

Effect of Electromagnetic Waves Emitted from Mobile Phone on Cognitive Functions in Males and Females

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Abstract

Aims and Objectives: Use of mobile phones always raises the issue of health implications in humans. Gender differences in cognitive abilities have been reported as a neuropsychological feature for many years. So, it was planned to study the effect of electromagnetic waves (EMW) emitted from mobile phone (MP) on cognitive functions in males and females.

Material and Method: The present study was conducted in 20 males and 20 female healthy subjects in the age group of 18 to 40 years using mobile phones for the last 5 years or more with per day exposure of at least 30 minutes or more. Subjects with history of diseases of ear, eye and brain (neurological and psychological) or the presence of diabetes, hypertension and consumption of any drug were excluded.

After explaining the whole procedure and seeking a written consent, the Trail making test A (TMT A), Trail making test B (TMT B) and TMT A + TMT B, Single letter cancellation test (SLC test) and the Playing card test (PC test) were performed before and after exposure to MP. Subjects were exposed to MP GSM Type, Samsung Model GT- N 7100, 902, MHz, SAR limit 2.0W/Kg, average power emitted 0.125 - 0.25W/cm² for a period of 10 minutes. Statistical analysis was done by statistic package SPSS 20 using paired t test. A value of $p < 0.05$ was considered significant.

Results: TMT A time (sec) was reduced in both males and females, but significant reduction was seen in females (< 0.05) after exposure to MP. On the contrary, on exposure to MP TMT B time (sec) was found to be reduced significantly in males (< 0.05). But when both (TMT A + TMT B) are combined, significant reduction (< 0.05) was found in both males and females after exposure to EMW compare to pre -exposure value. On single letter cancellation test, time is decreased (< 0.05) in males, while score decreased (< 0.05) in female after MP use. Playing card test score was also found to be reduced (< 0.05) in males without any effect in female after exposure to MP.

Conclusion: The cognitive functions in males and females are affected differentially by the EMW emitted from MP.

Keywords: Mobile phone, Electro-magnetic waves, Cognitive functions, Gender.

Introduction

Since dependency on mobile phone (MP) is growing at an alarming pace due to Covid-19 pandemic

and present situation of multiple lock downs of long duration. Biological effects resulting from exposure to electromagnetic waves (EMW) emitted from MP have also been demonstrated.¹ It is reported that some aspects of cognitive function and brain physiology may be affected by exposure to EMW emitted from MP.² It is also stated that mobile radiation increases the activity of brain, can cause damage to nerves around ears and also to the blood brain barrier (BBB).³ Also wide spread use of MP is associated with mental health and psychological

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problems in young adults.⁴ It is pointed out that there are gender differences in cognitive functions i.e., males outperform females in spatial, working memory tests and mathematics whereas the females outperform males on verbal fluency, perceptual speed and fine motor skills.⁵⁻⁷ Attributes of cognitive abilities are perception, attention, memory (working and long term), motor, language, visual and spatial processing and executive functions.⁸ Cognitive functions can be assessed by battery of tests i.e., trail making, letter cancellation, playing card tests.⁹ The trail making tests (TMT) tests the speed of processing, attention, mental tracking and visual search.¹⁰ The letter cancellation test (LCT) indicates sustained attention and visual scanning accuracy.¹¹ Playing card tests (PCT) examine visual memory and learning process.¹² Therefore it was planned to study the effect of EMW emitted from mobile phone on cognitive functions in males and females.

Material and Method

The present study was conducted in 20 males and 20 female healthy subjects in the age group of 18 to 40 years using mobile phones for the last 5 years or more with per day exposure of at least 30 minutes or more. Males and females were homogenous in relation to age and educational level. All subjects were right-handed. Clearance was taken from institutional ethical committee. Subjects with history of diseases of ear, eye and brain (neurological and psychological) or the presence of diabetes, hypertension and consumption of any drug were excluded.

After explaining the whole procedure and seeking written consent, the basic parameters like height, weight, heart rate, blood pressure and respiratory rate were recorded from subjects. The TMT - A, TMT - B, SLC

test, PC test were performed before and after exposure to MP.

Exposure to mobile phone: Subjects were exposed to MP GSM Type, Samsung Model GT- N 7100, 902, MHz, SAR limit 2.0W/Kg, average power emitted 0.125 - 0.25W/cm² for 10 minutes (average duration of a common phone call). During that time examiner was reading a fixed text from a newspaper into another mobile phone, which the subject was hearing. The tests were again conducted after the exposure to EMW emitted from mobile phone.¹³ Vital parameters were also recorded after the exposure to mobile phone. Statistical analysis was done by statistic package SPSS 20 using paired t test. A value of $p < 0.05$ was considered significant.

