Electromyography Analysis of Upper Trapezius Relaxation Induced by Interferential Current in Subjects with Neck Discomfort

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ABSTRACT

Purpose: To evaluate the muscular relaxation of the upper trapezius induced by interferential current (IFC) application during rest and functional activities using surface electromyography registration (EMG).

Method: We evaluated the "root mean square" value (RMS) of the upper trapezius during rest and functional activities in subjects with neck discomfort before and after IFC applications. Thirty female participated in the study, mean age of 23.0 (±4.0) years and a body mass of 22.1 (±2.5) kg/m^2. The subjects received three IFC applications over a 5-day period, with a frequency of 4.000 Hz, an amplitude modulated frequency (AMF) of 75 Hz, a frequency variation (ΔF) of 35 Hz, a slope of 1/1, a sensorial level intensity, and an application time of 30 minutes per session in the upper trapezius.

Results: Repeated measures analysis of variance demonstrated significant bilateral decrease ($p<0.001$) of mean RMS value of the upper trapezius in the final evaluation in relation to initial evaluations. This suggests that IFC can promote a muscle-relaxing effect after a few applications such as during rest as well as during functional activities.

However, we did not find relaxing effect immediately after an IFC application (p>0.05).

Conclusion: IFC seems to induce a relaxation of the upper trapezius muscle in both medium-term analyses at rest and during functional activities. Therefore, there was not an immediate effect in the experimental model used.

INTRODUCTION

The increasing stress level of the population is probably related to several musculoskeletal disorders, such as joint muscle disorders.[1] These disorders may affect mainly the postural muscles, because they are physiologically the most requested during functional activities. The muscles of the neck and shoulder are the most affected in workers of different occupations, especially those that involve repetitive movements.[2,3] This pattern of muscle tension is found mainly in the upper fibers of the trapezius muscle, and for this reason, it is an area much investigated in the literature.[4,5] It is believed that patients with neck pain or instability caused by degenerative processes or disc herniation of the spine frequently present this pattern of involuntary compensatory tension as a segmental stabilization trial.[5]

However, the vicious cycle involving repetitive activities, stress, and tension in the trapezius also leads to greater difficulty in returning to basal muscle activity after a workday [6]. All these overload patterns can lead to biomechanical and to motor activity changes.[4]

To alleviate this tension and stress in the musculature, there are several modalities used in physical therapy aimed at pain relief and muscle relaxation such as physical agents for cooling, heating, electrical stimulation, and others[7-10]. Transcutaneous electrical stimulation equipment have been used in clinical practice mainly for analgesia, acting at the sensory level by closing the spinal cord gates, releasing endorphins, [8-10] and helping in tissue repair.[11] Although these effects are already well established in the literature for low-frequency current, there are no studies showing the direct effect of medium frequency current in the induction of large or polyarticular muscle relaxation.

Among these forms of medium frequency electrical stimulation, interferential current (IFC) is a device frequently used clinically, with a higher tissue penetration and less discomfort when compared to low-frequency current.[7,12] IFC therapy is the application of alternating medium-frequency current (4,000 Hz) amplitude modulated at low frequency (0-250 Hz). [12] A claimed advantage of IFC over low-frequency currents is its capacity to diminish the impedance offered by the skin. [7] Several theoretical physiological mechanisms such as the “gate control” theory, increased circulation, descending pain suppression, and block of nerve conduction have been proposed in the literature to support the analgesic effects of IFC.[7,8,12]

However, there is no evidence in the literature that IFC can also contribute to muscle relaxation on a sensory level, ie, using current intensity (mA) only in the sensory threshold. If this effect really occurs, this therapy probably could be an important tool to decrease muscle tension, especially when caused by stress or dysfunctional conditions.

Therefore, the aim of this study was to investigate muscle relaxation of the superior trapezius muscle induced by IFC during rest and functional activities using surface electromyographic analysis (EMG) in subjects with neck discomfort.

METHODS

This study was performed in the Motion Analysis Laboratory of the Centro Universitário São Camilo (CUSC) between October 2008 and November 2009. All subjects were informed about the procedures that would be performed, and signed a document stating that all volunteers participate of their own free will and received informed consent conducted in accordance with the National Health Council, resolution 196/96. This study was approved by the CUSC Research Ethics Committee according to protocol 125/07.

