Torque Production, Sensation Thresholds and Perceived Discomfort Using Low and Medium Frequency Electrical Stimulation

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ABSTRACT

This study was conducted to (1) investigate and compare maximum electrically induced isometric torque (MEIT), sensation thresholds (sensory, motor, and pain), and perceived discomfort using two forms of low frequency electrical stimulating currents (symmetric biphasic and faradic currents) and medium frequency electrical stimulating currents (Russian and interferential currents). (2) To determine relation between MEIT with both sensation threshold and perceived discomfort. Twenty healthy male subjects with mean age (25±2.4 years), mean height (168±5.4 cm), and mean weight (70.5±4.1 kg) participated in the study. Each subject participated in 5 separate testing sessions, with 24 hours between each session. In the first session, maximum voluntary isometric torque (MVIT) of the right quadriceps femoris muscle was determined for each subjects. In the following 4 sessions, MEIT, sensation thresholds (sensory, motor, and pain), stimulus efficiency (pain threshold/motor threshold), and perceived discomfort were determined for the four studied currents one in each session at random order. Data analyses of the measured variables revealed that, electrical stimulation with low as well medium frequency are capable of inducing isometric torque which can be used as training stimulus for muscle strengthening. Symmetric biphasic current induced the highest isometric torque among the studied currents as it induced 48.6% of MVIT, while faradic current induced 36.8% and Russian and interferential current induced 44.6% and 30.7% respectively. The MEIT has strong positive correlation with stimulation efficiency, and mild to moderate negative correlation with perceived discomfort, sensory threshold and motor thresholds and no correlation with pain threshold. The highest correlation was recorded between MEIT and stimulation efficiency. The study demonstrated superior effect of symmetric biphasic current in inducing high level of isometric torque with minimum discomfort with the recommendation of its use in strengthening weak muscles. Stimulation efficiency is an important factor which determine the success of electrical stimulating current in increasing muscle strength.
Key words: Torque, Sensation Thresholds, Perceived Discomfort, and Electrical stimulation.

INTRODUCTION

Neuromuscular electrical stimulation is used extensively in physical therapy to develop muscle strength and improve muscle performance[5,11,15]. Several types of electrical stimulating currents that differed in electrical characteristics and parameters are available in practice[9,16,21].

There are two categories of electrical stimulating currents that are commonly used by the physical therapists for neuromuscular electrical stimulation, low frequency currents and medium frequency currents modulated at low frequency. Under these two categories there are many types and forms of stimulating currents[3,8].

Numerous researches have been performed to determine the preferred optimum clinical parameters for stimulation and to establish protocol for the various types of electrical stimulation[1,4,9,13,17]. It was suggested that for the electrical current to be effective in increasing muscle strength must provide a maximal contraction, yet be relatively pain free. In addition, it was found that the electrical stimulation parameters that caused the greatest muscle strength was the one that produced the greatest average muscle tension and torque induced by higher current intensities[5,15]. Investigators have been trying to reach to the greatest effect with minimum discomfort by varying the current frequencies, waveforms or pulse duration[2, 6,10].

Both low frequency and medium frequency currents have been reported to be effective in muscle strengthening[2,3,21]. The studies comparing types of low and medium frequency currents, with the aim of selecting the optimal current for increasing muscle strength tend to be inconclusive or contradictory. In addition there were no enough well designed controlled reported studies comparing between the two categories, which makes choice of the best electrical stimulating current problematic[4,6,7,8,16,22].

It was reported that both Russian and low frequency current produced higher torques than interferential current and there was no significant difference between Russian current and low frequency current[16]. Laufar et al., (2001) compared MEIT using Russian current, low frequency monophasic pulsed current, and low frequency biphasic pulsed current and found that low frequency biphasic current produce higher torques than Russian current and low frequency monophasic pulsed current[8].

In contrast to those studies cited above other investigations have shown that interferential stimulation can produce an electrically induced muscle contraction, which is stronger and less unpleasant than low frequency stimulation[7]. While Bircan et al., (2002) concluded that both interferential and low frequency currents can be used in strength training and that there was no significant difference between the two forms[3]. Recently in review by ward and Shkuratova (2002), it was concluded that the presented differences between findings of those studies could be, in part, related to the experimental protocols used and recommended further direct comparisons of force production using low frequency and modulated KHz frequency currents[22].

From all the above cited contradictory in the reported result, it can be postulated that, although the literature reports the popularity of electrical stimulation in the field of physical therapy for augmentation of muscle strength, there appear to be insufficient reported data to substantiate the possible selection between different types of low and medium frequency currents.

Most of the existing studies on the effect of neuromuscular electrical stimulating currents on muscle strength focused on the clinical outcomes as torque or fatigue without providing explanation to the superior effect of one current over an other beside the discomfort during stimulation[6,10]. So different approach would seem appropriate, one option is to investigate the stimulus intensity required by different currents to elicit sensory, motor, and pain sensation or in other-word to determine sensation thresholds (sensory, motor, and pain) and determine motor/sensory ratio and pain/motor ratio. It was reported that larger separation between the sensation thresholds provides more chance for more fibers to be stimulated. So the current that has higher motor/sensory threshold is more convenient to sensory stimulation and currents that has higher pain /motor ratio is more convenient to motor stimulation with minimal discomfort[18,20].

