

SWEEP FREQUENCY OF INTERFERENTIAL CURRENTS THERAPY ATTENUATE FATIGUE OF BICEPS BRACHIA MUSCLE IN NORMAL 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.

Material 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 5 Hz & a high beat frequency of 110 Hz for thirty minutes & 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 concentric contraction before fatigue 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 \pm SD of the two sessions were compared in a terms of pain intensity level, number of submaximal repetitions & time elapsed to reach biceps brachia muscle fatigue in favour of active interferential currents therapy.

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

KEY WORDS: muscle fatigue, interferential currents therapy.

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Access this Article online

Quick Response code



DOI: 10.16965/ijpr.2017.109

International Journal of Physiotherapy and Research

ISSN 2321- 1822

www.ijmhr.org/ijpr.html

Received: 05-02-2017

Accepted: 20-02-2017

Peer Review: 06-02-2017

Published (O): 11-04-2017

Revised: None

Published (P): 11-04-2017

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 performance 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 (1KHz-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 10-20 Hz [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

ate SMF. The study aims to find out the effect of pre-exercise sweep frequency interferential currents 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

Subjects: A Convenience sample of 20 healthy physiotherapy male students (11 undergraduates and 9 postgraduates students) with mean age 21.05 ± 1.36 years & mean body mass indexes 22.85 ± 2.94 kg/meter² were selected from fifty students volunteered to participate in the study after posting an advertisement on the student notice board at the Faculty of physical therapy, Cairo University.

The eligible participants were required to be right handed male students with aged ranged between 20 and 30 years; BMI < 30; healthy; recreationally active and Non smoker. A complete health screening questionnaire was required prior to the study.

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. The recruitment started in January 2013 and ended in July 2013. Ethical approval was obtained from the local ethical committee of the Faculty of Physical Therapy, Cairo University.

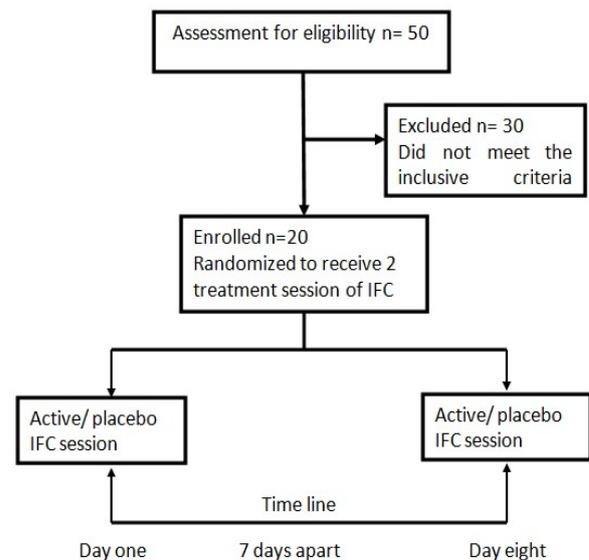
Experimental protocol:

The study was conducted at isokinetic lab of Faculty of Physical Therapy, Cairo University. It

was 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. (Refer CONSORT diagram)

CONSORT diagram

Flow chart 1: Flowchart for the randomized controlled trial.



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 & 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 10 cm 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].

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 (PHYACTION 780- UniphyBV, 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 9 am 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:

A complete clinical examination including anthropometric measurements (weight and height) and body mass index was calculated (BMI).

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.

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 10 cm 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.

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 & 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 & strapped to his trunk, the height & 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 & 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.

Fig. 1: Calculation of the maximum voluntary biceps brachia flexion.



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 60 s 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 parameter of IFC therapy was selected to delivered a trapezoid sweep frequency interferential current that set between a low beat frequency of 5 Hz & a high beat frequency of 110 Hz. 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 the current amplitude, while actually no current was delivered. We told to the subjects that you were receiving a non-sensory treatment and you should feel nothing, as shown in Fig 2.

Fig. 2: Bipolar application of IFC therapy on biceps brachia.