Subjects Thirty female volunteers participated in the study, with a mean age of 25.0 (±4.0) years old, a body mass index of 22.1 (±2.5) kg/m^2 dominant right limb, neck area discomfort caused by computer activities for at least 14 hours per week or 2 hours daily, a score over 3/10 in the visual analog scale (VAS), and pain during trigger point palpation of the neck area. For this evaluation, the trigger point was considered active if the subject presented local pain during a moderate digital pressure in the middle third of the upper trapezius. Females were excluded with referred or irradiated pain, previous surgery history, physical therapy in the last 6 months, rheumatic or neuromuscular diseases, cognitive or sensory deficit, depression, hormonal or non-hormonal anti-inflammatory medication, a body mass index over 28, and other traditional IFC contra-indications.[7].

Procedure

The IFC applications and EMG registration were performed on each patient during 5 days. On the first day, patients remained at rest in the supine position for 30 minutes before the first assessment. We then analyzed the RMS value of the EMG signal on both sides of the upper trapezius muscle.

Figure 1: *Subject position to EMG registration* of the upper trapezius fibers seating on the quick massage chair (A) and standard chair (B)*

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This first registration (initial evaluation) was performed in four different conditions:

- First, the patient remained seated on a quick-massage chair (Figure 1A).
- Second, the patient was sitting on a standardized chair (Figure 1B). In both conditions, the patients remained relaxed during the capture procedure. To achieve this relaxation, the registration started only after stabilization of the EMG signal.
- In the third condition, the patients performed the task of typing a standard text on the computer keyboard while keeping their limbs supported on the same standard chair (Figure 2A).
- In the fourth condition, the subjects typed the same standard text, but without their forearms supported (Figure 2B). For the last two conditions, the patients were instructed to type as fast as possible.

After this initial evaluation, all subjects were submitted to bipolar IFC application on the trapezius bilaterally by 30 minutes. Soon after this application, another registration was performed of the RMS value in the four

Figure 2: *Subject position to EMG registration* of the upper trapezius fibers in functional activities: typing a standard text with the forearms supported (A) and non-supported (B)*

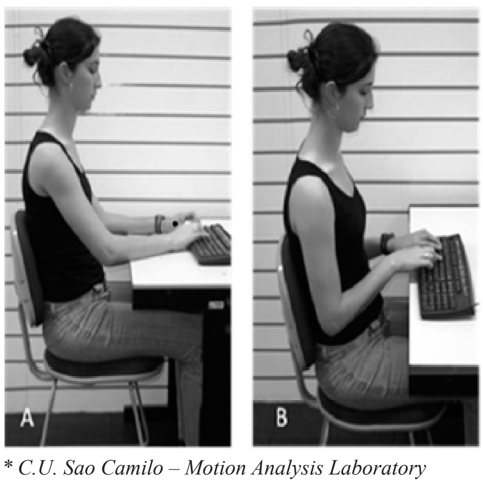

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__Table 1__: Mean RMS values (± SD) of the upper trapezius muscle (µV) considering the dominant and non-dominant side before and after interferential current (IFC) applications (n = 30) in the four studied conditions

Dominant					
Quick-massage chair	9.4 (±0.7)	9.5 (±0.8)	9.2 (±0.7)	9.2 (±0.7)	8.8 (±0.4)
Standard chair	10.7 (±2.0)	10.4 (±1.4)	10.2 (±1.5)	10.1 (±1.1)	9.5 (±0.7)
Forearm supported *	26.1 (±13.3)	21.2 (±10.7)	19.3 (±8.8)	17.9 (±8.8)	14.7 (±5.4)
Forearm non-supported *	35.7 (±16.6)	33.2 (±19.3)	26.3 (±12.7)	24.1 (±10.8)	21.3 (±9.9)
Non-dominant					
Quick-massage chair	9.4 (±0.4)	9.6 (±0.8)	9.5 (±0.7)	9.4 (±0.8)	9.0 (±0.2)
Standard chair	11.7 (±2.9)	10.6 (±1.3)	10.8 (±1.8)	10.4 (±1.2)	9.8 (±0.8)
Forearm supported *	20.9 (±12.9)	17.2 (±6.6)	17.0 (±6.6)	15.9 (±5.8)	13.4 (±3.4)
Forearm non-supported *	28.6 (±14.6)	24.5 (±12.5)	24.3 (±13.6)	22.8 (±13.0)	13.6 (±5.1)

** Typing with forearms supported and non-supported.*

conditions mentioned above (evaluation 1).

On the second day, the patients received only the bipolar IFC application on the upper fibers of the trapezius muscle bilaterally for 30 minutes. On the third day, the patients were initially assessed in relation to the RMS value of the trapezius muscle in the four conditions (evaluation 2), followed by bipolar IFC application. After this application, we performed the EMG registration again (evaluation 3). There were not activities or analysis on the fourth day.

