Effect of Pre-Exercise Sweep Frequency Interferential Current Therapy on the Biceps Brachia Muscle Fatigue in Normal Healthy Male Subjects. A Randomized Placebo Control Trial

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Abstract

Background: Skeletal muscle fatigue is one of the most common problems encountered in general practice clinic population and sport activities. Interferential currents therapy is widely used by physiotherapists throughout the world to manage a range of musculoskeletal condition.

Objective: To find out the effect of pre-exercise sweep frequency interferential currents therapy on the induced fatigue of Biceps brachia muscle in normal healthy untrained male subjects.

Subjects and Methods: Twenty healthy male subjects were participated and randomly allocated to receive two treatment sessions of interferential currents therapy before inducing biceps brachia muscle fatigue with 7 days apart. Active interferential currents session with trapezoid sweep frequency that set between a low beat frequency of 5Hz and a high beat frequency of 10Hz for thirty minutes and placebo interferential currents session. After the treatment session each subject was asked to perform voluntary elbow flexion repetitions with 30% of their one repetition maximum using dumbbells until they reached fatigue determined by inability to reach 90 degrees of elbow flexion. Pain intensity level before and after reaching fatigue was measured by visual analogue scale, number of submaximal repetitions and time elapsed to reaching fatigue point were measures for all subjects in the two sessions.

Results: A significant difference (p ≤ 0.05) was found between active and placebo interferential currents sessions, when the means ± SD of the two sessions were compared in terms of pain intensity level, number of submaximal repetitions and time elapsed to reach biceps brachia muscle fatigue in favour of active interferential currents.

Conclusion: The application of sweep frequency interferential current with the used parameters could be effective in delaying the development of skeletal muscle fatigue and enhancing skeletal muscle performance.

Key Words: Muscle fatigue – Interferential currents therapy.

Introduction

SKELETAL Muscle Fatigue (SMF) is a common experience in a human daily life either on practice clinical problem or sport activity [1]. Muscles that are used intensively show a progressive decrease of capacity which mostly recovers after a period of rest [2].

Skeletal muscle fatigue is not the point of task failure or the moment when the muscles become exhausted. Rather, SMF is a lowering in the maximum force-producing capacity of the muscle that can occur at any sites within the neuromuscular system and it develops gradually soon after the onset of the sustained physical activity [3].

Common features of SMF are decreased muscle strength, impaired movement coordination, precision, muscle reaction times, proprioceptive capabilities and subsequent muscular pain [4]. Age and gender are remarkable factors that determine human capability to contract skeletal muscle and to resist fatigue development [5]. Males and females differ in their ability to resist fatigue. Generally males are display a lesser relative fatigue resistance than females [6].

The mechanisms of development of SMF, or prevention are not fully understood. Researchers suggest that SMF is due to changes in the muscle intracellular milieu that include lactic acid accumulation, increase intracellular free calcium concentration, decrease intracellular pH, intramyoplasmic accumulation of inorganic phosphate (Pi), Adenosine Triphosphate (ATP) diminution, changes in the structure of the sarcoplasmic reticulum and in the trans membrane sodium and potassium ion concentration, muscle glycogen and blood glucose depletion [2].
Many therapeutic modalities could be used to attenuate the development of SMF and promote neuromuscular function that would be helpful during sports and rehabilitative exercise by reinforcing muscle’s ability to carry out work for a longer period. These modalities include massage, low intensity exercise, cryotherapy, contrast bath, hyperbaric oxygen therapy, electromyostimulation and low level laser therapy. The results on their effectiveness have not been consistent [7-13].

Interferential Currents therapy (IFC) is one of the most commonly used electrotherapeutic modalities within the clinical practice for the management of musculoskeletal pain [14]. It is a medium frequency current (1 KHz-100KHz), amplitude modulated at low frequency (0 to 250Hz) that produced by the mixing of two slightly out-of-phase medium frequency currents. It has proved advantage that it is able to penetrate deeply and overcome the skin resistance within the areas of treatment [15]. IFC therapy has been widely used to induce analgesia, elicit muscle contraction, modify the activity of the autonomic system, promote healing, and reduce oedema [16,17].

