried out a block randomization. Three blocks were established, with seven participants in each. In the envelope designated for the randomization, there were nine pieces of paper: three with "4kHz/100Hz" written on them, three with "4kHz/2Hz", and three with "PG". The pieces of paper were picked by the participants themselves, who were not aware of the groups to which they had been allocated. The randomization process was carried out three times.

Intervention

A researcher who did not participate in the evaluation was responsible for the intervention. The participants were positioned in the prone position on the examination table. Four silicone electrodes (9cm x 5cm) were bilaterally and transversely placed 5cm both to the right and left of the spinous processes of L3 and L5. After sterilizing the skin by wiping it with 70% alcohol, we placed the electrodes with conductive gel and fixed them with adhesive tape. The equipment used was a previously calibrated Neurodyn (IBRAMED).

All groups received a single application lasting 30 minutes, with a carrier frequency of 4kHz and a frequency variation (ΔF) of 0Hz. To IG4kHz/100Hz, the amplitude-modulated frequency was of 100Hz and sensory intensity. To IG4kHz/2Hz, the AMF was of 2Hz and motor intensity. The PG group was also submitted to the intervention, but in this group, the equipment was turned off.

Statistical analysis

We analyzed the parameters using SPSS Software (25.0). The results were expressed as mean±standard deviation and submitted to analysis of normality and homogeneity of variances by Shapiro-Wilk and Levene tests, respectively. For the parametric variables, we used the analysis of covariance (ANCOVA) of repeated measures in the intragroup and intergroup comparison, with SBST acting as a covariate; as for the nonparametric variables, we used the Wilcoxon test for intragroup analysis and the Kruskal Wallis test for the intergroup analysis. The prospective intention--to-treat analysis was carried out. We adopted a value of $p<0.05$ for statistical significance.

RESULTS

We invited 80 people between February and December 2019 to participate in the study, but 17 of them were excluded because they presented pain intensity< 3 at the moment of the evaluation. The remaining 63 participants were randomized into three groups: IG4kHz/100Hz (n=21), IG4kHz/2Hz (n=21), and PG (n=21). (Table 1, Figure 1)

Table 1 presents the participants' sociodemographic data. The majority of the study population were women (n=38), with incomplete college degrees (n=30), and non-smokers (n=53). Most of the participants had pain in a centralized region (n=26), with an average duration of four and a half months, and which increased during the night (n=34) and on physical effort (n=56). Regarding the biopsychosocial factors, 29 of the participants presented low risk, 17 medium risk, and 17 high risk.

Table 2 shows the results of the intragroup analysis concerning the assessment of pain and the flexibility tests. The pain intensity, assessed using NRS, decreased considerably in all three groups. However, the intervention groups (IG4kHz/100Hz and IG4kHz/2Hz) had a reduction of more than 3 points on the NRS, which according to Chou et al.[38,39] represents a strong effect of the treatment, while PG reduced only 1.7 points. There was a reduction in MPQ, total score and categories, of the three groups, except for the

Table 1. Clinical and sociodemographic characteristics.