On the fifth day, only the EMG registration (final evaluation) was performed of the trapezius muscle in all four conditions (Figure 3). The same procedure prior to the EMG registration in the initial evaluation was performed in the evaluation 2 and final evaluation, ie, the patients remained at rest in the supine position for 30 minutes to avoid or minimize possible tensions due to the test situation ("lab effect").

Instrumentation The IFC equipment used for all applications was the pulse generator--Endophasys/KLD Biosistemas with a carrier frequency of 4.000 Hz, an amplitude modulated frequency (AMF) equal to 75 Hz, a variation frequency (ΔF) of 35 Hz, and a slope of 1/1. We used the bipolar technique, ie, one channel with two electrodes on each side of the upper fibers of the trapezius muscle.[7,12] In each side, one electrode was placed laterally on the C7 spinous process, and the other on the supraspinatus fossa.

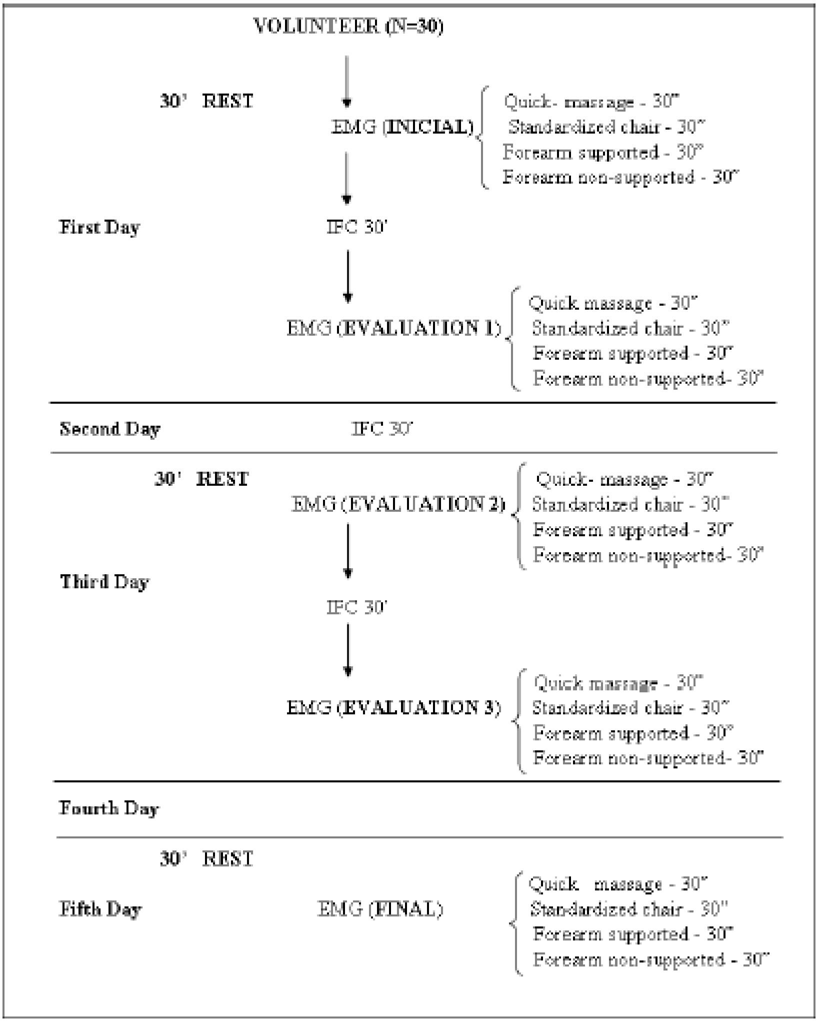
The EMG equipment utilized in this study was the portable CS400/EMG System with eight channels. The EMG rectified signals of the trapezius muscle were obtained by surface Ag/AgCl (10x20 mm) differential-type electrodes with inter-electrode capture distance of 20 mm and a pre-amplification of 20-fold, and send to the amplifier (frequency range: 20-500 Hz; noise signal rate: 3 µV RMS; CMMR: 100 dB), which has a gain of a factor of 50, achieving a gain of 1,000 for the EMG signal.

The capture electrodes were positioned at the midpoint between the spinous process of the C7 vertebra and the acromion bilaterally according to SENIAM criteria.[13] The reference electrode was positioned in right lateral malleolus. Before the electrodes were positioned, we shaved the exposed area, followed by sterilization with hydrated 70% ethyl alcohol. Afterwards an EMG signal capture was performed in the four predetermined conditions for 30 seconds. The first and last 5 seconds were removed. Thus, the raw EMG signal was rectified and the RMS values were calculated during the intermediate 20 seconds.

