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Effect of Electromagnetic Waves Emitted from Mobile Phone on Neuropsychological Functions in Adults

K. Singh[1] and Ashita[2]

[1]MD. PGIMS, Rohtak
[2]2nd year PG.PGIMS, Rohtak
E-mail: [1]dr_rb_singh@rediffmail.com, [2]ashinain07@gmail.com

Abstract—

BACKGROUND: *With the increase in mobile phone use, the concern of possible health effects of electromagnetic waves (EMW) emitted from mobile phone (MP) on various body functions have also risen. The effect of EMW on neuropsychological functions is still unclear.*

OBJECTIVE*: Study was planned to investigate the acute effects of EMW emitted from MP on neuropsychological functions.*

MATERIAL AND METHODS*: Study was conducted on 40 subjects (20 male and 20 females) in the age group 18-40 years using MP for last 5 years or more with per day exposure of more than 1hour. Subjects with history of head trauma, neurological or ear diseases, psychiatric illness, neuroleptic medication and fracture of upper arm were excluded. Trail Making tests A and B (TMT A and B) were performed before and after 10 minutes of exposure to mobile phone (GSM 900). Paired "t test" was used for statistical analysis using SPSS 20.*

RESULTS*: The mean age of subjects was 26 ± 6.02 years. Mean per day exposure to MP was 58.23± 17.37 min. TMT A time (sec) and TMT B time (sec) ($p<0.01$), and TMT (A+B) ($p<0.001$) were reduced significantly, without any effect on indirect tests i.e., TMT B-A,TMT B:A and TMT B-A/A.*

CONCLUSION*: Neuropsychological functions are affected by EMW emitted from MP.*

Keywords*: Electromagnetic Waves, Mobile Phone, Neuropsychological functions, Trail making test.*

1. INTRODUCTION

The Trail Making Test (TMT) is widely used paper and pencil neuropsychological test for estimation of cognitive impairment [1]. It was originally derived as a part of Army Individual test battery (1944) which then became the sensitive indicator of brain damage. The TMT is part of Halstead-Reitan Battery which measures cognitive dysfunction [2]. TMT is used to test the speed of processing, sequence alteration, cognitive flexibility, visual memory, motor performance, and executive functioning. TMT consists of two parts (A and B). In TMT –A subject connects sequentially 25 encircled numbers in ascending order (i.e., 1-2-3-4, etc) distributed on a sheet of paper randomly. It measures efficiency of visual scanning and speed of psychomotor performance. In TMT –B subject alternates between numbers (1-13) and letters (A-L) when connects them (1-A-2-B-3-C, etc), thus measure executive control and retention of working memory. The amount of time required to complete the task is taken as score (direct). Indirect scores i.e., difference score (B-A) and ratio score B/A are indicators of executive control function [3]. The proportional score B-A/A is index of prefrontal cortex function [4].

Mobile Phone (MP) is indispensible part of life now a days. Electromagnetic radiation (EMR) emitted from MP is reported to cause difficulty in concentration, fatigue, headache, changes in evoked potential, and cognitive P_{300} potential [5, 6, 7]. Electromagnetic waves (EMW) emitted from MP may adversely affect the endocrines, reproduction, cardiovascular system and so on. Information processing by neurons is based on bioelectro - magnetic phenomenon [8]. Changes in electroencephalogram (EEG) are reported by use of MP [9]. Thus, it has been found that exposure to radiofrequency radiation (RFR) could affect nervous system [10]. Since outcome of studies demonstrating the effects of EMW emitted from MP on cognition and memory remains controversial. So, it was aimed to study the effect of EMW emitted from MP on neuropsychological functions in humans.

2. MATERIALS AND METHODS:

The study was conducted in the department of Physiology, PGIMS, Rohtak in 40 subjects of either sex in the age group of 20-40 years, using the MP for last five years or more with /day exposure of at least 30 min -1 hour. Healthy subjects with normal hearing and minimum of 10 grade of education

knowing English alphabets and numbers with similar cultural background were included in the study. Subjects with history of head trauma, psychiatric illness, neurological disorder, drug administration, and learning disabilities were excluded from the study.

3. PROCEDURE:

The complete procedure was explained to the subject, written consent was taken. Subjects were asked to complete TMT -A and TMT -B as quickly, accurately as possible according to the guidelines of Spreen and Strauss (1998) [11]. TMT -A and TMT-B tests, both consist of one sample test and one main task. All the participants performed both sample test and main task for TMT-A and TMT-B separately. Whenever error was made, subjects were instructed to return to the part where error was originated and continue until test was finished. Total time required to complete the task (TMT -A and TMT-B) was recorded (in sec) separately as direct score. Then indirect scores were calculated for all subjects: difference score (B-A), ratio score (B: A), and proportional score (B-A/A).

4. EXPOSURE TO MOBILE PHONE:

TMT -A and TMT-B tests were performed before and after 10 min of exposure to MP. For exposure to EMW emitted from MP, examiner was reading a fixed text from news paper into one MP (GSM type, Samsung Model GT-N 7100, SAR limit 2.0 W/Kg, average power emitted 0.125-0.25 W/cm2) monotonously, without variation in speech, and this text was heard by subject through another MP, held near to ear (according to comfortability of subject, right or left) at a distance of 1.5 cm from the body [12]. Tests were again performed after the exposure.

5. STATISTICAL ANALYSIS:

Statistical Analysis was done by paired “t”test using the SPSS version 20. Values were expressed as mean ±SD.