	IG4KHz/100Hz (n = 21)	IG4KHz/2Hz (n = 21)	PG (n = 21)
Age (mean±SD)	29.9±13.7	35.3±16.1	28.9±12
Sex (n, %)			
Female	12 (57.1)	14 (66.7)	12 (57.1)
Male	9 (42.9)	7 (33.3)	9 (42.9)
Level of Education (n, %)			
Incomplete elementary	0 (0)	0 (0)	0 (0)
Complete elementary	0 (0)	0 (0)	0 (0)
Incomplete high school	1 (4.8)	0 (0)	0 (0)
Complete high school	4 (19)	7 (33.3)	4 (19)
Incomplete college	10 (47.6)	10 (47.6)	10 (47.6)
Complete college	6 (28.6)	4 (19)	7 (33.3)
Life habits			
Smoker (n, %)	3 (14.3)	2 (9.5)	5 (23.8)
Alcohol consumption (n, %)	7 (33.3)	5 (23.8)	3 (14.3)
Sedentary (n, %)	11 (52.4)	8 (38.1)	9 (42.9)
Time of pain (months) (mean, min, max, median)	4;8;1;20	7;8;1;40	3;1;1;6
Location of pain (n, %)			
Centralized	7 (33.3)	6 (28.6)	13 (61.9)
On the right	4 (19)	4 (19)	3 (14.3)
On the left	3 (14.3)	3(14.3)	2 (9.5)
On both sides	7 (33.3)	8 (38.1)	3 (14.3)
Time of day when the pain is worst (n, %)			
Mornings	1 (4.8)	5 (23.8)	7 (33.3)
Afternoons	6 (28.6)	6 (28.6)	4 (19)
Night	14 (66.7)	10 (47.6)	10 (47.6)
Activities that exacerbate pain (n, %)			
Walking	7 (33.3)	5 (23.8)	9 (42.9)
Sitting	8 (38.1)	10 (47.6)	12 (57.1)
Bending	14 (66.7)	4 (19)	12 (57.1)
Getting up	7 (33.3)	7 (33.3)	12 (57.1)
Climbing stairs	9 (42.9)	9 (23.8)	5 (23.8)
Effort/lifting objects	17 (81)	20 (95.2)	19 (90.5)
Psychosocial factors (start back)			
Low risk	4 (19)	10 (47.6)	15 (71.4)
Medium risk	6 (28,6)	5 (23.8)	6 (28.6)
High risk	11 (52.4)	6 (28.6)	0 (0)

PG = placebo group.

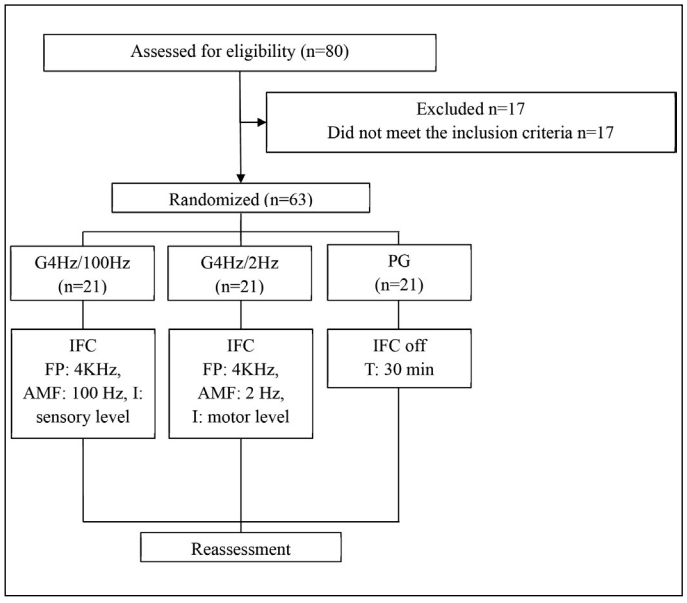

Figure 1. Study design.

miscellaneous category of PG. Regarding the algometry, significance difference ($p<0.05$) was found only in IG4kHz/100Hz. Analyzing the flexibility tests, we observed significant results of IG4kHz/100Hz in MST. The IG4kHz/2Hz showed significant results in SRT, FTF, and PSLR bilaterally.

Table 3 presents the intergroup analysis of pain assessment and flexibility tests. There was a significant improvement in NRS of IG4kHz/100Hz compared to PG with a small effect size (Cohen's $d=0.22$). Regarding IG4kHz/100Hz, superior results were obtained (reduction in the number of words chosen) in relation to PG in all categories of MPQ ($p<0.05$). The IG4kHz/2Hz group presented significant differences in the sensory and evaluative categories, compared to PG. Concerning the algometry results, there was no significant intergroup difference in MPTo of the points of the low back region. Regarding the flexibility tests, a significant difference of both IG4kHz/100Hz and IG4kHz/2Hz was observed in comparison to PG in MST and PSLR, and of IG4kHz/2Hz in comparison to PG in SRT.