Nerve fibres characterised by accommodation to a constant signal of electrical stimulation parameters [18]. A sweep frequency (or gradually changing frequency) is often used to overcome this problem. Most machines of IFC therapy offer several sweep patterns. The principle of using the sweep is that the machine is set to automatically vary the effective stimulation frequency using either pre-set or user set sweep ranges. The sweep range employed should be appropriate to the desired physiological effects [19]. There is very limited evidence to justify some of these options. In the triangular sweep pattern, the machine gradually changes from the base to the top frequency, usually over a time period of 6 seconds while other machines offer 1 or 3 second options. A rectangular (or step) sweep produces a very different stimulation pattern in that the base and top frequencies are set, but the machine then ‘switches’ between these two specific frequencies rather than gradually changing from one to the other [19]. There is a clear difference between these two patterns, even though when the same ‘numbers’ are set. One will deliver a full range of stimulation frequencies between the set frequency levels and the other will switch from one frequency to the other. There are numerous other variations on this theme, and the ‘trapezoidal’ sweep is effectively a combination of these two [19].

The decline in muscle strength and pain that combined with SMF is thought due to deficiencies in substrate bio-availability, blood flow, and tissue oxygenation, as well as the accumulation of metabolites and neuromuscular alterations [20]. There is evidence from research studies that IFC therapy enhance blood flow with modulated frequency of 10-20Hz [21,22], relief pain by several mechanisms utilizing high and low frequency [23,24], reduces inflammatory pain [25] and muscular activity at low frequency with sensory level stimulation [26].

According to the author knowledge, no published randomized controlled trial has investigated the effect of sweep frequency IFC therapy to attenuate SMF. The study aims to find out the effect of pre-exercise sweep frequency interferential therapy on pain level intensity, time elapsed to reach fatigue and number of submaximal concentric contraction of induced Biceps brachia muscle fatigue on healthy male subjects.

**Subjects and Methods**

A convenience sample of 20 healthy male students with aged ranged between 20 and 30 years; BMI <30; healthy; recreationally active and non-smoker were recruited on voluntary basis via notice board advertisements at the Faculty of Physical Therapy, Cairo University. The recruitment started in January 2013 and ended in July 2013.

This sample size was chosen based on a priori sample size calculations using $\alpha=0.05$, power of 80% and an effect size of 0.15 for the measured parameters [11,12,21].

All subjects who had an interest in the study were informed by the experimental procedure (both verbally and in written form) and were screened for contraindications to electrotherapy such as peripheral vascular abnormalities, hyper and hypotension, peripheral neuropathies, recent trauma. Other exclusion criteria consisted of any previous musculoskeletal injury or pain to the shoulder, elbow or wrist regions; regular strength training (more than once per week) for the previous 3 months; the use of any kind of nutritional supplement or pharmacological agent; suffered from unstable cardiovascular, pulmonary conditions or other health problems.

**Experimental protocol:**

This study designed as a cross-over randomized placebo-controlled design. Subjects were scheduled to receive two different sessions of IFC therapy (active IFC and placebo IFC) with one week apart
before inducing biceps brachia muscles fatigue at two different days.

**Randomization:**
Randomization was performed by a simple drawing of card, which was determine whether session A (Active IFC therapy) or session B (Placebo IFC therapy) should be given before the fatigue exercise session for all subjects. Then the second session was performed after seven days following the first session and participants were received the last treatment which was not given in the first session. The group allocation code from the drawing of cards was carried to an assistance (postgraduate physiotherapy student) that pre-set the interferential unit accordingly to either an active IFC or placebo IFC mode. The assistance was instructed not to communicate the type of treatment given to the participant, or the observers (postgraduate physiotherapy student).