So accordingly, it can be postulated that determining the correlation between sensation threshold and the produced torque could provide an explanation to the different effect induced by different electrical stimulating currents.

With the aim to establish the optimal current for maximum torque production with minimal discomfort, the current study was designed to (1) investigate and compare maximum electrically induced isometric torque (MEIT), the sensation (sensory, motor, and pain) thresholds and perceived discomfort using two forms of low frequency current (symmetric biphasic pulsed current and faradic current) with that produced by medium frequency current (Russian current and interferential current). (2) to determine the correlation of MEIT with both sensation thresholds and perceived discomfort.

MATERIALS AND METHODS

Subjects

Twenty healthy male subjects with mean age (25±2.4 years), mean height (168±5.4 cm), and weight (70.5±4.1 kg) volunteered to participate in the study. Subjects were selected from the postgraduate students and members of the faculty of physical therapy, Cairo University and were free from neurological or musculoskeletal impairment. All subjects were refrained from strenuous activities and caffeine drink for 24 hours prior to testing.

The study was conducted in February through March 2002, at the Faculty of Physical Therapy. Torque measurements were conducted at the Police Hospital, Agouza.

Instrumentation

1- Electrical stimulator (Phyaction 790) was used to deliver the four types of electrical stimulating currents.
2- MERAC isokinetic system was used to measure the torque produced by subjects.
3- Visual numerical scale (VNS) for rating perceived discomfort.

Testing procedure

Each subject participated in 5 separate testing sessions, with 24 hours between each session. At the first session the maximum voluntary isometric torque (MVIT) was determined. At each session of the following 4 sessions, one type of the 4 electrical stimulation currents investigated in the study was tested and MEIT, sensation thresholds and perceived discomfort with each current were determined. The order of stimulation was randomly selected and the subjects were not informed of the type of current being used during each testing session assigned. The right quadriceps femoris (QF) muscle was used for all tests of all subjects.

Measurement of muscle torque

Maximum voluntary isometric torque (MVIT)

Each patient was informed about the steps of the test procedures and the apparatus was calibrated according to the manufacture manual. The subject was seated on the apparatus chair with hip 120 degrees flexion and knee at 60 degrees flexion. The subject back, thigh, and leg were stabilized by the system pads and belts. The backrest was set at 110 degrees of posterior incline. The fulcrum of the lever arm was aligned with the lateral epicondyle of femur and the inferior portion of the shin pad was adjusted at 5 cm superior to the right medial malleolus. The subject performed three trials of 10 seconds maximum voluntary isometric contraction with 1-minute rest between trials. The subject was asked to maximally extend the knee joint while verbal encouragement was done. The MVIT was recorded and averaged for the three trials [8].

Maximum electrically induced torque (MEIT)

For each subject, the area of electrode placements of the right thigh was cleaned with alcohol. Two standard carbonized rubber electrodes of equal size (5x10.5 cm) with sponge pads soaked in tap water were used to stimulate the QF muscle. One electrode was placed over the motor point of vastus medialis and the other electrode was placed over the motor point of vastus lateralis. The electrodes were secured in position using velcro straps. in an attempt to ensure identical electrode placement for subsequent testing trials, the electrode sites were traced onto a clear transparency [8].

After electrodes placement with the subject positioned in the same position during measurement of MVIT, the current intensity was then increased gradually giving time for perception of each sensation level (sensory, motor). Once reaching motor threshold, the stimulation intensity was slowly increased to the subject maximum tolerance (pain level) at this level the MEIT was recorded for each current type. The MEIT was defined as the torque recorded at maximum tolerable intensity of current. Three consecutive trials were done with about the same a 60 seconds of rest between trials. the torque recorded was averaged for the 3 trials[20].

Sensation threshold level

For each type of the investigated currents, the intensity threshold in miliamber (mA) required for eliciting the sensory, motor and pain response was recorded. The sensory threshold was defined as the intensity of the current at which the subject first perceived cutaneous sensation. The motor threshold was defined as the lowest intensity of the current to produce a minimally visible contraction of the stimulated muscle. The pain threshold was defined, as the maximum stimulus intensity at which the subject believed that could not tolerate[18].

First the intensity was increased to a level that the subject could just tell that the current was on (sensory threshold). The intensity was turned off and again the intensity was turned to a level to obtain minimally visible contraction (motor threshold). The current was turned off and then intensity was again on and increased to the maximum tolerable level that believed they could sustain for 1:2 minutes (pain threshold). At this level MEIT was recorded. The procedures were repeated for 3 times with a period of 60 seconds rest allowed between trials and the average of the measurements were calculated[18].