When SBST was inserted as a covariable, we found no difference in the intra- and intergroup results, i.e., biopsychosocial factors did not influence pain response and flexibility after the application of IFC.

DISCUSSION

The present study demonstrates the benefits of IFC in the pain and flexibility of the lumbar spine and lower limbs of individuals with CLBP. Due to pain, and fear of exacerbating the symptoms, patients with CLBP are often unable to perform the activities and physical exercises that are required for long-term relief of the pain. Therefore, it is important to evaluate the immediate analgesic effect of the application of IFC, because it can reduce or momentarily extinguish pre- and/or post-exercise pain.[17,39,40]

Few studies have compared the immediate effect of IFC,[16,17,40-43] but only three of them[16,40,42] use the 4kHz carrier frequency, and do not compare different AMFs. Similarly to Correa et al.,[18] this study found a significant reduction of pain through NRS after the application of IFC in all groups. However, only the intervention groups showed a strong treatment effect, i.e., a difference of more than 3 points in post-intervention NRS.[38] Moreover, when compared to PG, only IG4kHz/100Hz obtained significant results. Pain improvement in PG may be associated with personal, psychosocial, and neurological factors through the alteration of neuronal activity in brain areas responsible for pain modulation, thus releasing endogenous opioids.[15,16]

Furthermore, IG4kHz/100Hz also presented significant results in the evaluation of pain quality through post-intervention MPQ in comparison to PG. The results are consistent with those of Almeida et al.,[40]

Table 2. Assessment of NRS, MPQ, MPT and flexibility test (between groups).

	IG4kHz/100Hz (n = 21)		IG4kHz/2Hz (n = 21)		PG (n = 21)	
(mean ± SD)	**Before**	**After**	**Before**	**After**	**Before**	**After**
NRS	4.3±1.8	0.4±0.8*	4.7±2.9	0.9±1.2*	4.4±1.0	2.7±1.8*
MPQ						
Sensory	7.3±1.7	0.9±1.5*	7.8±1.9	2.5±2.6*	8.0±2.3	5.6±3.5*
Affective	2.5±1.4	0.0±0.2*	3.2±1.8	1.0±1.7*	3.4±1.3	1.4±1.9*
Evaluative	1.0 ±0.0	0.1±0.3*	1.0±0.0	0.2±0.4*	0.9±0.2	0.7±0.4*
Miscellaneous	2.3 ±0.8	0.2±0.7*	2.7±1.1	0.7±1.3*	2.3±1.4	1.9±1.7
Total	13.2±2.9	1.3±2.4*	14.8±4.0	4.5±5.6*	14.8±4.7	9.3±7.1*
MPT						
ATL	3.9 ±1.4	4.0±1.1	3.8±1.2	3.9±1.4	6.2±2.9	6.3±3.2
ATR	3.9 ±1.3	5.2 ±6.8	3.8±1.1	3.8±1.2	6.2±3.2	6.4±3.8
L3L	3.6 ±1.4	4.1 ±1.4*	3.7±0.9	4.0±1.1	4.3±1.7	4.1±2.0
L3R	3.6 ±1.4	4.1±1.4*	3.7±1.1	4.0±1.0	4.6±2.1	4.6±2.5
L5L	3.4 ± 1.3	4.2±1.3*	3.7±0.9	3.9±0.8	4.2±1.7	4.0±2.0
L5R	3.6 ±1.5	4.1±1.3*	3.9±0.9	4.0±0.9	4.4±2.3	4.5±2.3
Flexibility tests						
Schober	5.1±1.1	5.4±1.2*	4.9±0.6	5.1±0.6	9.9±2.2	9.7±2.7
SRT	17.4±12.8	17.3±13.2	14.1±5.8	16.7±6.9*	23.2±6.5	21.6±7.5
3rd finger-floor	17.6±16.0	19.3±16.4	14.7±13.5	11.5±11.3*	11.2±10.2	12.1±8.3
SLR-R	48.8±10.4	49.4±10.7	48.9±17.2	50.8±16.6*	65.0±8.9	61.9±17.6
SLR-L	48.5±11.2	49.1±11.0	48.5±14.4	50.0±14.2*	61.8±9.9	60.1±15.7

NRS = Numerical Rating Scale of Pain; MPQ = McGill Pain Questionnaire; MPT = mechanical pain threshold; PG = placebo group; AT = anterior tibial; L3 = 3rd lumbar vertebra; d= Cohen's d; L5 = 5th lumbar vertebra; L = left; R = right. *p<0.05 (Between-groups repeated-measures ANCOVA).