**Instrumentations:**
- **Visual Analogue Scale (VAS):** To determine the level of pain intensity. The VAS consists of a 10cm horizontal line with the two end points labelled 0 (no pain) to 10 (worst soreness ever). The distance between the extreme left of the scale (“no pain”) and the subject's mark was measured to the nearest millimeter. High levels of reliability and validity of VAS had been reported [27,28].
- A hand dynamometer was used to establish the Maximum Voluntary Concentric Contraction (MVC) (or 1-repetition maximum test).
- **Stop-watch:** To calculate the time in seconds lapsed to reach fatigue induced by MVC contraction of biceps brachia exercise.
- Dumbbells of different weights; were used to induce fatigue in non-dominant biceps brachia muscle [8].
- Interferential current stimulation unit (PHYACTON 780-Uniphy BV, AN Eindhoven, Netherlands) device, multi channels) was used for experiment in both sessions.

**Procedures:**
Time of experimental was considered to be performed at approximately the same time of the day (to control the circadian rhythm). The IFC sessions, the biceps brachia fatigue exercise and evaluation were performed in two sessions (day 1 and day 8) on the same day of the week (Tuesday) at the same time of day (between 9Am and 11:00 Am). Subjects were instructed not to change their daily activities during the 48 hours before the exercise tests and to avoid any form of medication, including anti-inflammatory agents for 2 days before testing and for the duration of the study.

At the evaluation day, subjects were allowed to rest for 15 minutes before the evaluation. The room temperature was settled to be constant all over the study through air conditioner controller (24 degree centigrade). All participants were subjected to the following:

1. A complete clinical examination including anthropometric measurements (weight and height) and Body Mass Index was calculated (BMI).
2. The dominant hand was detected by asking the subjects to fill a sheet about their personal data (name, birth day, contact number), absorb which hand they wrote and documented it by the assistance.
3. Pain level intensity and tenderness were evaluated at the baseline and immediately post biceps brachia muscles fatigue exercise using VAS in the two treatment session. Participants were asked to make a vertical mark across the 10cm line that identify the level of pain intensity between the limits of no pain felt (left end of line) and worst soreness ever (right end of line). A new scale was used each time to avoid the influence from the previous measurements.

4. Calculation of the Maximum Voluntary Contraction (MVC): A hand held dynamometer was fixed to a single adjustable parallel bar firmly. The subject was seat on an armless stable chair with his testing elbow flexed to 90 degrees. A strap was secured and marked sure that the subject testing shoulder did not go into flexion during elbow flexion. Five centimetre distance was measured from the subjects testing arm’s ulnar styleoid process. Once the subject was seated with testing elbow flexed at 90 degrees and strapped to his trunk, the height and the distance of the parallel bar was adjusted so that the hand dynamometer came in direct contact with the five centimetre mark. At this position the subject was asked to perform one maximal isometric elbow flexion contraction. The value in kilograms was noted and repeated for a total of three trails with five minutes break between each trail. The average of all three trails was calculated in kilograms, as shown in Fig. (1).

5. Treatment procedures: Active or placebo IFC therapy session was given after the warming up exercise (stretching exercises to all major muscles of the non dominant arm “two repetitions of 60s for each muscle group”, finished with the flexor muscles of the non-dominant elbow and
immediately before the fatigue exercise protocol. All active IFC therapy and placebo IFC procedures were given by a single therapist. The device was calibrated before and after data earning, and the equipment showed the same power output in both calibrations. The subject lied in comfortable supine position, with a pad under his knee to support and relax lower limb. Bipolar application of two carbon rubber electrodes encased in water soaked sponges electrodes were put proximally and distally on the non-dominant biceps brachia muscle to ensure full muscle activation. The parameters of IFC therapy was selected to delivered a trapezoid sweep frequency interferential current that set between a low beat frequency of 5Hz and a high beat frequency of 110Hz. The machine was gradually changed from the base to the top frequency over a time period of 6 seconds for thirty minutes for each session. The intensity of the IFC was set to sensory level.