Results

Study was carried out in 40 subjects (20 males and 20 females) in the age group of 20 to 40 years (mean 28.75±6.26 in males and 23.25±4.40 in females), having BMI 24.34±2.55 and 21.42±3.16 in males and females respectively. Subjects were using MP for the last 5-9 years; per day exposure was more than 30 minutes. Duration of per call from MP varies from 10 to 30 minutes. Although TMT A time (sec) was reduced in both males and females, but significant reduction was seen in females (< 0.05) after exposure to MP. On the contrary, on exposure to MP TMT B time (sec) was found to be reduced significantly in males (< 0.05). But when both are combined (TMT A +B), significant reduction (< 0.05) was found in both males and females after exposure to EMW. On SLC test, time is decreased (< 0.05) in males, while score decreased (< 0.05) in female after MP use. PC test score was also found to be reduced (< 0.05) in males without any effect in female after exposure to MP (Table 1).

Table 1: Shows batteries of tests for cognitive functions in males and females before and after exposure to mobile phone

Variables	Males		Females	
	Before exposure	After exposure	Before exposure	After exposure
TMT-A (sec)	39.20±15.07	34.90±17.93	40.55±15.32	35.75±14.69*
TMT-B (sec)	81.95±30.94	66.30±27.93*	72.00 ±20.34	65.30±15.98
TMT-A+B (sec)	121.15±38.97	101.2±38.77*	112.55±33.55	101.05±24.11*
SLC Test (sec)	21.35±7.37	18.21±6.87*	19.84±5.37	18.38±6.70
SLC Test score (out of 10)	9.30± 1.42	9.20±1.32	9.85±0.49	9.10±0.97*
PC Test score (out of 10)	7.85±2.37	6.3±2.70*	5.75±2.38	5.70 ±2.58

P value * < 0.05 significant, TMT-Trail Making Test, SLC Test -Single Letter Cancellation Test, PC Test- Playing Card Test.

Discussion

Gender differences in cognitive abilities have been reported in literature.⁷ Male and female brains show anatomical, functional, and biochemical differences throughout life. Origin of differences in male and female brain is not clear, though it is assumed that both biological and environmental factors may play the roles. Biological factors include differences in neurological structures and functions and the differences in hormones i.e., androgen in male and ovarian hormones in female. High and low level of steroid hormonal levels during prenatal developments induce morphological, anatomical and functional differences in brains of males and females and also in later life these hormones have activational effects on behavior. It is also reported that cognitive properties in females, when tested during pre-ovulatory phase (estrogen – female sex hormone, level is high) were comparable to male cognitive properties (testosterone-male sex hormone, is converted in oestrogen in many tissues including CNS). Sex differences in cognitive abilities have also been affected by environmental factors, education background and cultural idiosyncrasies.¹⁴ The differences in test scores between male and female disappears with increase in education level. Results of our study on cognitive functions have shown facilitating effect of EMW emitted from MP. Attention function is differentially enhanced after exposure to EMW emitted from MP and this transient facilitating effect may be dose dependent.¹⁵ TMT-A is more affected in female showing better efficiency of visual scanning and better psychomotor performance.¹⁰ While TMT-B is affected more in males in our study which indicates better executive control and more retention of working memory. TMT improved, supporting the hypothesis that digital mobile phone (DMP) radiofrequency emission improves the speed of processing of information in working memory.¹⁶ It is reported that time completion for TMT-A and TMT-B increases with age¹⁷ and in patients of schizophrenia and traumatic brain injury.¹⁸ In cancellation test also time is more reduced in female (<0.05), pointing females are more attentive. While males scored better. In playing card tests score, females performed better. Symthe and Costall reported sex dependent effects of EMW exposure on human memory. They demonstrated that MP facilitates memory in males and not in females.¹⁹ While Drowing et al stated that females have more command on memory and language.²⁰ Similarly it was found that out of 131 scores, girls scored 97.5 % and boys 86%

for short memory.²¹ Difference in scores on TMT-A and TMT-B may suggest that exposure to MP may have a differential impact on different human attention functions.¹⁵ Also they reported baseline EEG energy of males was greater than that of females, while exposure to EMF decreased EEG energy of males and increased that of females.²² Although effect on cognitive functions in males and females are not so obvious, but it is clear that MP do have biological effects.¹ Mechanism behind the alterations in the neuro-psychological functions is not clear. But it is suggested that EMWs increase brain activity, can cause nerve damage around ears and may damage blood brain barrier (BBB).^{3, 23} Researchers also reported that man complaints of strange feeling in his head after MP use. Localized heating effect while using the MP is also one of the suggested mechanism.²⁴ It is also reported that effect is not immediate, probably time is needed for physiological changes to take place i.e., heat shock protein production and vascular intimal hyperplasia occur when one is exposed to MP for a period of 30 minutes daily.¹⁵ It is also mentioned that MP exposure can affect cells without heating them.²⁵ It was found that female nematode worms exposed to MP radiation produced stress hormones, grew 10% larger and produced more eggs. Similarly, micro-wave radiation similar to MP radiation also makes worm more fertile.²⁶ Differences between two genders may be related to difference in information processing or existence of gender related BBB differences. According to modern plasticity research, it is interesting to mention that brain can adapt and change anatomically and functionally through practice and learning, which varies in male and female depending on situation.^{27, 28} So, it is concluded that gender differences in cognitive functions are differentially affected by EMW emitted from mobile phone.