Table 3. Between-group differences at 30 min after randomization for subjects with chronic low back pain who received Interferential Current or placebo group.

			Intergroup Difference Mean Adjusted Difference (95% CI) Follow-up de 30 min (95% CI)			
	IG4kHz/100Hz vs IG4kHz/2Hz	**Cohen´s d**	**IG4kHz/100Hz vs GP**	**Cohen´s d**	**IG4kHz/2Hz vs GP**	**Cohen´s d**
NRS	-0.4 (-1.4 to 0.6)	0.04	-1.1* (-2.1 to -0.1)	0.22	-0.7 (-1.7 to 0.2)	0.91
MPQ						
Sensory	-1.0 (-2.6 to 0.4)	0.57	2.7* (-4.2 to -1.1)	0.30	-1.6* (-3.1 to -0.9)	1.09
Affective	-0.8 (-1.8 to -0.1)	0.12	-1.1* (-2.1 to -0.1)	0.07	-0.3 (-1.3 to 0.6)	1.17
Evaluative	-0.04 (-0.2 to 0.1)	0.28	-0.2* (-0.4 to -0.08)	0.29	-0.2* (-0.3 to -0.03)	1.11
Miscellaneous	-0.4 (-1.2 to 0.3)	0.00	-0.8* (-1.5 to -0.03)	0.21	-0.3 (-1.1 to 0.3)	0.93
Total	-2.3 (-5.4 to 0.6)	0.34	-4.7* (-7.8 to -1.7)	0.24	-2.4 (-5.4 to -0.6)	0.84
MPT						
ATL	0.1 (-1.4 to 1.5)	0.08	-2.3 (-3.8 to 0.8)	0.02	-2.4 (-3.9 to 0.8)	0.04
ATR	0.7 (-1.4 to 2.9)	0.27	-1.7 (-3.9 to 0.4)	0.05	-2.4* (-4.7 to -0.2)	0.11
L3L	-0.006 (-1.1 to 1.1)	0.27	-0.2 (-1.4 to 0.8)	0.17	-0.2 (-1.4 to 0.8)	0.44
L3R	0.03 (-1.2 to 1.2)	0.26	-0.7 (-1.9 to 0.5)	0.14	-0.7 (-1.9 to 0.4)	0.38
L5L	0,02 (-0.9 to 1.0)	0.66	-0.3 (-0.9 to 1.0)	0.17	-0.3 (-1.3 to 0.6)	0.38
L5R	-0.1 (-1.3 to 1.1)	0.54	-0.5 (-1.8 to 0.6)	0.08	-0.4 (-1.6 to 0.7)	0.01
FT						
Schober	0.2 (-0.6 to 1.2)	1.41	-4.5* (-5.4 to -3.5)	0.28	-4.7* (-1.2 to 0.6)	1.11
SRT	1.9 (-3.5 to 7.5)	3.02	-4.9 (-10.4 to 0.4)	2.23	-6.9* (-12.5 to -1.4)	5.07
3rd finger-floor	5.3 (-2.4 to 13.0)	3.10	6.8 (-0.8 to 14.5)	1.97	1.5 (-6.2 to 9.2)	1.07
SLR-R	-0.7 (-8.9 to 7.4)	2.74	-14.3* (-22.4 to -6.2)	0.58	-13.6* (-21.7 to -5.4)	0.80
SLR-L	-0.3 (-7.8 to 7.0)	4.50	-12.0* (-19.4 to -4.2)	0.05	-11.7* (-19.1 to -4.2)	0.25

NRS = Numerical Rating Scale of Pain; MPQ = McGill Pain Questionnaire; MPT = mechanical pain threshold; PG = placebo group; AT = anterior tibial; L3 = 3rd lumbar vertebra; FT: flexibility test; SRT: sit and reach test; SLR: straight leg raise; d= Cohen's d; L5 = 5th lumbar vertebra; L = left; R = right. *p<0.05.

who found a significant difference from the group with parameters of 4kHz and AMF of 100Hz compared to PG.