Perceived discomfort measurement

Visual numerical scale (VNS) was used to determine the degree of perceived discomfort during each stimulation type. The subject was asked to choose a number between 0 to 10 with 0 indicated no discomfort and 10 the worst pain. The subject marked the number corresponded to the pain intensity to determine the degree of discomfort during electrical stimulation[12].

Electrical stimulation

Low frequency currents utilized were: (1) symmetric biphasic alternating current square waveform with frequency 50 Hz, and pulse duration 0.4 msec. (2) faradic current rectangular waveform, with frequency 50hz, 0.4msec pulse duration, train time 10 sec, and rest time 10 sec. Intensity of low frequency currents was ramped on over a 2-second period hold constant for 6 second and ramped off over 2 second period. While medium frequency current included: (1) Russian current polyphasic sinusoidal waveform, with frequency 2500 Hz modulated at 50 Hz bursts, pulse duration 0.4 msec., stimulation time 10 sec, and rest time 10 sec with surge 50%. (2) interferential current (two poles) sinusoidal waveform with frequency 4000 Hz modulated at 50 Hz and 0.4 msec pulse duration.

Data Analysis

The variables that have been under investigation were, maximum voluntary isometric torque (MVIT), maximum electrically induced isometric torque (MEIT), sensory threshold, motor threshold, pain threshold, stimulation efficiency (pain threshold/ motor threshold), and perceived discomfort. To determine stimulation efficiency, values of pain threshold were divided by motor threshold for each subject. The percent MEIT (% MEIT) was calculated from the raw data as percentage of MVIT scored for each subject. The data were expressed as mean and standard error (SE).

One way ANOVA test was performed for each recorded variable to determine differences among the studied currents. Bonferroni post hoc pair-wise comparison was used to examine difference between each pair to determine differences between studied currents. Pearson correlation tests was performed to determine correlation of MEIT with other tested variables. Level of significance level was set at (0.05).

RESULTS

Maximum electrically induced torque

The maximum voluntary isometric torque (MVIT) mean and standard error (SE) was (174.1±7.31 Nm). as shown in table (1) and fig.(1) symmetric biphasic current induced higher torque than other currents, where scored (84.3± 4.16 Nm) and % torque 48.6%, while mean and SE of faradic, Russian, and interferential currents were respectively (63.5±2.5, 77.7±3.74, and 53.2±2.1) with % torque (36.8%, 44.6%, and 30.7%). The results of the ANOVA test revealed significant difference among the studied current (P<0.0001).

Table (1): Mean, standard error (SE), F and P values of the tested variables for the studied currents.

Current Type	Symmetric Biphasic Current		Faradic Current		Russian Current		Interferential Current		Significance	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	F	P
MEIT (N.m)	84.3	4.16	63.5	2.5	77.7	3.74	53.2	2.1	28.9	<0.0001*
%Torque	48.6	1.39	36.8	0.97	44.6	1.15	30.7	0.39	25.3	<0.0001*
Perceived Discomfort	2.7	0.16	6.2	0.19	3.5	0.15	2	0.21	30.4	<0.0001*
Sensory Threshold	19.9	0.36	16.8	0.48	21.35	0.49	25.85	0.51	46.1	<0.0001*
Motor threshold	26.4	0.43	26.2	0.55	28.3	0.59	38.3	0.56	40.4	<0.0001*
Pain Threshold	61.15	1.21	46.35	0.49	61.3	1.35	63.5	1.24	42.2	<0.0001*
Stimulation Efficiency	2.35	0.04	1.75	0.02	2.15	0.05	1.6	0.02	45.7	<0.0001*

*Significant

As presented in table (2) the results of Bonferroni post hoc comparison indicated that symmetric biphasic current induced significant higher isometric torque than faradic current (P< 0.001), Russian current (P<0.05), and interferential current (P< 0.001). In addition there were significant increase of induced torque by Russian current than faradic current (P<0.001), and interferential current (P<0.001). Faradic current induced higher torque than interferential current (P<0.001).

Perceived discomfort

Interferential current and symmetric biphasic currents revealed to be the most comfortable current, as they scored the lowest level of perceived discomfort (2±0.21degrees), and (2.7±0.16 degrees) respectively. While Russian and faradic currents revealed to be more painful evidenced in the higher level of perceived discomfort (3.5±0.15 degrees) and (6.2±0.19 degrees) respectively. ANOVA test results demonstrated that there was significant difference among the studied current ($P<0.0001$) as shown in table (1), figure (2).

