# Extremely Low Frequency Magnetic Field Effects on Nerve Conduction Velocity, Depolarization Amplitude and Latency on Nerve Action Potential

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*Abstract:* - The aim of this study was to investigate the effects of extremely low frequency (ELF) magnetic field on nerve conduction velocity, depolarization amplitude and latency. The nerve was exposed to extremely low frequency magnetic field by utilizing a special Helmholtz applicator. The experiments were carried out on a group of healthy volunteers. The group consisted of 20 persons, aged 30–52 years, 10 male and 10 female. This study two main states were conducted; pre-exposure group and post-exposure group. 4-channel NCS/EMG/EPS digital electromyography was used for the recording on latencies, depolarization amplitude and nerve conduction velocity from pre-exposure and post exposure group. The values of distal and proximal responses from median nerve were obtained as procedure. In this study demonstrated that affect power frequency with 50 Hz-1 mT magnetic field on human median nerve. 50 Hz-1 mT magnetic field should not be recognized as safe for conduction mechanism on a nerve.

*Key-Words:* Magnetic Field, Nerve Conduction Parameters, Median Nerve, Possible Effect

## 1 Introduction

The presence of electromagnetic fields (EMF) in our environment is a fact but biological effects of EMF are still poorly understood. During recent years, there has been increasing scientific evidence for biological effects of EMF and public concern on potential health risks of EMF [1].

Large public and occupational populations are exposed to two types of EMF: the extremely low frequency magnetic fields (ELF-MF), generally produced by electrical and electronic appliances and power lines, and radio frequency magnetic fields (RF-MF) produced by wireless devices such as cell phones and cordless phones, cellular antennas and towers, and broadcast transmission towers.

At present the mechanisms by which 50 Hz ELF magnetic fields interact at the cellular level is poorly documented.

Studies have shown that magnetic field exposure (in the order of mT to T depending on the distance between the devices and biological tissue) might induce harmful biological effects [2, 3]. For example, the blood count in mice, the mortality and viability in Drosophila; and the fertilization of trout eggs have been reported to be affected by magnetic field exposure [4, 5]. In humans, physiological effects on bone, the connective tissue, immune system, nervous system and the endocrine system due to magnetic field exposure have been widely reported [6, 7, 8]. Unfortunately, most of these reports on the effects of magnetic field on biological systems were phenomenological described and not always verifiable.

Interestingly, most of the verifiable reactions to magnetic field exposure in animals are mediated primarily by the nervous system [9]. Additionally, evidence from the studies of magnetic field exposure have revealed several biochemical changes in nervous systems, including changes in water, oxygen, calcium and some regulatory peptides such as serotonin and histamine [10, 11, 12]. Although many studies of the biochemical effects of magnetic fields on nervous systems have been performed, only few electrophysiological studies such as in cultured neurons from adult mice and in striate cortex adult cats have been reported [13, 14, 15]. Since the electrophysiological properties of the neuron are the functional basis of behavior in all animals, any changes in the electrophysiology of the nervous system by magnetic field exposure need to be explored.

## 2 Material and Methods

**Subjects:** The experiments were carried out on a group of healthy volunteers. The group consisted of 20 persons, aged 30–52 years, 10 male and 10 female. The experiments were conducted with the understanding and the written consent of each participant. The right nervus medianus motor nerve fibers were under the study. Measurements were carried out with every subject. Temperature of the arm was kept above 28 ± 2°C for excluding temperature effect on conduction velocity [16].

All of the subjects met the following criteria:

1. No present or past major illness.
2. No history of surgery in the area to be irradiated
3. No metal in the forearm and hand to be irradiated
4. No abnormality of sensation or circulation in the area to be irradiated.

**Magnetic field exposure system:** Magnetic field density between coils was set to 1 mT (mili tesla) by using to set the output voltage of 25 Volts from 50 Hz alternating current source (Philip Harris, Shenstone, UK). The magnetic field during exposure was controlled by input current to the Helmholtz coils and measuring the magnetic flux density with a magnetic field probe (Philip Harris, Shenstone, UK). Induced RMS (root mean square) voltage across the output leads of probe was monitored by using digital voltmeter (Chauvin Arnoux Max 3000 TRMS, Paris, France). A field of 1 mT as calculated from voltages induced in pick up standardized coil probe, placed midfield, was generated in a pair of Helmholtz coils 10 cm in diameter, with 220 turns of 0.8 mm (mili meter) gauge copper wire each. The coils were placed parallel to the table so the magnetic field has to be vertical oriented. The coils were mounted on a plastic framework, 15 cm apart, and connected in series to a generator delivering a sine wave output current of 0.875 $A_{rms}$ at 50 Hz.