The electrodes placement was circled (30-mm diameter) by a permanent black marker that drew on the skin over the biceps brachia muscle on each subject in order to remain the placement would be consistent throughout the study. Subjects were instructed not to remove the black

circle on the skin over the biceps brachia muscle. The black circle was assessed daily for clarity and blackened as needed. Immediately after IFC treatment, the subjects were repositioned and started the biceps brachia fatigue exercise protocol. The time between biceps brachia and starting the exercise was 180 s.

Fatigue Protocol: the subjects were seated on an armless stable chair with the knees and hips flexed at 90° & their testing arm hanging to the side. Using free weights, the previously defined individual load equal to 30% of MVC was used for each subject. Using their non-dominant arm, the subjects were instructed to perform repeated elbow flexion-extension, from the full elbow extension to the full elbow flexion at the maximal available speed. A goniometer was fixed to the side of the subjects to monitor the elbow flexion angle. The number of contraction repetitions performed until reach fatigue was counted by one observer and the total time to reach fatigue was measured by other observer. The fatigue was considered at the point when the subjects were not able to reach 90° of the elbow flexion. During the execution of exercise protocol, the subjects were received verbal encouragement that was provided by the observe who was measure time to reach fatigue [8], as shown in Fig.(3a &b).

Fig. 3a: Starting position of elbow flexion.



Fig. 3b: End position of elbow flexion.



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 respectively (number).

Data analysis: Data were col-lected, revised, and analyzed by Statistical Package for Social Science (SPSS) program version 18. Compari-son

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 \pm standard deviation (SD). Statistical significance was set with α at $P \leq 0.05$.

RESULT

Twenty healthy male untrained subjects were recruited & met the inclusion criteria. Their mean heights were 1.62 ± 0.059 meters, their mean weights were 59.60 ± 7.56 kg, their mean ages were 21.05 ± 1.36 years & their mean body mass indexes were 22.85 ± 2.94 kg/meter² respectively, as show in Table1.

Table 1: The Means & Standard Deviations for the demographic data of the Heights, Weights, Ages & Body Mass Indexes of the subjects.

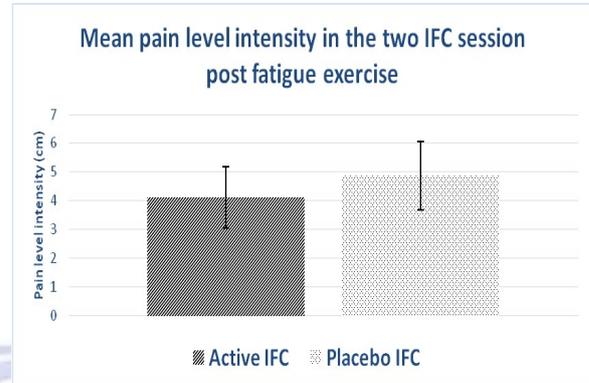
| Parameters | Means | \pm Standard Deviation |
|-------------------------|-------|--------------------------|
| Height (m) | 1.62 | ± 0.059 |
| Weight (kg) | 59.6 | ± 7.56 |
| Age (yrs) | 21.05 | ± 1.36 |
| Body mass Index (kg/m2) | 22.85 | ± 2.94 |

Pain level intensity: The baseline values for the pain level was assessed by the VAS for each subjects before the exercise that induced biceps brachia muscle fatigue 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 that 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 ($p < 0.0005$). 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).

Fig. 4: Comparison between the mean \pm SD of the pain level intensity of the two IFC therapy sessions post fatigue exercise.



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 ± 5.24 repetition whereas; the mean of the placebo IFC session was 15.65 ± 5.86 repetition. Therefore a high significant differences was found between the active & placebo IFC session as $t = 6.87$ and $P = 0.0001$ to word active IFC session, as show in figure 5.

