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Effect of Electromagnetic Waves Emitted from Mobile Phone on Nerve Conduction Velocity in Ulnar Nerve in Adult Males

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Abstract—*Extensive use of wireless mobile phone (MP), which emits the electromagnetic radiation in microwave range, may be harmful to human health. The changes in the membrane permeability or myelin sheath caused by microwave, may affect the nerve conduction velocity. So, study is aimed to investigate the acute effect of electromagnetic waves (EMW) emitted from MP on nerve conduction velocity in ulnar nerve in adult males, in the upper limb used to hold the MP before and after exposure to MP. Nerve conduction velocity (NCV) was recorded on RMS EMG EP MK 2 machine in resting condition. Then subject was exposed to EMW emitted from MP for 10 min. During that time examiner was reading a fixed text from newspaper into one MP, which the subject was hearing through another MP (GSM type, SAMSUNG model). The statistical analysis was done using paired "t"test. There was statistically significant decrease (p<0.01) in CV in ulnar nerve in the upper limb used to hold the MP. So, it is concluded EMW emitted from mobile phone affects the conduction velocity in ulnar Nerve in the limb used to hold the MP.*

Keywords*: Electromagnetic Waves, Mobile phone, Ulnar nerve, Conduction velocity*

1. INTRODUCTION

Wireless communication devices i.e., mobile phone is extensively used in recent years. This technology uses the electromagnetic radiation in microwave range, which is responsible for "Electro-pollution" of the environment, so it becomes the matter of public health concern. It is demonstrated that electromagnetic waves (EMW) emitted from mobile phone (MP) interferes with brain's signal processing activity due to their oscillatory similitude to the inherent rhythm of the brain [1]. Thus these EMW could affect functions of central nervous system (CNS) .i.e., difficulty in concentration, fatigue, headache [2], changes in auditory and visual evoked potential [3-4], electroencephalogram (EEG), and cognitive functions [5].

Information processing and transmission in nervous system is based on (bio) electromagnetic phenomena. But there is scarcity of literature showing effect of EMW emitted from MP on peripheral nervous system (PNS). Impulse transmission by nerve propagating through nerve axons and synapses is based on complex electro-chemical processes. In comparison with functions of CNS, the process of nerve pulse propagation in axon can easily be measured and discriminated [6].

So, it was planned to study the acute effect of electromagnetic waves emitted from mobile phone on nerve conduction velocity (NCV) in ulnar nerve in the upper limb used to hold the MP before and after exposure to mobile phone.

2. MATERIAL AND METHODS

The present study was carried out in thirty healthy male subjects in the age group 18-40 years. Conduction velocity (CV) in ulnar nerve was measured in MP users, who were using the MP for at least thirty minutes / day for the last 5 or more years. Exclusion criteria included any metabolic disease, diabetes mellitus, hypertension, symptoms of abnormal sensation or numbness, history of fracture in upper limb, peripheral nerve injury, radiculopathy, cervical spondylosis and history of drug administration for the past one month.

Procedure was explained to the subjects and allowed to relax to allay the anxiety and written consents were taken. The basic parameters were recorded prior to the procedure. Conduction velocity of ulnar nerve of the upper limb, used to hold the MP, was recorded in resting conditions before exposure to the MP. Most of the persons were using the MP Nokia (9), Samsung (7) and other MP i.e., Micromax, Motorola etc. Twenty persons were using the MP for >40 min / day and seventeen subjects using it more >9 years. The study was approved by Ethical Committee.

Exposure to mobile phone: The subject were exposed to electromagnetic waves emitted from MP (mobile phone was of GSM type, Samsung model E2232) for a period of ten minutes (average duration of common phone call). During that time examiner was reading a fixed text from newspaper into one MP, which the subject was hearing through another MP (GSM type, SAMSUNG model) [4]. NCV was again recorded after the exposure in the upper limb used to hold the MP.

Nerve conduction study: Nerve conduction study of ulnar nerve was performed on RMS EMG EP MK2 machine.

Motor nerve conduction study: settings were: sensitivity 2-5 mV/ mm, low frequency filter 2-5 Hz, high frequency filter 10 KHz, sweep speed 2-5 ms / mm. Active electrode was placed over the mid portion of abductor digiti minimi & reference electrode was placed over the proximal phalanx of the little finger. Ground electrode was placed over the dorsum of the hand. The site of stimulation was at the palmer aspect of wrist just medial or lateral to the flexor carpi ulnaris tendon and slightly above the ulnar groove at the elbow [7].

