Effect of Low Pulsed Magnetic Field Therapy on The Motor Neuron Excitability in Normal Subjects

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ABSTRACT

Background: Pulsed magnetic field therapy has the ability to modulate neuropathic pain. Objective: The aim of our work is to investigate the effect of the low pulsed magnetic field therapy (LPMFT) on the motor neuron excitability in normal subjects. Methods: Thirty volunteer male subjects were studied; assigned randomly into two groups; a study group (20 subjects) and a control group (10 subjects). The study group received LPMFT with a frequency of 10Hz and an intensity of 60 G for 30 min at the posterior aspect of the right calf muscle. The H reflex latency, amplitude, H/M ratio and intensity threshold were measured within 30 minutes before and after application of the therapy and 30 minutes after. Results: A statistically significant decrease in H intensity threshold in the study group was noticed (P< 0. 0001). Conclusion: Low pulsed magnetic field with a frequency of 10 Hz and an intensity of 60 G can increase the motor neuron excitability, providing us with an effective modality that could be used for the treatment of many neurological disorders. (Egypt J Neurol Psychiat Neurosurg. 2010; 47(1): 131-136)

Key Words: LPMF, motor neuron excitability, pain.

INTRODUCTION

Transcranial electrical and electromagnetic stimulation methods of the human brain are now widely used in research and in clinical practice to evoke motor responses. It had been proved to be an effective tool to modify the excitability of the cerebral cortex and affect spinal segmental excitability by changing the descending cortico-spinal projections.

The theory behind the use of magnetic fields to increase the blood flow stems from a physics principle known as the "hall effect". It implies that an electromotive force can cause charged particles to accumulate towards each other like poles creating a magnetic field. This magnetic field induces a voltage against concentration gradient and is known as the Hall voltage. The movement of these particles is resisted because the particles are forced to accumulate against their normal direction of flow. This migration against resistance may cause production of heat that in turn would result in blood vessel dilation. Because substantial evidence exists that pulsed electromagnetic fields (PEMF) safely induce small electrical eddy currents within the body that can depolarize, repolarize and hyperpolarize neurons, it was hypothesized that these electrical currents could potentially influence neuropathic pain scores.

It was also postulated that this energy can inhibit transmission of the action potentials or block the propagation of nerve impulses so they can prevent sensory conduction. Magnetic field (MF) is in principle, capable of inducing selective changes in the microenvironment around and within the cell, as well as the cell membrane, and it might be a practical method for inducing modifications in the cellular activity.

Any change in the electrochemical microenvironment of the cell can cause modifications in the structure of its electrified surface regions by changing the concentration of a specifically bound ion or dipole that may be accompanied by alterations in the conformation of molecular entities (such as lipids, proteins, and enzymes) in the membrane structure. Therefore, even small alterations in transmembrane voltage could trigger a significant modulation of the cell function.

The H-reflex is a valuable tool to evaluate the neurologic function in various populations. It is an estimate of the alpha motor neuron excitability when presynaptic inhibition and intrinsic excitability of the motoneuron remain constant. The H reflex amplitude provides an indication of the number of nerve fibers activated by electrical stimulation, while The H reflex latency is the time interval between the onset of a stimulus and the onset of a response. In addition, the H reflex intensity threshold is the stimulation strength sufficient to evoke a maximum response size.
SUBJECTS AND METHODS

Subjects:
This study included thirty male volunteers, ages ranged from 18 to 27 years old with a mean age of (21.66±1.87) years, height ranged from 160 to 185 cm with a mean value of (174.53±6.74) cm and weight ranged from 55 to 98 kg with a mean value of (70.52±11.32) kg. All should have no history of neurological, orthopedic, urinary, cardiovascular or psychological problems that may affect the motor neuron excitability, be non-smokers, avoid heavy physical activities 12 hours before the study, refrain from drinking or eating any substance containing caffeine, with no history of taking any tranquilizers or analgesics that may influence the motor neuron excitability. They were randomly assigned into two groups; study and control groups; Study group: included 20 normal subjects received (LPMFT) with a frequency of 10 Hz and an intensity magnitude of 60 G for 30 minutes. It was applied on the posterior aspect of the right leg. The H-reflex amplitude, H/M ratio, H-reflex latency, and H-reflex intensity threshold were measured 3 times; before, immediately after application and after 30 minutes of application. Control group: included 10 normal subjects used as a guide for variations of the H reflex excitability, they were examined for H-reflex amplitude, H/M ratio, H-reflex latency, and H-reflex intensity threshold measured twice within 30 minutes.