Subjects in the Placebo IFC group were received a mock treatment. The machine was turn on, and the electrodes wire was connected to a false channel. This manipulation was allowed the subjects to see what they were perceived as an increase in muscle activation. The number of submaximal repetitions before reaching fatigue were 59.60 ± 7.56kg, their mean ages were 21.05 ± 1.36 years and their mean body mass indexes were 22.85 ± 2.94kg/meter² respectively, as show in (Table 1).

7- Data collection: Data concerning pain intensity level, time elapsed to reach fatigue and the number of submaximal repetitions before reaching fatigue were collected from the subjects through measuring VAS (cm), time (sec) and repetition (number).

8- Data analysis: Data were collected, revised, and analyzed by Statistical Package for Social Science (SPSS) program version 18. Comparison between the two groups for pain intensity level was done using general linear model for repeated measure followed by post hoc least significant difference test when the results were found significant. Comparison between the two sessions for time elapsed to reach fatigue and the number of submaximal repetitions before reaching fatigue was done using two tailed dependent t-test. Normality of the data was assessed and confirmed prior to each test via the Shapiro Wilk statistic and data are presented as mean ± Standard Deviation (SD). Statistical significance was set with α at p≤ 0.05.

Results

Twenty healthy male untrained subjects were recruited and met the inclusion criteria. Their mean heights were 1.62 ± 0.59 meters, their mean weights were 59.60 ± 7.56kg, their mean ages were 21.05 ± 1.36 years and their mean body mass indexes were 22.85 ± 2.94kg/meter² respectively, as show in (Table 1).

Pain level intensity:

Before exercise induced biceps brachia muscle fatigue, the baseline values for the pain level was assessed by the VAS for each subjects in both sessions revealed no significant difference (p > 1.000) between groups. This indicated that the subjects had no prior muscle pain and understood how to use the VAS scale correctly.

Post exercise induced biceps brachia muscle fatigue, the score on the VAS significantly increased. This was recorded in both sessions. In the active IFC session; the mean VAS score increasing from zero at base line to 4.13 ± 1.06 (p < 0.0005) and in the placebo IFC session; the mean VAS score increasing from zero at baseline to 4.87 ± 1.19
This significant increase indicated that this fatigue exercise protocol was effective to induce biceps brachia muscle fatigue. It can also be seen that the placebo session reported a significantly greater \((p<0.01)\) increase in pain level than the active treatment session after fatigue exercise, Fig. (4).

**Number of concentric elbow flexion before fatigue:**

The two tailed dependent \(t\)-test demonstrated that the mean of the number of concentric elbow flexion for the active IFC session was \(19.35\pm5.24\) repetition whereas the mean of the placebo IFC session was \(15.65\pm5.86\) repetition. Therefore a high significant differences was found between the active and placebo IFC session as \(t=6.87\) and \(p=0.0001\) to word active IFC session, as show in Fig. (5).

**Time elapsed to reach muscle fatigue:**

The time taken to reach biceps brachia muscle fatigue was longer after active IFC session \((55.28\pm16.54s)\) than after placebo IFC session \((47.67\pm17.53s)\). This difference was statistical significance with mean difference \(7.61\pm0.49\) s and \(p<0.0001\), as show in Fig. (6).
Number of concentric elbow flexion (number)

<table>
<thead>
<tr>
<th></th>
<th>25</th>
<th>20</th>
<th>30</th>
<th>15</th>
<th>10</th>
<th>5</th>
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<tr>
<td>Time (sec)</td>
<td>40</td>
<td>20</td>
<td>60</td>
<td>80</td>
<td>0</td>
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</tbody>
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Effect of Pre-Exercise Sweep Frequency Interferential Current Therapy

Mean number of concentric elbow flexion before fatigue in the two IFC sessions

Fig. (5): Comparison between the mean ± SD numbers of concentric elbow flexion before fatigue of the two IFC therapy sessions.