The results found in this study, using algometry for the objective measurement of pain, indicate a significant increase in MPTo in the low back region after the intervention only in the group with 100Hz AMF. This corroborates the results of other studies[41] in which patients were submitted to identical parameters. Correa et al.[16] and Venancio et al.[9] obtained positive results for the placebo group, but with 1kHz CF.

Although therapeutic exercises, such as stretching, were not applied in this study, we found that with the instantaneous pain relief, there was an improvement in the flexibility of the spine and lower limbs in both IG4kHz/2Hz and IG4kHz/100Hz.

It is known that electrotherapeutic resources are coadjuvant elements in the treatment of CLBP, and the prescription of exercises is essential. Therefore, if we decrease the pain and consequently, increase the flexibility after the application of IFC, we can often make it possible for patients to perform the exercises earlier, which may speed up the rehabilitation process.

As strong points of this study, we highlight the double blinding, the use of validated and culturally adapted instruments to assess pain, performance of flexibility tests, and the specific population (individuals with low back pain).

CONCLUSION

We found that 4kHz carrier frequency IFC is effective in immediately reducing low back pain, thus momentarily increasing lumbar spine flexibility. There were more significant positive outcomes when an amplitude-modulated frequency of 100Hz was adopted, such as decreased pain in NRS and MPQ, total and categories, when compared to PG.

ACKNOWLEDGMENTS

The author would like to thank the Academic Publishing Advisory Center (www.capa.ufpr.br) of the Federal University of Paraná (UFPR) for providing assistance with the English language translation and editing.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: Each author made significant individual contributions to this manuscript. NA, LHP: Collected the data, contributed data or analysis tools, wrote the paper. LVD, RSS: Collected the data, wrote the paper. ACBM: Conceived and designed the analysis, collected the data, contributed data or analysis tools, performed the analysis, wrote the paper.