Methods:
I. Computerized four channel EMG: Tonnies neuroscreen plus 1.59 was used to record the H-reflex amplitude, latency and H/M ratio. The H-reflex was elicited by stimulation of the posterior tibial nerve at the popliteal fossa using 1.0 ms pulse duration; square wave was applied with a stimulus frequency one every 2 sec, and a wide range of stimulus intensities were applied starting from that needed to obtain the threshold value of the H or the M to the highest value required for a maximum M value (M_max). This range of stimulus intensity also provided the maximum value of the H reflex (H_max), the normalized value of H/M_max was computed for each subject. Measurement of the H-reflex latency was carried from the stimulus onset to the first deflection from the baseline.

II. Low Pulsed Magnetic Field Therapy: MTS 20 manufactured by VIDA ELETTRONICA according to the standards of national and international safety (CEI65-CEI 62.24) was used. MTS 20 is a compact electro medical apparatus, portable with a good design realized inside a suitcase, conceived for electro stimulation, ionophoresis, TENS, magnetotherapy, ultrasounds therapy and laser therapy. In our study, the MTS 20 device was used to deliver the magnetic field with a frequency of 10 Hz, intensity 60 G and applied for a duration of 30 minutes. To check the validity of the magnetotherapy apparatus, the machine was calibrated at the Faculty of Science, Cairo University using Flux meter type T2B HEME AC He Me.

Statistical Analysis:
The statistical analysis was done using an IBM compatible computer. Data were included in a database and analyzed by means of Microsoft Office Excel XP Windows. Descriptive statistics were presented as means ± standard deviations and number percentage. Analytical tests used included unpaired student t test (two sided) for comparing means of two groups and Chi-square test: for qualitative data. The significance level was P<0.05 and P<0.001 was considered highly significant.

RESULTS
A decrease in the mean value of the H reflex amplitude immediately after application of the LPMF and remained at the same level after 30 min (P=0.4) was noticed but was statistically insignificant. Also, there was no statistically significant difference in the H/M ratio between the pre and post pulsed magnetic therapy (P=0.7) (Table 1).

No significant changes were also obtained in H reflex amplitude and in the H/M ratio among the control group (Table 2).

There was no statistically significant difference in the H reflex amplitude or H/M ratio between both groups in the pre- test value (P= 0.2) or in the post -test values (P=0.6) (Table 3).

No statistically significant difference was found between the mean value of the H-reflex latency pre- and post-application of the LPMFT either immediately after or after 30 min of application (P=0.1) (Table 4).

On the other hand, a high statistically significant decrease in the mean value of the H-reflex intensity threshold was noticed in the present study between before the application of LPMFT and immediately after application and it was maintained at this intensity for 30 min (P= 0.0001) (Table 5).
Table 1. The effect of LPMFT on the H reflex amplitude and H/M ratio in the study group.

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>After 30 min</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>After 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>H amplitude</td>
<td>5.4±0.9</td>
<td>5.1±0.8</td>
<td>4.7±0.7</td>
<td>26.8±3.8</td>
<td>25.7±3.6</td>
<td>24.6±3.5</td>
</tr>
<tr>
<td>H/M ratio</td>
<td>F 0.84</td>
<td></td>
<td></td>
<td>P 0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of change</td>
<td>-4.7% (I.M. after)</td>
<td>-12.4% (after 30 min)</td>
<td>-4.3% (I.M. after)</td>
<td>-8.3% (after 30 min)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X: mean SEM: standard error of mean F: ANOVA P: Probability IM: immediately

Table 2. Evaluation of H- reflex amplitude and H/M ratio in the control group.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st time</th>
<th>2nd time</th>
<th>MD</th>
<th>% of Change</th>
<th>t-value</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>H amplitude</td>
<td>3.5±0.7</td>
<td>5.3±1.0</td>
<td>-1.7</td>
<td>49.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>H/M ratio</td>
<td>23.9±3.0</td>
<td>35.9±6.</td>
<td>11.9</td>
<td>49.8</td>
<td>-1.7</td>
<td>0.1</td>
</tr>
</tbody>
</table>

X: mean SEM: Standard error of mean MD: Mean Difference t value: Paired t value P: Probability

Table 3. Comparison of H reflex amplitude and H/M ratio in both groups.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Study Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>H amplitude</td>
<td>5.4±0.9</td>
<td>3.5±0.7</td>
</tr>
<tr>
<td>H/M ratio</td>
<td>26.8±3.8</td>
<td>23.9±3.03</td>
</tr>
</tbody>
</table>

T value: unpaired t value P: Probability

Table 4. Effect of the LPMF on the H reflex latency in the study group.