Time elapsed to reach Biceps brachii muscle fatigue in the two IFC sessions

Fig. (6): Comparison between the mean ± SD time elapsed to reach muscle fatigue of the two IFC therapy sessions.

Discussion

Skeletal muscle fatigue is a very well-known phenomenon and major issue that concerns all patients and athletes in their respected fields. This could lead to an incomplete recovery between training sessions, increase the risk of injuries and ultimately reduce the patient’s and an athlete’s overall performance level [8].

Bearing this in mind we are attempting to delay this phenomenon and improve the quality of individual’s life span. This study was conducted to find out the effect of pre-exercises IFC therapy with trapezoid sweep current, set between a low beat frequency of 5Hz and high beat frequency of 110Hz for thirty minutes/session would have an effect on pain level intensities, time elapsed to reach muscle fatigue and number of submaximal concentric elbow flexion of biceps brachia muscle fatigue in healthy untrained male individuals.

The study utilized VAS to determine the level of pain intensity. VAS allows clinician to measure decreases or increases in the levels of pain felt by patients and to measure effectiveness of treatment [29]. Bijur et al., [30] suggested that the VAS is sufficiently reliable to be used to assess acute pain.

The study data results indicated that the sweep frequency of IFC therapy attenuate the development of biceps brachia muscle fatigue of normal male subjects as a high significant differences were found between the active and placebo IFC therapy sessions in terms of pain level intensities after induced fatigue, number of concentric elbow flexions before fatigue and the time elapsed to reach muscle fatigue.

Our findings extend the conclusions of several studies supporting the effectiveness of the IFC-therapy for musculoskeletal pain [15,31-33] and experimental pain [34-36]. The research studies reported that interferential current seems to be more effective for reducing pain than a control treatment and more effective than a placebo treatment at the 3 month follow-up with either high or low frequency range.

The analgesic effect produced by IFC stimulation was attributed to its effect on the local blood supply that reduced the pain inducing chemicals from the site of pathology [21,22]. The descending suppression mechanism of pain by endogenous opiates is also determined to modulate pain experience [17,37] and the muscle relaxation induced by IFC therapy [38].

The mechanisms by which IFT provides relief of pain are not totally known. There is evidence that IFT may inhibit the nociceptive inputs. De Domenico, [17] has suggested several mechanisms of IFC for pain relief. Frequencies around 100Hz stimulates large diameter nerve fibres and activates ‘pain-gating’ mechanisms proposed by Melzack & Wall, [39]. Lower frequencies of 10-25Hz may stimulate A-delta and C fibres causing the release of endogenous opiates such as enkephalin and endorphin [17,37]. The frequency range of IFC

Table (1): Means and standard deviations for the demographic data of the heights, weights, ages and body mass indexes of the subjects.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Means ± Standard deviation</th>
</tr>
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<tbody>
<tr>
<td>Height (m)</td>
<td>1.62 ± 0.059</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.6 ± 7.56</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>21.05 ± 1.36</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>22.85 ± 2.94</td>
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therapy used in this study allows modulation of pain by activation of different nerve fibres.

Santos et al., [38] found that the electromyography activity of upper trapezius reduced by inter-
ferential current at sensory level with frequency 35Hz and 75Hz through improving circulation. The study suggested that IFC therapy can promote a muscle relaxation effect after a few applications such as during rest as well as during functional activities.

The underlying mechanism of the physiological effect of IFC therapy upon peripheral blood low and circulation is still unclear. Nevertheless, a number of theories have been postulated, the most common being the loss of sympathetic tone within the smoothmuscular wall of blood vessels, thus causing vasodilatation with low frequency current [24].