REFERENCES

1. Buchbinder R, van Tulder M, Öberg B, Costa LM, Woolf A, Schoene M, et al. Low back pain: a call for action. Lancet. 2018;391(10137):2384-8.
2. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. What low back pain is and why we need to pay attention. Lancet. 2018;391(10137):2356–67.
3. Quaseem A, Wilt TJ, MClean RM, Forciea MA, Clinical Guidelines Committee of the American College of Physicians, Denberg TD, et al. Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline From the American College of Physicians. Ann Intern Med. 2017;166(7):514-30.
4. Chou R, Fanciullo GJ, Fine PG, Adler JA, Ballantyne JC, Davies P, et al. Clinical guidelines for the use of chronic opioid therapy in chronic noncancer pain. J Pain. 2009;10(2):113-30.
5. Delitto A, George SZ, Dillen LV, Whitman JM, Sowa G, Shekelle P, et al. Low Back Pain - Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2012;42(4):A1-57.
6. Kent PM, Keating JL. The epidemiology of low back pain in primary care. Chiropr Osteopat. 2005;13:13.
7. Cabello AM, Maya-Martín J, Domínguez-Maldonado G, Espejo-Antúnez L, Heredia-Rizo AM. Effect of interferential current therapy on pain perception and disability level in subjects with chronic low back pain: a randomized controlled trial. Clin Rehabil. 2017;31(2):242–9.
8. Mlekusch S, Schliessbach J, Cámara RJ, Arendt-Nielsen L, Jüni P, Curatolo M. Do central hypersensitivity and altered pain modulation predict the course of chronic low back and neck pain? Clin J Pain. 2013;29(8):673-80.
9. Venancio RC, Pelegrini S, Gomes DQ, Nakano EY, Liebano RE. Effects of carrier frequency of interferential current on pressure pain threshold and sensory comfort in humans. Arch Phys Med Rehabil. 2013;94(1):95-102.
10. Corrêa JB, Costa LOP, Oliveira NTB, Sluka KA, Liebano RE. Effects of the carrier frequency of interferential current on pain modulation in patients with chronic nonspecific low back pain: a protocol of a randomized controlled trial. BMC Musculoskelet Disord. 2013;14(195).
11. Melzack R, Wall PD. Pain Mechanisms: a new theory. Science. 1965;150(3699):971-9.
12. Ainsworth L, Budelier K, Clinesmith M, Fiedler A, Landstrom R, Leeper BJ, et al. Transcutaneous electrical nerve stimulation (TENS) reduces chronic hyperalgesia induced by muscle inflammation. Pain. 2006;120(1-2):182-7.
13. Ward AR, Oliver WG. Comparison of the hypoalgesic efficacy of low-frequency and burst--modulated kilohertz frequency currents. Phys Ther. 2007;87(8):1056–63.
14. Johnson MI, Tabasam G. An investigation into the analgesic effects of different frequencies of the amplitude modulated wave of interferential current therapy on cold-induced pain in normal subjects. Arch Phys Med Rehabil. 2003;84(9):1387-94.
15. Almeida CC, Silva VZMD, Júnior GC, Liebano RE, Durigan JLQ. Transcutaneous electrical nerve stimulation and interferential current demonstrate similar effects in relieving acute and chronic pain: a systematic review with meta-analysis. Braz J Phys Ther. 2018;22(5):347–54.
16. Corrêa JB, Costa LO, Oliveira NT, Lima WP, Sluka KA, Liebano RE. Effects of the carrier frequency of interferential current on pain modulation and central hypersensitivity in people with chronic nonspecific low back pain: a randomized placebo-controlled trial. Eur J Pain. 2016; 20(10):1653-66.
17. Almeida N, Paladini LH, Pivovarski M, Gaideski F, Korelo RI, Macedo AC. Immediate analgesic effect of 2kHz interferential current in chronic low back pain: randomized clinical trial. Braz J Pain. 2019;2(1):27-33.
18. Wong JJ, Côté P, Sutton DA, Randhawa K, Yu H, Varatharajan S, et al. Clinical practice guidelines for the noninvasive management of low back pain: A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. Eur J Pain. 2017;21(2):201-16.
19. Fuentes JP, Armijo Olivo S, Magee DJ, Gross DP. Effectiveness of interferential current therapy in the management of musculoskeletal pain: a systematic review and meta-analysis. Phys Ther. 2010;90(9):1219-38.
20. Teles Filho RV. Analgesic effect of the interferential current in chronic low back pain management. Braz J Pain. 2019;2(2):208.
21. Johnson MI. The mystique of interferential currents. Physiot. 1999;85(6):294-7.
22. Claro AD, Kanezawa BA, Camargo MD, Paes VM, Portolez JL, Bertolini GR. Pressure and cold pain threshold in healthy subjects undergoing interferential current at different amplitude modulated frequencies. Rev Dor. 2014;15(3):178-81.
23. Gundog M, Atamaz F, Kanyilmaz S, Kirazli Y, Celepoglu G. Interferential current therapy in patients with knee osteoarthritis: comparison of the effectiveness of different amplitude--modulated frequencies. Am J Phys Med Rehabil. 2012;91(2):107-13.
24. Boonstra AM, Stewart RE, Köke AJ, Oosterwijk RF, Swaan JL, Schreurs KMG, et al. Cut-off points for mild, moderate, and severe pain on the numeric rating scale for pain in patients with chronic musculoskeletal pain: variability and influence of sex and catastrophizing. Front Psychol. 2016;7:1466.
25. Jensen MP, McFarland CA. Increasing the reliability and validity of pain intensity measurement in chronic pain patients. Pain. 1993;55(2):195-203.
26. Pimenta CA, Teixeira MJ. Questionário de dor McGill: proposta de adaptação para a língua portuguesa. Rev Esc Enferm USP. 1996;30(3):473-83.
27. Pilz B, Vasconcelos R, Marcondes FB, Lodovichi SS, Mello W, Grossi DB. Versão brasileira do STarT Back Screening Tool - tradução, adaptação transcultural e confiabilidade. Braz J Physl Ther. 2014;18(05):453-61.
28. Hill JC, Dunn KM, Main CJ, Hay EM. Subgrouping low Back pain: a comparison of the STarT Back tool with the Orebro musculoskeletal pain screening questionnaire. Eur J Pain. 2010;14(1):83–9.
29. Macrae IF, Wright V. Measurement of back movement. Ann Rheum Dis. 1969;28(6):584-9.
30. Tousignant M, Poulin L, Marchand S, Viau A, Place C. The Modified – Modified Schober Test for range of motion assessment of lumbar flexion in patients with low back pain: A study of criterion validity, intra- and inter-rater reliability and minimum metrically detectable change. Disabil Rehabil. 2005;27(10):553–9.
31. Wells KF, Dillon EK. The sit and reach: a test of back and leg flexibility. Res Q Exerc Sport. 1952;23(1):115-8.
32. Lemmink KAPM, Kemper HCG, de Greef MHG, Rispens P, Stevens M. The validity of the sit-and-reach test and the modified sit-and-reach test in middle-aged to older men and women. Res Q Exerc Sport. 2003;74(3):331-6.
33. Perret C, Poiraudeau S, Fermanian J, Colau MM, Benhamou MA, Revel M. Validity, reliability, and responsiveness of the fingertip-to-floor test. Arch PhysI Med Rehabil. 2001;82(11):1566-70.
34. Ayala F, De Baranda PS, De Ste Croix M, Santonja F. Reproducibility and concurrent validity of hip joint angle test for estimating hamstring flexibility in recreationally active young men. J Strength Cond Res. 2012;26(9):2372-82.
35. Sweetman BJ, Anderson JAD, Dalton ER. The relationships between little-finger mobility, lumbar mobility, straight-legraising, and low back pain. Rheumatol Rehabil. 1974;13(4):161-6.
36. Costa LOP, Maher CG, LAtimer J, Ferreira PH, Ferreira NMI, Pozzi GC, et al. Clinimetric testing