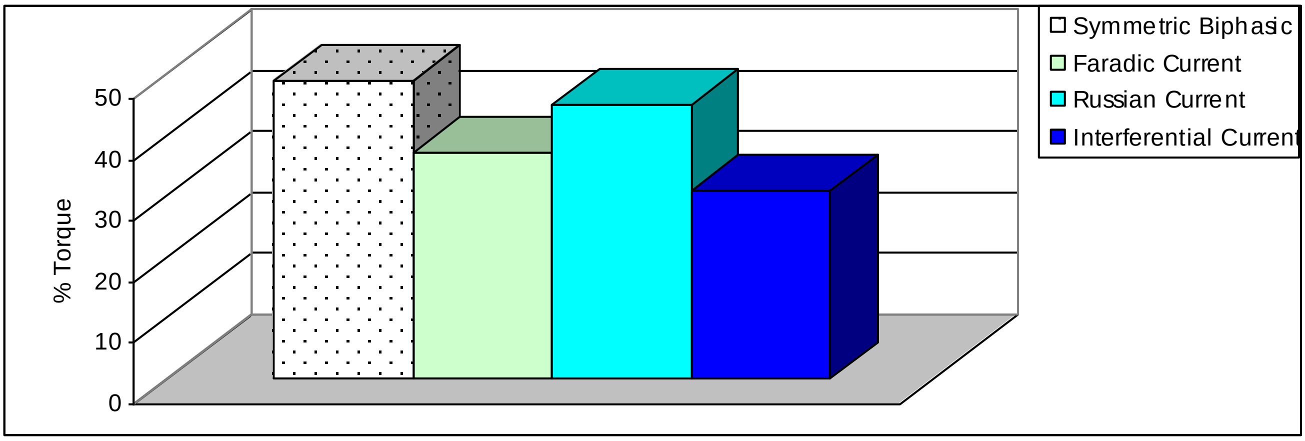

Fig. (1): % torque mean of the studied currents.

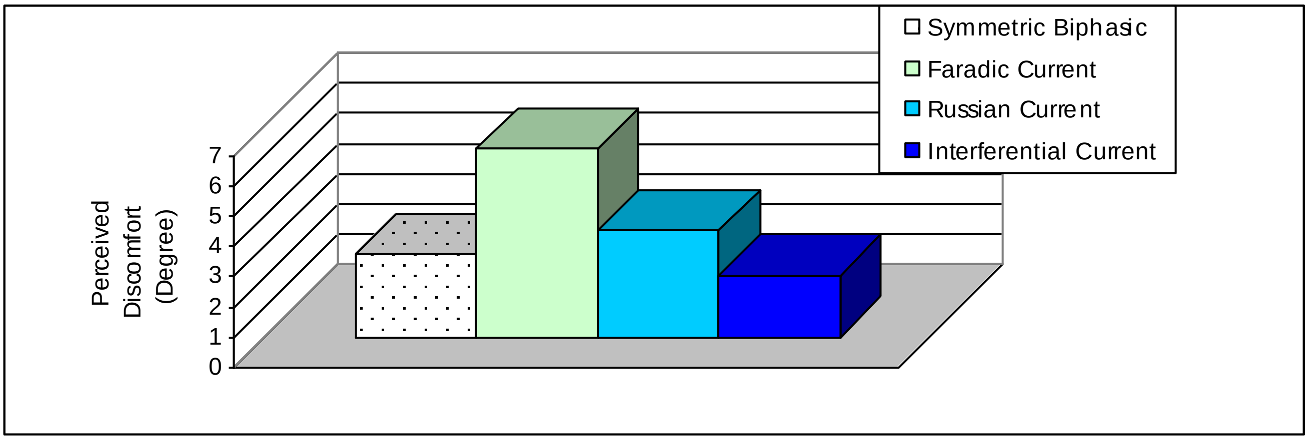

Fig. (2): Perceived discomfort experienced with studied currents.

Comparison between currents showed that there was no significant difference between symmetric biphasic and interferential currents ($P>0.05$). On the other hand both currents were significantly less painful than Russian and faradic currents ($P<0.05$, and $P<0.001$) and ($P<0.05$, and $P<0.001$) respectively. While there was significant increase of perceived discomfort experienced with faradic current than Russian current ($P<0.001$) table (2).

Table (2): Bonferroni post hoc pair-wise comparisons between studied currents.

		MEIT (N.m)	Pain Intensity	Sensory Threshold	Motor Threshold	Pain Threshold	Perceived Discomfort
Symmetric biphasic Vs faradic Current	t P	9.1 < 0 .001*	12.8 < 0.001*	7.2 < 0.001*	0.31 > 0.05	14.8 < 0.001*	13.9 < 0.001*
Symmetric biphasic Vs Russian urrent	t P	2.8 < 0.05*	2.92 < 0.05*	3.3 < 0.01*	2.8 < 0.05*	0.5 > 0.05	4.6 < 0.001*
Symmetric biphasic Vs Interferential Current	t P	13.6 < 0.001*	2.37 > 0.05	13.9 < 0.001*	18.1 < 0.001*	1.4 > 0.05	17.3 < 0.001*
Russian Vs Faradic Current	t P	6.2 < 0.001*	9.87 < 0.001*	10.6 < 0.001*	3.1 < 0.05*	14.2 < 0.001*	9.3 < 0.001*
Faradic Vs Interferential Current	t P	4.5 < 0.001*	15.5 < 0.001*	21.7 < 0.001*	18.3 < 0.001*	16.2 < 0.001*	3.4 < 0.01*
Russian Vs Interferential Current	t P	5.3 < 0.001*	2.9 < 0.05*	10.5 < 0.001*	15.1 < 0.001*	1.9 > 0.05	12.7 < 0.001*