Sensory nerve conduction study: Settings were: sensitivity 10-20 µV/ mm, low frequency filter 5-10 Hz, high frequency filter 2-3 KHz, sweep speed 1-2 ms/mm. For ulnar sensory nerve conduction study active electrode was placed at proximal inter phalangeal joint of 5^{nd} digit. Reference electrode was placed at the distal phalanx of 5^{th} digit. Ground electrode was placed over the dorsum of the hand. The site of stimulation was at the wrist either medial or lateral to the flexor carpi ulnaris tendon at the 2^{nd} distal- most crease.

Supra-maximal stimulation was used using a square pulse wave of 0.1 ms duration. Distance between two points of stimulation was measured with a tape and expressed in m / sec [7].

Parameters recorded: Motor and sensory conduction velocity of ulnar nerve were recorded from the limb used to hold the mobile phone before and after exposure to MP. Latency was measured as time interval between stimulus artifact and onset of electrical response. Amplitude was also noted. Nerve conduction velocity was calculated by dividing the latent period by nerve length. Statistical analysis was done by using paired "t" test. P value <0.05 was considered as significant.

3. RESULTS

The study group comprised of 30 healthy male subjects. The age of the subjects varies from 19-40 years (mean 26.97 ± 6.15), height varies from 160 to 180 cm (mean 166.83 ± 5.00) and weight varies from and 42 to 87 kg (mean 62.9 ± 10.01). Most of the persons were using the MP Nokia (9), Samsung (7) and others other MP i.e., Micromax, Motorola etc. Twenty persons were using the MP for >40 min / day and seventeen subjects using it more >9 years.

There was statistically significant (p <0.001) increase in latency and decrease (p <0.001) in sensory nerve conduction velocity of ulnar nerve after exposure to MP without any effect on amplitude (Table -1, Fig1).

Table 1: Comparison of Sensory Nerve Conduction velocity in Ulnar Nerve before and after exposure to Mobile Phone (Mean + SD).

Parameters	Before Exposure (Mean ± SD)	After Exposure (Mean ± SD)	P value
Latency (ms)	2.057±0.26	2.107±0.28	<0.001
Amplitude (µV)	57.67±29.82	51.3233±22.13	>0.05
Conduction velocity((m / s)	49.6773±5.15	48.692±5.21	<0.001

P value <0.001 = highly significant.

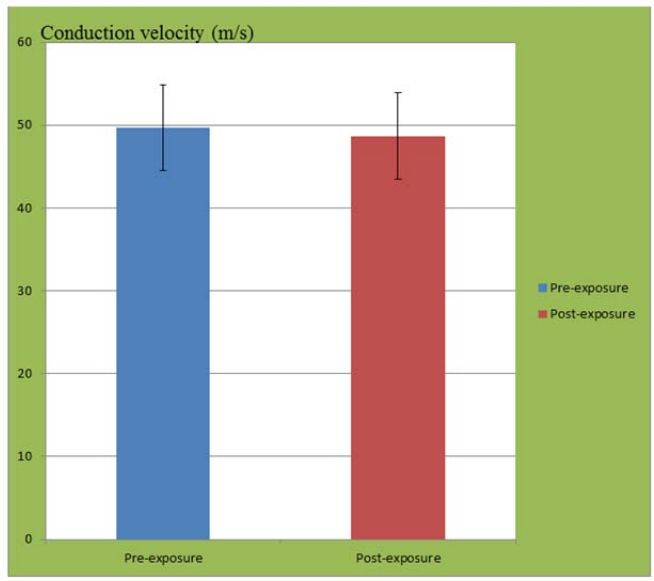

Fig. 1: Comparison of conduction velocity of Sensory Nerve fibers in Ulnar Nerve before and after exposure to MP (mean ± SD)

Motor conduction velocity of ulnar nerve was similarly affected. Latent period was increased (p< 0.001) and motor nerve conduction velocity of ulnar nerve was decreased (p < 0.001) significantly without any alteration in amplitude (Table -2, Fig2). Although amplitude was not affected statistically significantly, but it was reduced in sensory nerve conduction and increased in motor nerve conduction recording.