**Study design:** This study was performed at Electrophysiology laboratory of Medical Faculty in Suleyman Demirel University. In this study two main states were conducted; pre-exposure group and post-exposure group. 4-channel NCS/EMG/EPS digital electromyography (Nihon Kohden Neuropack Corporation, Tokyo, Japan) was used for the recording on latencies, depolarization amplitude and nerve conduction velocity (NCV) from pre-exposure and post exposure group. Recordings were made on a Neuropack-4 digital electromyography (Nihon Kohiden) with its tune to the 10 kHz sampling rate. The ambient temperature and relative humidity percent of the room housing this facility were maintained at 28 ± 2°C and 55% ± 5 respectively.
During the experiment the subjects were lying in a relaxed position, any physical activity was excluded. Before starting the test, all procedure was explained to the subjects to reduced anxiety and relax them mentally. For Median nerve, abductor pollicis brevis (APB) muscle was used to record compound motor action potential (CMAP). Stimulation was applied between tendons of Flexor Carpi Radialis (FCR) and Palmaris Longus (PL) muscles at the wrist for distal recording and proximal stimulation was applied in the medial aspect of the antecubital space. The whole procedure took about 20-25 minutes for Median nerve responses. The stimulus used for nerve conduction experiments was a square-wave supra-maximal pulse of constant duration (0.2 ms). A brief direct current (DC) pulse of 250 V was used.

The values of distal and proximal responses from median nerve were obtained as mentioned above. Just after this recording procedure, magnetic field source was kept as switched on for the first 5-minute exposure duration.

After this process, a new recording was performed. Figure 1 and 2 show median nerve excitation in distal and proximal areas respectively. Then, exposure process was ended. Entire process was applied to all subjects.

**Figure 1.** Distal application to the subject's arm. For shunt polarization of axial magnetic field vector to the nerve fiber, arm was placed axial position to the Helmholtz set.

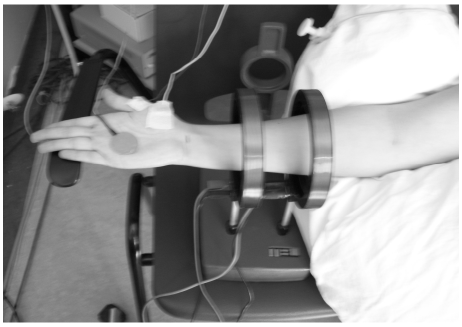

**Figure 2**. Proximal application to the subject's arm.

**Measurements of NCV and other CMAP Parameters:**

These parameters other than the phase of hyperpolarization were measured to assure that all the cases included in the study belong to axonal neuropathy. For the measurement of Motor NCV, two stimulation sites, one distal and one proximal sites were used. The latency values were directly noted from the digital facility given in the Neuropack-4 digital electromyography (Nihon Kohden Corporation, Tokyo, Japan). Following parameters were obtained from CMAP records latencies, depolarization amplitude and nerve conduction velocity.

**Data Analyses:**

Differences between means were evaluated by one-way analysis of variance (ANOVA). Statistical significance of the differences between means was assessed by Student's t test. The level of significance was set at $p<0.05$. All computations for the statistical analysis have been carried out in SPSS program (SPSS Inc., Illinois, USA). All values are given as mean ± standard deviation (SD).

## 3 Results

**Latencies:**

**TABLE 1:** Comparison of latencies obtained from CMAP records of pre-exposure group and post-exposure group. The stimulation was done at both the distal and proximal sites of median nerve.

| Stimulation Site | Latency (ms) | |
|---|---|---|
| | Pre-exposure | Post-exposure |
| Distal | 2,78±0,362 | 2,82±0,369 |
| Proximal | 3,01±0,274 | 3,16±0,087 |

All values are given as mean ± standard deviation (SD).

Latencies of median nerve recorded at abductor pollicis brevis of post-exposure group were greater than pre-exposure group. The difference was found to be significant statistically ($p<0.05$) in both distal and proximal recordings, respectively as shown in (Table 1).