The study finding agrees with the results of Schmitz et al., [40], ondallied onset muscle soreness (DOMS). Where IFC of high and low beat frequency (100 & 10Hz) significantly decreased perceived pain levels associated with DOMS. However the limitation of this study was that no placebo or control group was used. Therefore, the reduction of pain in both treatment groups may be due to a placebo effect. And disagree with Minder et al., [41] on DOMS. Where hypoalgesic efficacy of IFT was assessed under double blinded placebo controlled conditions using experimentally induced DOMS as pain model, the VAS scores failed to provide a clear picture of IFC’s ability to reduce pain associated with DOMS (where no significant differences between active and placebo treatments).

The strength of the present study is the design that supports strong evidence. The use of a placebo group enables an analysis of the therapy’s effectiveness and aids in understanding the placebo effect. The present study is the first study utilizing two different frequencies (low and high) at the same time to investigate the combined effect on the muscle fatigue. The study’s limitations include the impossibility of blinding due to the nature of the intervention and the lack of a control group (undergoing no treatment) for comparison with the other groups. The results are only applicable to healthy subjects experiencing induced fatigue. Hence, these results cannot be generalized to clinical conditions. Future studies should be conducted with larger sample sizes, on female and in clinical setting or on sport athletes’.

Conclusions:
The study concludes that the application of sweep frequency interferential current sets between a low frequency of 5Hz and a high frequency of 110Hz could be effective in delaying the development of skeletal muscle fatigue and enhancing skeletal muscle performance.

References
Effect of Pre-Exercise Sweep Frequency Interferential Current Therapy


الملخص العربي

خلفية: التعابي العضلي الليهيكل العظمي هو أحد أكثر المشاكل شيوعًا التي تتواجد الأنشطة في العبادات ومارسات الرياضة. يستخدم العلاج بالتيارات المتداخلة على نطاق واسع من قبل أخصائيين العلاج الطبيعي في جميع أنحاء العالم للعلاج حالات العضلات والأنظمة.

الهدف: لمعرفة تأثير العلاج بالتيارات المتداخلة قبل ممارسة التعابي الناجم عن العضلة ذات الرأسين في الذكور غير مدربيين.

الأشخاص والطرق: تم مشاركة عشرون شاب طبيعي تم توزيعهم عشوائياً لتلقي العلاج خلال جلستين من العلاج التيار المتداخلة قبل أحداث تعبي العضلة ذات الرأسين مع فارق 7 أيام بين الجلستين. جلسات التيار المتداخلة النشطة مع تزويق شبه منحرف الإشتقاق التي وضعت بين إنهفام وثقب ضربات من 5 إلى 7 وتدش ضربات أعلى 100 هرتز لمدة ثلاثين دقيقة وجلسات تيارات متداخلة وهمية. بعد جلسات العلاج طلب من كل شخص لداء التكبير أثناء الكوع الطوعية مع 20% من واحد التكبير الحد الأقصى باستخدام الأوزان المختلفة حتى يصل إلى التعب بسبب عدم القدرة ليصل إلى 90 درجة من شع الكوع. وقد تم قياس مستوى شدة الألم قبل وبعد الوصول إلى التعب. وقد تم قياس مستوى شدة الألم قبل وبعد الوصول إلى التعب من نطاق التفاعلية البصرية، وعدد من إنكماش متحدة المركز قبل التعب والوقت المخصص لصل إلى نقطة التعب لجميع الأشخاص في الجلستين.

النتائج: وجد فرق كبير (0.05) ما بين الجلسات النشطة والجهيدة للتيار المتداخلة عند المتوسط ± الإحراض من حيث المقارنة بين مستوى شدة الألم. انخفض عدد من حالات التكبير والوقت للوصول إلى التعب العضلي لصالح التيارات المتداخلة النشطة.

الخلاصة: إن تطبيق العلاج بالتيار المتداخلة بالمعايير المستخدمة يمكن أن يكون له فعالية في تأخير تطوير التعب في العضلات والهيكل العظمي وتتزن آداء العضلات والهيكل العظمي.