*Significant

Sensation thresholds

Both interferential and Russian currents scored higher sensation thresholds than symmetric biphasic and faradic currents where sensory, motor and pain thresholds for interferential current were (25.8±0.51, 38.3±0.56, and 63.5±1.24 ma), for Russian current (21.3±0.49, 28.3±0.59, and 61.3±1.45 mA). In the other hand for symmetric biphasic were (19.9±0.36, 26.4±0.43, and 61.1±1.21 mA). While faradic current had the lowest sensation thresholds (16.8±0.48, 26.2±0.55, and 46±0.35 mA) as shown in table (1), figure (3).

Regarding stimulation efficiency calculated as pain threshold/ motor threshold, symmetric biphasic current scored the highest stimulation efficiency (2.35±0.04) followed by Russian current (2.15±0.05), and faradic current (1.75±0.02), while interferential current scored the lowest values (1.6±0.02) table (1), figure (4).

As presented in table (1), ANOVA test demonstrated significant differences among studied currents in all sensation thresholds and stimulation efficiency as ($P<0.0001$).

As demonstrated in table (2), when comparing each pair of currents there were significant increases in sensory and motor thresholds of interferential and Russian currents than symmetric biphasic and faradic currents. Also there was significant increase of sensory and motor thresholds of interferential current than Russian current. When comparing pain threshold, faradic current was tolerated to significantly low thresholds than all other three types ($P<0.001$). While there were non-significant difference between symmetric biphasic and both interferential and Russian current.

Symmetric biphasic current has significantly better stimulation efficiency than all other studied currents when compared to Russian current ($P<0.01$), also ($P<0.001$) compared to both faradic and interferential currents.

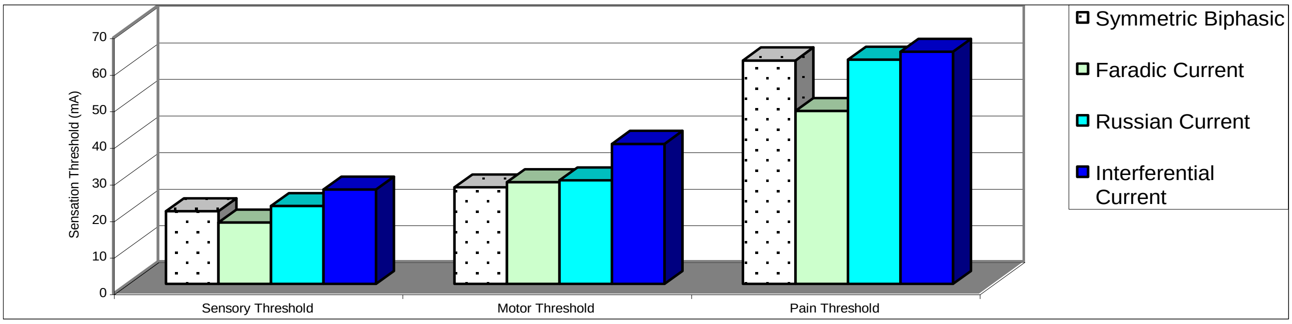

Fig. (3): Sensation thresholds of the studied currents.

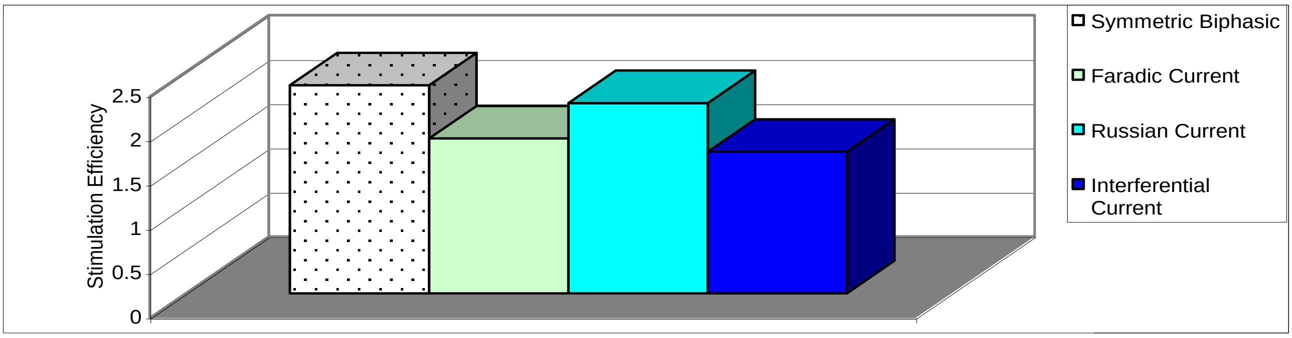

Fig. (4): Stimulation efficiency of the studied currents.