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

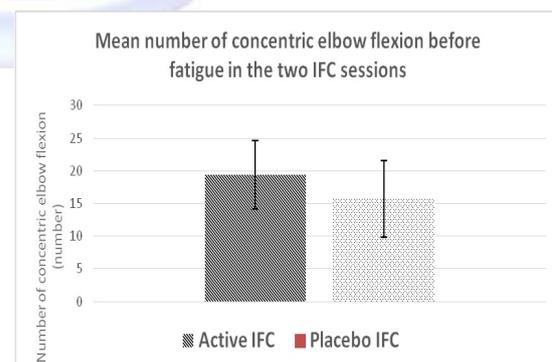
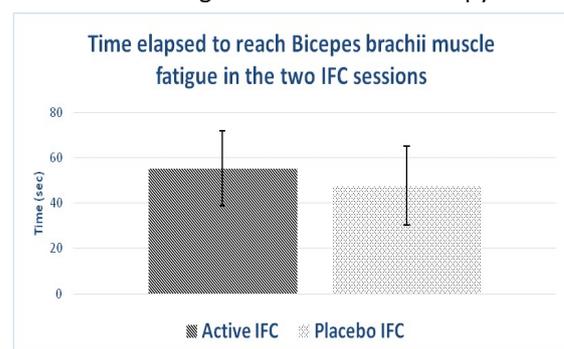


Fig. 6: Comparison between the mean \pm SD time elapsed to reach muscle fatigue of the two IFC therapy sessions.



Time elapsed to reach muscle fatigue: The time taken to reach biceps brachia muscle fatigue was longer after active IFC session (55.28 ± 16.54 s) than after placebo IFC session (47.67 ± 17.53 s). This difference was statistical significance with mean difference (7.61 ± 0.49 s) and $p < 0.0001$, as show in figure 6.

DISCUSSION

Skeletal muscle fatigue is a very well-known phenomenon & 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 & ultimately reduce the patient's and an athlete's overall performance level [8].

Bearing this in mind we are attempting to delay this phenomenon & 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 5 Hz & high beat frequency of 110 Hz for thirty minutes / session would have an effect on pain level intensities, time elapsed to reach muscle fatigue & 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., 2001, [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 & Placebo IFC therapy sessions in terms of less pain level felt after induced fatigue, more number of concentric elbow flexions before fatigue & longer 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, 1982, [17] has suggested several mechanisms of IFC for pain relief. Frequencies around 100 Hz stimulates large diameter nerve fibres and activates 'pain-gating' mechanisms proposed by Melzack & Wall, 1965 [39].

Lower frequencies of 10–25 Hz may stimulate A-delta and C fibres causing the release of endogenous opiates such as enkephalin and endorphin [17, 37].

Santos et al., 2011, [38] found that the electromyography activity of upper trapezius reduced by interferential current at sensory level with frequency 35 Hz and 75 Hz 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 flow and circulation is still unclear. Nevertheless, a number of theories have been postulated, the most common being the loss of sympathetic tone within the smooth muscular wall of blood vessels, thus causing vasodilatation with low frequency current. [24].

The sweep frequency range of IFC therapy used in this study allows modulation of pain by activation of different nerve fibres. It was used at sensory level that allow relaxation of the muscle with frequency range improve peripheral blood flow.

The study finding agrees with the results of Schmitz et al., 1997 [40], on delayed onset muscle soreness (DOMS). Where IFC of high and

low beat frequency (100 & 10 Hz) significantly decreased perceived pain levels associated with DOMS. However the limitation of Schmitz et al.,1997 [40] 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., 2002 [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 & 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 & in clinical setting or on sport athletes'.

CONCLUSION

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

ACKNOWLEDGEMENTS

The author is grateful to students and assistance who volunteers to conduct the study.

Conflicts of interest: None

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How to cite this article:

Abeer A. Yamany. SWEEP FREQUENCY OF INTERFERENTIAL CURRENTS THERAPY ATTENUATE FATIGUE OF BICEPS BRACHIA MUSCLE IN NORMAL MALE SUBJECTS: A RANDOMIZED PLACEBO CONTROL TRIAL. *Int J Physiother Res* 2017;5(2):1937-1945. DOI: 10.16965/ijpr.2017.109