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>After 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>H latency</td>
<td>29.9±0.8</td>
<td>31.04±0.6039</td>
<td>31.4±0.7</td>
</tr>
<tr>
<td>F</td>
<td>2.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of change</td>
<td>(I.M. post)</td>
<td>3.55</td>
<td>(after 30 min)</td>
</tr>
</tbody>
</table>

X: Mean I.M: Immediately SEM: Standard error of mean %: Percent F: ANOVA P: Probability

Table 5. Effect of LPMFT on the H reflex intensity threshold in the study group.

<table>
<thead>
<tr>
<th>Items</th>
<th>Pre test</th>
<th>Post test</th>
<th>After 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>H- threshold intensity</td>
<td>21.3±2.3</td>
<td>15.8±1.6</td>
<td>15.8±1.6</td>
</tr>
<tr>
<td>F</td>
<td>11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of change</td>
<td>-25.56% (IM)</td>
<td>-25.82% (after 30 min)</td>
<td></td>
</tr>
</tbody>
</table>

X: Mean *: Significance SEM: Standard error of mean I.M: Immediately P: Probability F: ANOVA %: Percent
DISCUSSION

Low pulsed magnetic field (LPMF) is a very effective biophysical modality used for therapeutic purposes as well as in the area of diagnosis.9

Researchers investigated the effect of different frequencies of the LPMF and reported conflicting results concerning the effect of each frequency. Krause and Straube10 stated that the effect of applied low pulsed magnetic field at different frequencies 20, 15, and 10 Hz on patients with increased muscle tone was frequency independent as there was no difference between the three frequencies and found a significant decrease in the muscle tone compared to the control one. While in 2003, Pawluk11 concluded that application of LPMFs with frequency ranging from 5 to 25 Hz causing the membrane to be lowered to a hyperpolarized level of -90 mV resulted in sensory block.

Our findings indicate that the LPMF at 10 Hz with intensity of 60 G could produce no statistically significant changes in the H-reflex amplitude, H/M ratio or in the H-reflex latency. These could be explained by the fact that LPMF did not result in changes in the cell membrane potentials or the transmembrane current flow and the magnetic field could affect the component processes equally and oppositely resulting in the appearance of no effect.12

On the other hand, other studies have revealed that LPMF at 10 Hz had an effect on the motor neuron excitability and this was attributed to an increase in the chemical neurotransmitter and a decrease of the pre-synaptic inhibition of 1a fibers.13

In our study, the H-reflex amplitude was insignificantly decreased immediately after the application of the LPMF while it has no effect on the H/M ratio, that may be attributed to the weak effect of the low pulsed magnetic fields which was not enough to support the changes in the cell membrane to enhance the excitability and were not enough to produce the firing of the action potentials or change the resting membrane potentials.

The exposure to the low pulsed magnetic field can cause reversible blockade of the action potential firing (block firing of sodium-dependent action potentials of sensory neurons) and also reduction of responses to the pain and magnetic field has the ability to induce conformational changes in the ion channels and/or neuronal membrane and these multiple mechanisms must be acting simultaneously.14

Healthy subjects may be fundamentally different from people with neuromuscular diseases concerning how they are influenced by the LPMFT. This can be due to the instability of the cell membrane that may occur in pathological conditions that will lead to the lowest amount of stimulation needed to produce depolarization and firing of the action potentials.

In comparing the H reflex amplitude and H/M ratio between groups, we found that there was no statistically significant difference between them (P=0.6) which seemed to be due to the competence of the LPMF to produce sufficient effect on the cations flow to fire and evoke an action potential, therefore the H-reflex amplitude was not changed significantly.

As regards to the effect of the LPMFT on the H reflex latency, there was no statistically significant changes in the H-reflex latency (P=0.1) immediately after the application of the LPMFT or after 30 min of the application, that might be attributed to the local effect of the LPMF that was inadequate to affect the H reflex pathway.