6. RESULT:

Study was conducted on 40 subjects (20 males and 20 females). Mean age of subjects was 26 ± 6.02 years. Duration of education of subjects 10 grades. Subjects were using the MP for the last 6 to 9 years (Mean 7.2 ± 2.2), and / day exposure varied from >30 min to 5 hours (mean 58.23 ± 17.37 min), duration of / call varies from 2-30 min (10.2 ± 3.7). There was statistically significant reduction (P<0.01) in TMT-A and TMT-B score from 39.88 ± 15.01 to 35.33 ± 16.1 sec, and from 76.98 ± 26.33 to 65.8 ± 22.46 sec respectively after exposure to MP. Total time (TMT-A+TMT-B) was also reduced significantly (P<0.001) from 116.85 ± 36.15 sec to 101.13 ± 31.86 sec before vs after EMW exposure (Table I, Fig.1). Indirect scores, i.e., difference score (B-A), ratio score B/A, the proportional score B-A/A were also decreased after exposure to EMW emitted from MP comparison to pre exposure condition, which were statistically non-significant.

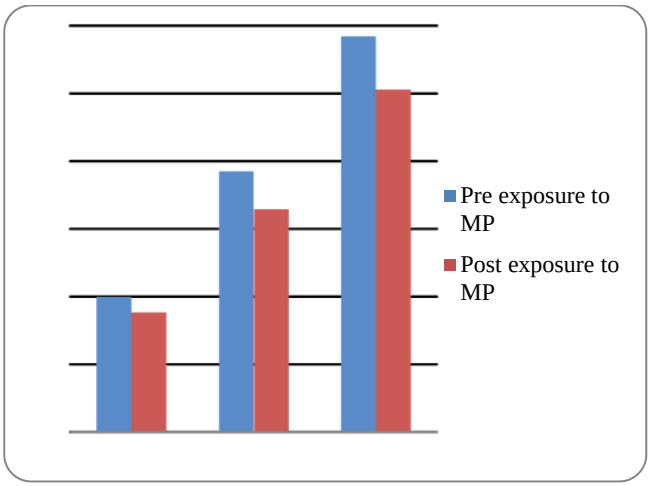

Fig. 1: Comparison of time taken for Trail Making Test (TMT) before and after exposure to electromagnetic waves (EMW) emitted from mobile phone (MP

Table 1: Comparison of time taken for Trail Making Test (TMT) before and after exposure to electromagnetic waves (EMW) emitted from mobile phone (MP). (Mean ± S.D.)

Trail Making Test	Pre exposure to MP	Post exposure to MP
TMT A (sec)	39.88 ± 15.01	35.33 ± 16.18**
TMT B (sec)	76.98 ± 26.33	65.80 ± 22.46**
TMT A+B (sec)	116.85 ± 36.15	101.13 ± 31.86***
TMT B-A (sec)	37.1 ± 23.02	30.47 ± 22.76
TMT B/A	2.08 ± .90	2.10 ± .91
TMT (B-A)/A	1.08 ± .90	1.09 ±. 91
**= p < 0.01 ***= p < 0.001		

7. DISCUSSION:

TMT -A and TMT-B were administered to evaluate neuropsychological functions before and after exposure to the EMW emitted from MP. These tests are used widely, since easily performed. They assess the frontal lobe functions along with visual working memory and ability to concentrate [2]. In our study TMT -A and TMT-B scores before exposure to MP in resting condition were 39.88 ± 15.01 sec and 76.98 ± 26.33 sec respectively, which is comparable to values described by other studies [13]. Performance is said to be impaired if scores exceeds 40 sec for TMT-A and 91 sec for TMT-B [11]. These direct scores, before exposure to EMW emitted from MP, are within normal range. These tests give information about following cognitive domains, i.e., attention, visuo - motor speed, and memory retention capacity. It is the prefrontal cortex, which regulates physiological functions by integrating the informations.

After exposure to EMW emitted from MP, direct scores (TMT -A and TMT-B) were reduced ($P<0.01$) and also total time for TMT-A +TMT-B was decreased ($P<0.001$). It is seen that there occurs faster decline in executive abilities with increasing age [14] due to reduction in volume and thickness of prefrontal cortex [15]. There are too many reports in the literature stating that time completion for TMT-A and TMT-B increases with age [16, 17]. Similarly, it is described that TMT performance is poor in patients of schizophrenia and traumatic brain injury [18]. Although effects of EMR on cognitive functions are conflicting, but there are many reports showing improved cognition after exposure to radiofrequency radiation [19]. They have stated that MP use was associated with faster and less accurate responding to higher level cognitive task. It is also found that prenatal and postnatal maternal exposures to MP were associated with behavioral problems [20]. Recently it is reported that GSM- EMFs for 45 min may enhance human cortical neural efficiency and simple cognitive motor processes in healthy adults [21]. On the other hand, Melek et al in 2015 found no statistical significant difference between exposure and sham exposure towards cognitive performance demonstrated by the computer administered Cambridge Neuropsychological Test Automated Battery (CANTAB eclipse TM) [22].Similarly it is reported that occupational exposure of the workers to radio frequency radiation in the international airport does not have any detrimental effect on visual reaction time and short term memory [23]. It is demonstrated that daily use of MP has no effect on cognitive function [24].

Our previous studies also demonstrated the increased amplitude of cognitive P_{300} evoked potential [7] and reduction in reaction time [25]. Basis of improved performance by simple cognitive task is not known, may be due to local rise of temperature [26], increased regional blood flow on the side of exposure to MP [27], interference in electrical signals of human body by electromotive forces of MP [26], or structural and functional changes in cell membrane [28]. Thus, it is concluded that EMW emitted from MP may alter neuropsychological functions and exploration is required in large number of subjects.

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