Correlation between MEIT and both perceived discomfort and sensation thresholds

As shown in table (3) correlation test revealed that all variables, except pain threshold, were significantly correlated with MEIT. The highest correlation were between MEIT and stimulation efficiency where (r= 0.88, 0.8, 0.72, and 0.65) in the studied currents respectively as shown in figure (5). The MEIT also has negative correlation with perceived discomfort (r= -0.33:-0.42), sensory threshold (r= -0.36:0.43), and motor threshold (r= -0.48:0.58). While there was no correlation between MEIT and pain threshold (r=0.005:0.11).

Table (3): Correlation between MEIT and the other tested variables.

Variable		Symmetric Biphasic	Faradic current	Russian Current	Interferential Current
Perceived Discomfort (degree)	r	-0.37	-0.33	-0.42	-0.35
	r^2	0.15	0.11	0.17	0.12
	P	<0.05*	0.01*	0.01*	0.01*
Sensory Threshold (mA)	r	-0.36	-0.43	-0.41	-0.39
	r^2	0.13	0.18	0.17	0.15
	P	0.01*	0.01*	0.01*	0.01*
Motor Threshold (mA)	r	-0.58	0.48	0.52	0.46
	r^2	0.33	0.23	0.27	0.21
	P	0.007*	0.005*	0.001*	0.03*
Pain Threshold (mA)	r	0.06	0.005	0.08	0.11
	r^2	0.004	0.00003	0.006	0.01
	P	0.7	0.1	0.7	0.4
Stimulation Efficiency	r	0.88	0.8	0.72	0.65
	r^2	0.77	0.65	0.52	0.43
	P	0.0001*	0.0001*	0.0001*	0.0001*

*Significant

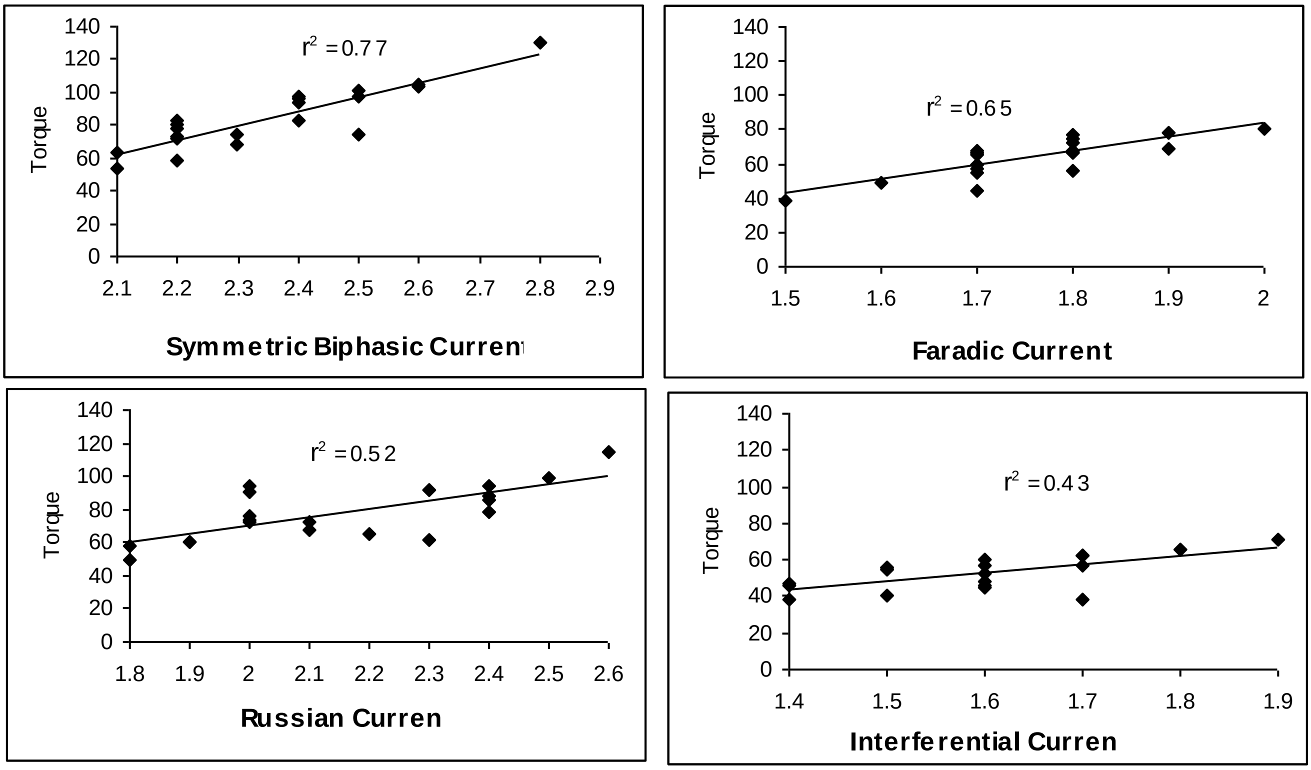

Fig. (5): Correlation between maximum electrically induced torque and stimulation efficiency.