**Depolarization Amplitude:**

**TABLE 2:** Comparison of depolarization amplitude obtained from CMAP of pre-exposure group and post-exposure group. The stimulation was done at both the distal and proximal sites of median nerve.

| Stimulation Site | Depolarization Amplitude (mV) | |
|---|---|---|
| | Pre-exposure | Post-exposure |
| Distal | 11,45±5,554 | 10,4±4,830 |
| Proximal | 10,48±4,779 | 10,18±4,689 |

All values are given as mean ± standard deviation (SD).

Depolarization amplitude of CMAP was markedly decreased in post-exposure group. The difference was highly significant ($p<0.05$) in both distal and proximal recordings, respectively as shown in (Table 2).

**Nerve Conduction Velocity:**

**TABLE 3:** Comparison of nerve conduction velocity obtained from median nerve between pre-exposure group and post-exposure group

| Stimulation Site | Nerve Conduction Velocity (m/sn) | |
|---|---|---|
| | Pre-exposure | Post-exposure |
| Median | 59,32±2,476 | 58,8±3,102 |

All values are given as mean ± standard deviation (SD).

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Nerve conduction velocity slows down in post-exposure group as compare to the pre-exposure group. The difference was also found to be significant statistically ($p<0.05$), in median nerve as shown (Table 3).

## 4 Results and Discussion

The effects of magnetic fields on tissues have been examined for over a century, and various claims have been made [17]. For many years, magnetic fields have been associated with therapeutic effects and have been used as a noninvasive means of aiding repair of soft and hard tissue [18]. On the other hand, claims of harmful effects arising from both the fluctuating magnetic field of power lines and electronic equipment have also been reported [19, 20]. Despite the uncertainty of biological effect, electromagnetic energy is increasingly present in a variety of forms that we encounter every day. Therefore, it is necessary to understand the influence of magnetic energy on human median nerve.

In the present study latencies of median nerve recorded at abductor pollicis brevis of post-exposure group was greater than pre-exposure group and this increase was found to be highly significant ($p<0.05$) in both median nerve and both the distal and proximal stimulation sites (Table 1). The increase in latency would be related to increase in sodium current, increase of threshold voltage. Possible increasing of the rest potential, caused by magnetic field, causes increasing in sodium current as well as in threshold potential. The changes in current and potential have approximately the same sensitivity to the changes in the rest potential. Therefore, the possible effect of magnetic field on the rest potential is not obligatory followed by changes in latency.

The depolarization amplitude has been found to decreased markedly in post-exposure group than pre-exposure group and this decrease was found to be highly significant ($p<0.05$) in both median nerve and both the distal and proximal stimulation sites (Table 2). This significant reduction in the depolarization amplitude in median nerve indicate lesser refractoriness in nerve and thus probably reduced the threshold level. Although such reduction of threshold level should increase the nerve conduction velocity (Table 3). But, in the present study nerve conduction velocity has been found to reduce significantly in post-exposure group and this decrease was found to be highly significant ($p<0.05$) in median nerve. In our opinion, the reduction in the depolarization amplitude was due to compensatory membrane phenomenon to reduce threshold level towards normal. However, the axonal loss was extreme which dominated over the compensation and thus nerve conduction velocity reduced significantly. It had been reported earlier that the nerve fiber membrane become more excitable after denervation, while in the present study, decreased nerve conduction velocity is actually associated with pure axonal pathology. In addition, another possibility of reduction in nerve conduction velocity may be the gross reduction in internodal distances due to regeneration phase of axonal neuropathy. However, we expect that instead of this regenerative reduction in internodal distance, large fiber were lost with preservation of smaller one in the post-exposure group.

## 5 Conclusion

In conclusion, results of the study demonstrated that effect power frequency with 50 Hz-1 mT magnetic field on nerve conduction parameters. Near whole-body exposures to gradient magnetic field, as are produced by power lines and large electrical equipment places, can affect latency, depolarization amplitude and nerve conduction velocity. The results of this study may be useful for some nerve rehabilitation, excitation, and stimulation in more effective/safe physical therapy. Additionally, 50 Hz-1 mT sinusoidal magnetic field should not be recognized as safe for conduction mechanism on a nerve. These mechanisms would be cleared by new advanced engineering models in other future works.

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