Data Analysis

The sample size was ascertained in a previous pilot study designed to choose the

Figure 3: *Diagram of the proceedings showing evaluations and IFC applications (n=30)*



Abbreviations: EMG (Electromyographic registration); IFC (Interferential current); Quick massage (Quick massage sitting condition); Standardized chair (Standardized chair sitting condition); Forearm supported and non-supported (Forearm supported and non-supported typing condition); 30' (30 minutes); 30" (30 seconds)

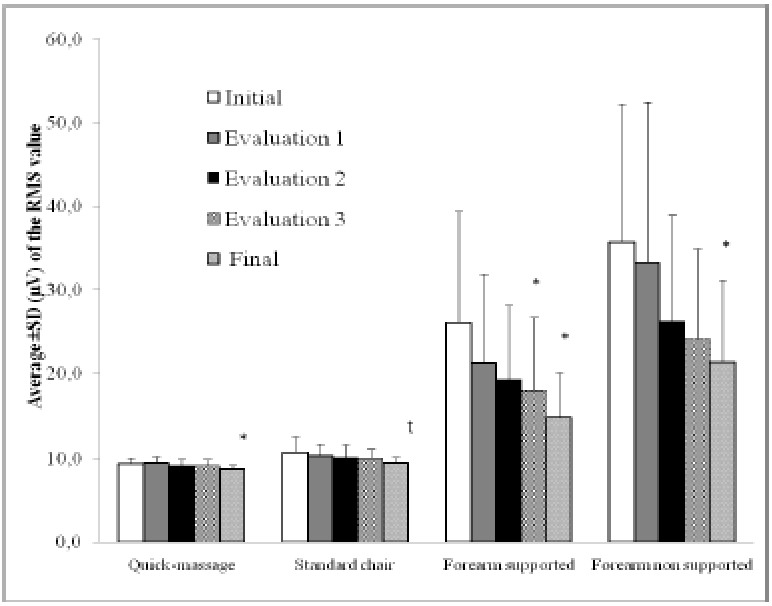
minimum number of patients needed to determine a significant difference (2 µV RMS difference in the EMG analysis in the sitting condition), taking into account a mean of 9.0 µV (± 2.0 µV), a significance level of $p<0.05$, and a test power of 90%.

We performed a sample homogeneity test (Kolmogorov-Smirnov) for each condition comparing the dominant and non-dominant side in relation to the mean RMS value of the EMG signal during the initial evaluation. For this analysis, the Wilcoxon matched pairs test was used with a significance level of 95%. Thus, we used the repeated measures analysis of variance (group by time), with significance considered at $p<0.05$. The factor group had 1 level (IFC), and the repeated factor, time, had five levels (mean RMS value in the initial, 1, 2, 3, and final evaluations). Data were analyzed with SPSS Version 13.0.

RESULTS

Table 1 shows the results with the mean (±SD) of RMS value of the EMG signal

Figure 4: Mean (±SD) of the RMS value of the upper trapezius muscle of the dominant side before and after IFC application in the four conditions (n = 30)



** Significant difference (P<0.05) in relation to Initial evaluation, 1 and 2 evaluation*
t Significant difference (P<0.05) in relation to Initial and evaluation 1

analyzed in the four conditions (sitting on a quick massage chair, a standardized chair, and typing with and without forearm supports).

We found a significant difference between the dominant and non-dominant side in the initial evaluation with the patient seated on a standardized chair, and typing with and without forearm supports ($p<0.05$). Therefore, we chose a separate analysis between the two sides in all conditions.

As shown in Table 1, there was, in general, a decrease in RMS value over the days after the IFC applications for the dominant as well as the non-dominant side. There was a statistically significant group-by-time interaction for the repeated measures analysis for the four conditions ($p<0.05$).

Planned pairwise comparisons showed that the mean RMS value of the dominant side was significantly lower in the final evaluation when compared to the initial ($p<0.001$), evaluation 1 ($p<0.001$), evaluation 2 ($p<0.01$) to the quick-massage chair sitting condition, and typing with and without forearm supports. In the standardized chair sitting condition, the RMS value in the final evaluation was significantly lower only in relation to the initial ($p<0.001$) compared to evaluation 1 ($p<0.01$). Moreover, we observed a decrease in the mean RMS value in evaluation 3 when compared to the initial evaluation when typing with a forearm support ($p<0.01$) (Figure 4).