of three self-report outcome measures for low back pain patients in Brazil: which one is the best? Spine. 2008;33(22):2459-63.
37. Werners R, Pynsent PB, Bulstrode CJ. Randomized trial comparing interferential therapy with motorized lumbar traction and massage in the management of low back pain in a primary care setting. Spine (Phila Pa 1976). 1999;24(15):1579–84.
38. Chou R, Huffman LH, American Pain Society, American College of Physicians. Medications for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians clinical practice guideline. Ann Intern Med. 2007;147(7):505-14.
39. Chou R, Huffman LH, American Pain Society, American College of Physicians. Nonpharmacologic therapies for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians clinical practice guideline. Ann Intern Med 2007;147(7):492-504.
40. Almeida N, Paladini LH, Korelo RG, Liebano RE, de Macedo ACB. Immediate effects of the combination of interferential therapy parameters on chronic low back pain: a randomized controlled trial. Pain Pract; 2020;20(6):615-25.
41. Fuentes J, Armijo-Olivo S, Funabashi M, Miciak M, Dick B, Warren S, et al. Enhanced therapeutic alliance modulates pain intensity and muscle pain sensitivity in patients with chronic low back pain: an experimental controlled study. Phys Ther. 2014;94(4):477-89.
42. Fuentes JP, Armijo Olivo S, Magee DJ, Gross DP. Does amplitude-modulated frequency have a role in the hypoalgesic response of interferential current on pressure pain sensitivity in healthy subjects? A randomized crossover study. Physiotherapy. 2010;96(1):22-9.
43. Facci LM, Nowotny JP, Tormem F, Trevisani VF. Effects of transcutaneous electrical nerve stimulation (TENS) and interferential currents (IFC) in patients with nonspecific chronic low back pain: randomized clinical trial. São Paulo Med J. 2011;129(4):206-16.