Table 2: Comparison of Motor Nerve Conduction velocity in Ulnar Nerve before and after exposure to Mobile Phone (Mean + SD).

Parameters	Before Exposure (Mean ± SD)	After Exposure (Mean ± SD)	P value
Latency (ms)	4.3813±0.46	4.489±0.45	<0.001
Amplitude (mV)	11.1233±2.44	11.2433±3.02	>0.05
Conduction velocity (m/s)	54.7507±4.18	53.4927±3.99	<0.001

P value <0.001 = highly significant.

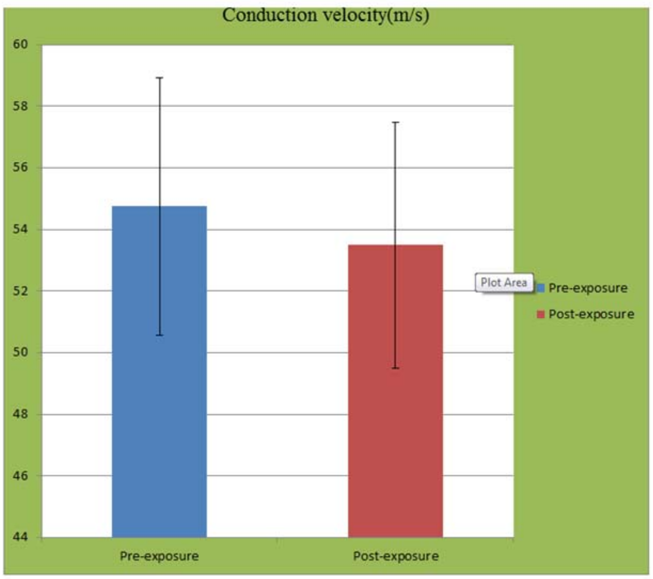

Fig. 2: Comparison of conduction velocity of motor nerve fibers in Ulnar Nerve before and after exposure to MP (mean ± SD)

4. DISCUSSION

Now a day, mobile phone has pervaded every aspect of the community. This exponential growth of mobile communications has been accompanied by a parallel increase in the level of environmental electro – pollution. Because of growing popularity of MP, children have started using it at an early age and thus have a longer life - time exposure to MP. However, its excessive use and its health effects are relatively new issues that have come forth only in the recent years.

EMW of microwave range has been reported to alter the functions of central nervous system (CNS) [8]. Short-duration (less than 1 hour) single exposure to continuous wave EMW at power densities from 20- 100 m^w /cm^2 and wave lengths of about 10 cm has potential to alter neuronal structure [9].

Less attention has been paid on effects of EMW on peripheral nervous system (PNS) and literature on effect of EMW on conduction velocity of nerves is very scanty. There is controversy in few reports that are available, as microwave radiations did not cause statistically significant change in nerve conduction velocity in human motor nerves [6]. Therefore we studied the effect of EMW emitted from MP on conduction velocity of ulnar nerve in the limb used to hold the MP.

The present study was carried out only in male subjects as it is shown that gender affects the nerve conduction velocity [10] due to differences in height [11], and in the age group 18-40 years because it is observed that this group is using the MP more compare to older age group and thus under the maximum influence of EMW emitted from MP as supported by Selvi et al [12]. CV is recorded in ulnar nerve, as no data is available showing effect of EMW emitted from MP on this nerve so far. CV in ulnar nerve was recorded in the same limb used to hold the MP, before and 10 minutes after the exposure (usual duration of call) of MP [3] because asymmetry in sensory CV in both limbs is reported by Bromberg et al [13].

Nerve conduction study is an important tool to evaluate peripheral nerve abnormality. The conduction velocity of the nerve depends on the fiber diameter, degree of myelination and inter nodal distance [10]. Onset latency is a measure of conduction in the fastest conducting fibers, the amplitude correlates with the density of nerve fibers. Electro diagnostic studies can help to determine whether the neuropathy is result of damage to the axons (axonal neuropathy) or the myelin (demyelinating neuropathy) or both (mixed). Axonal loss leads to lower amplitudes and demyelination causes prolonged latency and slow conduction velocity [14].

For many years, magnetic field have been used to aid therapeutic effects and is a noninvasive means of aiding repair of soft and hard tissue. 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 [15]. Despite the uncertainty of biological effects, electromagnetic energy is increasingly present in a variety of forms that we encounter in day to day life designated as electro- pollution [1].