On the non-dominant side, the mean RMS value in the final evaluation was significantly lower when compared to the initial ($p<0.001$), evaluation 1 ($p<0.05$), evaluation 2 ($p<0.001$), and evaluation 3 ($p <0.05$) for sitting on a quick-massage chair, and typing with and without forearm supports. The mean RMS value in the final evaluation was significantly lower only in relation to the initial evaluation and evaluation 1 ($p<0.05$) for sitting in a standardized chair (Figure 5).

DISCUSSION

This was an intervention study that evaluated females who used a computer daily and presented neck discomfort. The aim was to observe the effect of muscle relaxation of the upper trapezius fibers induced by IFC application during rest conditions and functional activities. The results of EMG registration show that IFC can reduce the trapezius muscle tension while at rest and while typing. It is important to remember that this relaxing effect was found for both the dominant and non-dominant sides.

The assessment of muscle activity can be performed by EMG,[14] since the RMS value is a tool of quantifying and processing the EMG signal, showing a linear relationship with muscle tension at rest and during functional tasks.[5,15,16]

Previous studies have linked the IFC application as a tool to provide pain relief and muscle relaxation.[7-9,17-19] However, some authors suggest that electrotherapy applied to muscle relaxation occurs at motor level stimulation, ie, applying a current intensity to generate muscle contraction, and consequently, decreasing muscle spasm due to increased local blood flow.[18,20]

The results of the present study demonstrate that a decrease in muscular activity can also be observed at sensorial level stimulation, ie., using current intensity (mA) only in the sensory threshold. However, this relaxation appears to be more related to cumulative rather than immediate effect, because we observed that there was significant relaxation in the final evaluation when compared to the initial evaluation. Corroborating these findings, we did not find differences in EMG assessments immediately after IFC application.

Based on this information, two factors should be taken into account when utilizing this equipment aimed at muscle relaxation. First, multiple applications are necessary to achieve therapeutic results. Second, it is necessary to receive IFC for a long time in each session.Since this study, the subjects have received applications for 30 minutes. Some authors have shown that applications for a short time (approximately 20 minutes) are not sufficient to promote therapeutic effects.[21] Although it was not the target of this study, we hypothesized that this relaxing effect can be related to increase of the local blood flow at the motor level.[20,22] However, this circulatory stimulation is not directly related to muscular contraction, but rather the physiological inhibitory mechanism of the sympathetic fibers in small arterioles.[23-25]

Nerve suppression can lead to increased circulation by reducing sympathetic tonus in the muscular layer of small arterioles.[24] The study conducted by Noble et al [24] showed that an increase in skin blood-flow induced by IFC is proportional to the increase in skin temperature. The literature has associated this local vasodilatation to electrode stimulation with a frequency below 30 Hz. [22,24] Nevertheless, in this study, we used a modulated frequency of 75 Hz. This demonstrated that the previous studies probably were not successful in this frequency range because they evaluated only the immediate effect. We believe that an increase in circulation could lead to late effects, mainly because it would increase the metabolism, oxygenation, reducing the intra-muscular lactic acid accumulation.

As previously described, there is evidence in the literature supporting physiological changes in blood flow related to electrical-stimulation. The present study contributed to this evidence because it is the first clinical study investigating immediate and cumulative muscle relaxation by surface EMG in subjects with discomfort in the cervical area. It is important to highlight that these subjects presented normal cervical and shoulder range of motion, ie, they were not patients with neck pain diagnostic.

This study presents a limitation due to the lack of a sham group. However, this bias was minimized because the subjects submitted to IFC therapy performed complete rest before the initial EMG evaluation trying to avoid or minimize possible tensions due to the test situation ("lab effect"). Another justification is the fact that EMG is a quantitative tool for analyzing the muscular tension, and therefore was not directly influenced by the placebo effect. We also performed a pilot study normalizing the data in relation to the maximum isometric contraction, but these data were not used because we did not find a rationale for using this kind of normalization for to evaluate muscle relaxing.

Further research is needed to relate other IFC parameters such as modulated or carrier frequency, duty cycle, intensity, and time.[19,26] In addition, these findings need to be correlated with clinical evaluations of local microcirculation in subjects with chronic diseases, neck, and superior limbs disorders, as well as in spastic muscles of neurological patients.

Based on the obtained results, it is thought that IFC seems to induce a relaxation of the upper trapezius muscle in both medium-term analyses at rest and during functional activities. There was not an immediate effect in the experimental model used. Future studies are necessary to investigate the IFC as a clinical tool for other patterns of muscle spasm, as well as to confirm the preference for at least three or four applications.

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