DISCUSION

Electrical stimulating currents are used by physical therapists to increase muscle strength and improve muscle performance. the optimal type of stimulating current is yet to be determined[22]. The current study was designed to investigate and distinguish between the effect of low and medium frequency currents regarding MEIT, sensation thresholds, and perceived discomfort.

The results of the present work showed that both low and medium frequency currents studied were capable of producing training stimulus for muscle strengthening. The %MEIT with each current was 48.6% for symmetric biphasic current, 36.8 for faradic current, 44.6 % for Russian current and 30.7% for interferential current. It was suggested that a training stimulus of 30% to 50% of MVIT was needed to produce strength gain in normal muscle[5].

When comparing the studied currents, the results of the present study demonstrated that symmetric biphasic current produced the highest torque among the studied currents, as there were significant increase of MEIT scored by symmetric biphasic current than those induced by faradic, Russian, and interferential currents. This could be attributed to the higher stimulation efficiency of the current. Our results showed significant strong positive correlation between MEIT and stimulation efficiency. Stimulation efficiency was defined as pain threshold / motor threshold. It was reported that the greater the stimulation efficiency, the greater the discrimination between motor threshold and pain threshold thus promoting greater chance for torque production[18,21].

The extent of separation between motor and pain thresholds was reported as empirical basis for the selection of electrical current used for augmentation of muscle strength. One explanation to this, is that the amount of force production in an electrically induced muscle contraction depend on a number of factors of which, the extent of the recruitment of motor nerve fibers and their frequency of excitation[9]. So the more the fibers recruited the greater the force of contraction, in other word, the greater the discrimination between motor and pain thresholds would allow greater chance for large number of motor fibers recruited[19].

This agree with reported results by Snyder-Macklet et al.,[16] and Laufar et al.,[8] that symmetric biphasic low frequency current produced higher torque than Russian current. On the other hand, it was reported no difference between low frequency and interferential or Russian current[3], while others reported superior effect of interferential than low frequency currents[7]. These could be attributed to using portable sources with low maximum intensity output for providing low frequency current which would limit torque production with low frequency current. In the current study this point was excluded by using on apparatus with same electrode type for providing the four currents.

When analyzing the sensation thresholds, there were significant negative correlation between MEIT and both sensory and motor thresholds, while there was no correlation with pain threshold. This could provide additional explanation to the superior effect of symmetric biphasic current over both medium frequency currents as it scored lower sensory and motor threshold than they did.

Although peak current intensity (pain threshold) tolerated by subjects was not significantly different between symmetric biphasic current and both Russian and interferential currents, the symmetric biphasic current scored significant higher torque ($P<0.001$). The results showed that there was no correlation between MEIT and pain threshold. Lieber et al., (1991) reported that there is no correlation between stimulation voltage and MEIT, reinforcing the concept that stimulation current causes muscle activation not stimulation potential[9].

In the current study, Russian current scored also higher torque with regard to both faradic and interferential currents, but lower torque levels than symmetric biphasic current. This was attributed also to the higher stimulus efficiency recorded for Russian current.

As interferential current is a medium frequency current and supposed to be comfortable and has deeper penetration and be more efficient in the stimulation of more deeply located nerves[7], yet it scored the lowest torque level among the studied currents. This could be explained by the lowest stimulus efficiency of the current that means little chance is provided for motor recruitment. The low level of torque production could be also attributed to the high sensory and motor thresholds of the current. Torque is negatively correlated to sensory and motor thresholds.

These results are in consistent with other reported study by Ward and Robertson (1998) who studied the torque produced with frequency using medium frequency alternating current. They presented that for maximum comfort with low torque a frequency close to 10 KHz is indicated and for maximum torque a lower frequency of 1 KHz is preferable. The interferential current used in this study having a frequency 4 KHz modulated at 50 Hz and the Russian current frequency was 2.5 KHz modulated as 50 bursts. This could provide another explanation to the higher torque scores of Russian current compared to that of interferential current[18].

In agreement with the presented results, it was reported that increase degree of perceived discomfort during electrical stimulation could limit torque production but this does not necessary speculate high torque with comfortable current, as there are many other factors influencing torque production[18,21].

Regarding the perceived pain, interferential current was the most comfortable current followed by symmetric biphasic, Russian current, while faradic current feels the most painful of the currents. This to somewhat agree with the reported literature that medium frequency alternating current between 2.5 KHz: 5 KHz is believed to minimize pain fiber stimulation in spite of great current intensity as the current is deeply penetrated and because pain fibers are believed to be more superficially located[14].