There is increase in latency in sensory and motor components of ulnar nerve in the present study. This may be because of increase in sodium current and increase in threshold voltage. The increase in sodium current and threshold voltage may be because of possible increase in the rest potential. The changes in current and potential have approximately of the same sensitivity as the changes in the rest potential [15].

Decrease in conduction velocity in sensory and motor components of ulnar nerve could possibly be because of increase in rest potential through increase in sodium current and threshold voltage.

Other possible mechanisms could be that EMW can affect the axonal membrane, and it is the axonal loss which can be related to the decrease in conduction velocity [15]. The role of EMW on myelin impedance is possibly negative means EMW decreases the myelin impedance [6]. If the effect of EMW is to decrease the impedance of myelin sheath, then the effect predicted would be decrease in conduction velocity. It is reported that EMW causes chronic oxidative stress, thus increased production of reactive oxygen species (ROS) such as superoxide anion, hydroxyl radical and hydrogen peroxide resulting in increased lipid peroxidation [16]. Moustafa et al [17] showed that lipid peroxide level in healthy male volunteers was significantly increased after 1, 2, and 4 h of exposure to radiofrequency fields. Malondialdehyde (MDA) is major oxidative degradation product of membrane and biologically active with genotoxic properties [18]. Normally adequate level of cellular antioxidants, mainly superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx) and reductase maintain the free radicals scavenging action. Oxidative stress is the result of imbalance between ROS generation and intrinsic ROS scavenging activities [16].

It is seen that brain tissues are more susceptible to EM fields because MP are generally used near to brain, presence of iron-particles (magnetites) in body tissues particularly in brain enhances free radical activity (cellular damaging effect), and cells which are more metabolically active are more susceptible to EMW, because hydrogen peroxide is generated by mitochondria to fuel the reaction [19]. Singh et al (2015) studied the effect of EMW exposed from radar on plasma melatonin and serotonin levels, on 166 male military personnel. The study showed that EMW decreases the melatonin and increases serotonin concentration [20]. According to Kumar et al [16] ROS are neutralized by melatonin and decreased concentration of melatonin on exposure to EMW, reduces the protective effect of it against ROS. Increased ROS could affect the myelin sheath [21] and myelin integrity is very essential for proper functioning of nervous system. It has been suggested that EMW directly affects neurons by reducing the neuronal reactivity, increasing the neural membrane conductivity and prolonging their refractory period [22]. Other possible mechanism responsible for decrease in conduction velocity may be gross reduction in internodal distance due to regeneration phase to axonal neuropathy [15]. Also it is proposed that increase in Ca+ ions efflux, changes level of protein kinase C (PKC), histone kinase, neurotransmitter levels, altered glucose utilization, increase in micronuclei formation accelerates apoptosis or neuronal cell death thus and promotes neurodegenerative processes [23].

Contrary to our result, Hinrikus et al [6] showed that there was not significant change in nerve conduction velocity in post exposure conditions. However their result was opposite to their preliminary study where they observed relatively small (about 4%) statistically significant increase in conduction velocity following exposure to low-level microwave radiation [24]. Pakhomov et al (1997) demonstrated that there was no effect of microwave exposure on isolated nerve fiber [25].

Our findings of increase in latency period and decrease in conduction velocity are in collaboration with Coskun et al (2012) who demonstrated increase in latency period and decrease in conduction velocity in median nerve following exposure to electromagnetic field [15]. It is demonstrated that wistar rats exposed to MP showed hypo-activity on elevated plus maze [26]. Westerman in 2013 reported that EM radiation may result in dysaesthesia and can cause peripheral neuro-physiological changes in some persons [27]. In rat brain, MP exposure induced hypertrophy of glial cells [28]. It is also reported that MP radiation produces disruption of blood brain barrier integrity [29]. It is probably the first study showing acute effects of EMW on sensory and motor components of ulnar nerve in the limb used to hold MP. Our study demonstrates that conduction velocity is affected by mobile phone, so, these should be used only in emergency and should not be heard for long period of time. As long term MP radiation exposure is associated with tumor formation [23].Since effect of mobile phone on conduction velocity can be utilized for rehabilitation purposes, mechanisms affecting conduction velocity must be explored on large group of subjects on large numbers of nerves.

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