These findings are in agreement with Hong et al.15 results, who reported that there was no change in the distal latencies or amplitude of the compound muscle action potentials (CMAP) after application of the magnetic field.

In the present study we found a highly statistically significant decrease in the H-reflex intensity threshold in the study group (P<0.0001). This reduction occurred immediately after exposure and lasted for 30 min after application of the LPMFT and this could be interpreted as an increase in the excitability of the motor neuron in the study group. Also, this might be due to an increase in the resting membrane potential of the cell membrane, moreover, the induced current of the LPMF increased the threshold level of the cell membrane.

Our finding was supported by the statement of most researchers16,17, who had proposed that exposure to time varying magnetic field induces electric current in the tissue that affect the resting membrane potentials, increasing its depolarization level which enhances impulses propagation.

Also, Rosen et al.18 assumed that the magnetic field acts on the phospholipids or other constituents of the nerve membrane and make some of the molecules rotate to the direction of maximal susceptibility because of the magnetic anisotropic nature, and this in turn induces change in the membrane properties, rather than a direct effect on the action potentials.

The results of our study can be used in studies of people with central nervous system (CNS) pathology and also provide physiotherapists with an effective modality in decreasing αMN excitability.

REFERENCES


الملخص العربي

تم إجراء هذا البحث لدراسة تأثير التيار المغناطيسي المتردد المنخفض على استجابة الخلية العصبية الحركية للأطفال الأصقان، وذلك من خلال قياس رد فعل هوفمان. معدل تغبيب المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد الفعل وكذلك شدة التيار. وقد أجريت هذه الدراسة في كلية العلاج الطبيعي جامعة القاهرة في مدينة شرم الشيخ من ديسمبر 2005 حتى مارس 2006.

وقد تم إجراء هذا البحث على ثلاثين شخصاً ذكوراً طبيعيين وخاريين من الأمراض العصبية والتي تراوح أعمارهم ما بين (18-27) بتموز (55±11.86955) و(65±21.66) و(75±20.525) وتوزيع ما بين (168-183) بتموز (6.53±21.7429) وقد تم تقسيم عشوائياً إلى مجموعتين. المجموعة التجريبية تحتوي على 20 شخصية وضع المجال المغناطيسي على سطح الرأس المريض بتردد 10 هرتز وشدته 60 جوز لدمع 30 دقيقة وضع قراءة على متر 30 لفعله. معدل تغبير المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد الفعل وكذلك شدة التيار قبل التطبيق، بعد التطبيق مباشرة وبعد ثلاثين دقيقة بعد التطبيق المجموعة الضابطة تحتوي على عشرة أشخاص وضع قراءة على متر 30 لفعله. معدل تغبير المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد الفعل وكذلك شدة التيار قبل وبعد ثلاثين دقيقة فقط. خروج النتائج إحصائياً باستخدام الإحصاء التربيع التحلي الدلي الاعتدال نظري لافتراض الفرق في كل مجموعتين عند كل الفئات وبين المجموعتين خلال كل وقت محدد للزمن عند مستوى تأثير 0.05.

نتيجة من هذه الدراسة:

1. يوجد فرق ذات دالة إحصائية على شدة التيار لحوممان بعد التطبيق وعلى مدى ثلاثين دقيقة بعد التطبيق حيث مستوى 0.01.
2. لملعى تغبير ذات دالة إحصائية على رد فعل العضلة. معدل تغبير المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد المغناطيسية العلاجية.
3. لملعى تغبير ذات دالة إحصائية على رد فعل العضلة. معدل تغبير المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد المغناطيسية العلاجية.
4. لملعى تغبير ذات دالة إحصائية بين تطبيق التيار المغناطيسي المنخفض المتردد على رد فعل هوفمان. معدل تغبير المدى لحوممان بالسعة لملعى تغبي رد فعل العضلة. كمون رد المغناطيسية العلاجية. المجموعة الضابطة.

الخصائص التي يمكن استنتاجها من الدراسة:

1. استخدام التيار المغناطيسي المنخفض المتردد يمكن أن يزيد من تنشيط الخلية العصبية الحركية.
2. استخدام التيار المغناطيسي المنخفض المتردد في حالات ضمور الأعصاب والعضلات.
3. استخدام التيار المغناطيسي المنخفض المتردد في أمراض الجهاز العصبي المركزي التي ينتج عنها ضعف في العضلات الطرفية.