Although both Russian and interferential currents are medium frequency current and supposed to be more comfortable, Russian current was significantly more painful than interferential current ($P<0.05$).

In the present study, the perceived pain by subjects during Russian current stimulation was described as a sensation like their muscles were going to tear and reported that was the reason to limit torque production. The nature of the Russian current which is modulated medium frequency current in which the frequency of 2500 Hz is divided to 50 bursts each include 10 seconds current on and 10 seconds off, so single nerve impulses are produced in response to each burst with the total current delivered in each burst is high[22]. So we could say that the perceived discomfort during Russian current stimulation was not totally due to stimulation of pain fibers but due to forced contraction/ burst which resulted in uncomfortable sensation which limits subjects from further torque production. So perhaps this could be prevented if the rest period increase with regard to the on period to allow more comfortable contraction thus more torque could be obtained.

It is suggested from this study that, Russian current should be used with the 10 second on and 50 second off for muscle strengthening to allow more comfortable contraction and more chance for torque production.

Faradic current is accepted to induce muscle contraction long ago[5] but in this study it was found to produce lower torque than symmetric biphasic and Russian current. this was attributed to the low stimulus efficiency and highest perceived discomfort together with high motor threshold.

Unlike Russian current, the perceived discomfort during faradic current was expressed as distinct painful sensation limiting further torque production, while Russian current discomfort due to forceful contraction.

Although symmetric biphasic and faradic current are low frequency currents, symmetric biphasic produced higher torque with less discomfort. This could be explained by the specific current characteristics as the wave shape with net no chemical reaction under the electrodes. In addition the square waveform of the symmetric biphasic current was found to be one of the favorable wave shapes for stimulation because of rapid rate of rise and fall[2,10].

From the result presented in the current work, it is reasonable to suggest that each current whether low or medium frequency has its own specification which determine its effect and ability to stimulate muscle and increase muscle strength. So we can not generally state that low frequency current is better than medium frequency current or vise versa.

Conclusion

Both low and medium frequency currents could be used to increase muscle strength. Symmetric biphasic current showed superior effect than faradic, Russian and interferential currents. This study shed light on the importance of stimulation efficiency of the electrical stimulation current during muscle stimulation. Further follow up study is needed to establish the long term effect of the studied currents.

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الملخص العربي

عزم اللي ومدى الإحساس وشدة الألم المحسوس نتيجة للتنبيه الكهربائي المنخفض و المتوسط التردد

أجريت هذه الدراسة لبحث هدفين.أولا: لدراسة و مقارنة تأثير نوعين من التنبيه الكهربائي المنخفض التردد (التيار المتماثل ثنائي الطور و التيار الفارادى) ونوعين من التنبيه الكهربائي المتوسط التردد (التيار الروسي والتيار المتداخل). ثانيا : لتحديد العلاقة بين أقصى عزم لى ايسوميترى مستحث كهربائيا و كل من مدى الإحساس و درجة الألم المحسوس المصاحب للتيار الكهربائي. أجريت هذه الدراسة على عشرين شخصا من الأصحاء متوسط أعمارهم (25 ± 2,4 سنه) و طولهم (168± 5,4 سم) و وزنهم (70,5± 4,1كجم). تم اختبار كل فرد خلال خمس جلسات. في الجلسة الأولى تم تحديد أقصى عزم لى إرادي ايسوميترى لعضله الفخذ الأمامية الرباعية الرأس اليمنى. وفي الجلسات الأربع الباقية تم تحديد أقصى عزم لي ايسوميترى مستحث كهربائيا و كذلك تم تحديد مدى الإحساس (الحسي _ الحركي _ الألم) وفاعلية التنبيه (بداية الإحساس بالألم/ بداية الإحساس الحركي) وتحديد درجة الألم المحسوس المصاحب لكل نوع من التيارات الكهربائية. أثبتت المعالجات الإحصائية للنتائج أن التيار المتماثل ثنائى الطور قد استحث أعلى مستوى عزم لى ايسوميترى بين التيارات الكهربائية المستخدمة حيث حقق نسبة 48,6% من أقصى عزم لي إرادي ايسوميترى بينما استحث التيار الفارادى 36,8% و التيار الروسي 44,6% و التيار المتداخل 30,7%. كما أثبتت وجود علاقة إيجابية قوية بين أقصى عزم لي ايسوميترى مستحث كهربائيا و فاعلية التنبيه و علاقة سلبية مع درجة الألم المحسوس و *بداية الإحساس الحسي و* بداية الإحساس الحركي وعدم وجود علاقة بينه وبداية الإحساس بالألم. ويستخلص من النتائج التأثير الفائق للتيار المتماثل ثنائي الطور في حث مستوى عالي من عزم اللي الايسوميترى مصحوبا بأقل إحساس بالألم ويوصى باستخدامه لتقوية العضلات الضعيفة وفي برامج التأهيل. أن فعالية التنبيه يعتبر أحد العوامل المهمة أثناء استخدام التنبيه الكهربائي لتقوية العضلات.