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References

1. Abramson MJ, Benke GP, Dimitriadis C, Inyang IO, Sim M, Wolfe R S, Croft R J. Mobile telephone use is associated with changes in cognitive function in young adolescents. *Bioelectromagnetics* 2009; 30: 678- 86.

2. Papageorgiou CC, Nanou ED, Tsiafakis VG, Capsalis CN, Rabavilas AD. *Neuro-Report* 2004;15(16):2057-60.
3. AlOrainy A. Recent research on mobile phones Effects. *Electromagnetic fields and Health* 2003; Proceeding of the International Conference on Non –Ionizing Radiation at UNITEN (ICNIR 2003), 20-22 OCTOBER 2003.
4. Kumar DE, Dinesh T. Effect of short-term breathing exercise practice on cognitive function in chronic mobile phone users. *Int J Medical Science and Public Health* 2019; 8 (3): 205-8.
5. Scherwin BB. Estrogen and cognitive functioning in women. *Endocrine Reviews* 2003; 24 (2): 133-51.
6. Zaidi ZF. Gender Differences in human Brain: A Review. *The Open Anatomy Journal* 2010; 2: 37-55.
7. Hyde JS. Sex and cognition: gender and cognitive functions. *Curr Opin Neurobiol* 2016; 38: 53-6.
8. Michelon P. What is cognitive ability/. What are cognitive abilities and skills? URL: <http://www.sharpbrains.com/blog/2006/1> What are cognitive abilities/.Dec/18, 2006, Accessed on :Oct. 14, 2012.
9. Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment*. 4th edition. New York: Oxford University Press; 2004. 337-74.
10. Stuss DT, Bisschop SM, Alexander MP, Levine B, Katz D, I zukawa D. The Trail Making Test: A study in focal lesion patients. *Psychological assessment* 2001; 13: 230-39.
11. Diller L, Weinberg J. Hemi–attention in rehabilitation: the evolution of a rational remediation program. *Adv Neurol* 1977; 18: 63-82.
12. Soni S, Joshi LN, Dutta A. Effect of controlled deep breathing on psychomotor and higher mental functions in normal individuals. *Indian J PhysiolPharmacol* 2015; 59 91): 41-7.
13. Singh K, Nain A. Effect of electromagnetic waves emitted from mobile phone on higher mental functions. *Int J Basic and Applied Physiology* 2018; 7 (1): 151-4.
14. Upadhaya N, Guragain S. Comparison of cognitive functions between male and female medical students: A pilot study. *J Clin Diagn Res* 2004; 8(6): BC 12- BC 15.
15. Lee TMC, Lam Pik-Kwan, Yee LTS, Chan CCH. The effect of the duration of exposure to the electromagnetic field emitted from mobile phones on human attention. *Cognitive Neuroscience and Neuropsychology* 2003; 14(10): 1361-64.
16. Keetley V, Wood AW, Spong J, Stough C. Neuropsychological sequel of digital mobile phone exposure in humans. *Neuropsychologia* 2006; 44 (10): 1843-8.
17. Tombaugh T N. Trail Making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology* 2004; 19: 203-14.
18. Perianez JA, Rios-Lago M, Rodriguez-Sanchez JM, Adrover-Roig D, Sanchez-Cubillo I, Crespo-Facorro B et al. Trail Making Test in traumatic brain injury, schizophrenia, normal aging: Sample comparisons and normative data. *Archives Clinical Neuropsychology* 2007; 22: 433-47.
19. Smythe JW, Costall B. Mobile phone use facilitates memory in male, but not in female subjects. *Neuroreport* 2003; 14: 243-6.
20. Downing K, Chan S, Downing W, Kwong T, Lam T. Measuring gender differences in cognitive function. *Multicultural Education and Technology Journal* 2008; 2(1): 4-18.
21. Ashwathy VT, Koujalgi RS, Bondade SY. Effect of gender difference on short term memory. 59th Ann Conference of IJPP, APPICON 2013, 28-30 Nov 2013.p 100.
22. Chang PF, Arendt-Nielsen L, Chen AC. Dynamic changes and spatial correlation of EEG activities during cold pressure test in man. *Brain Res Bull* 2002; 57: 667-75.
23. Salford LG, Brun AE, Eberhardt JL, Malmgren L, Persson BR. Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ Health Perspect* 2003; 111: 881-3.
24. Preece AW, Iwi G, Davis –Smith. Effect of 915 MHz simulated mobile phone signal on cognitive function in man. *Int J Radiat Biol* 1999; 75: 447-56.
25. Braune S, Wrocklage C, Gailus T, Lucking CH. Resting blood pressure increase during exposure to radio frequency electromagnetic field. *Lancet* 1998; 351: 1857.

26. Hardell L ET AL. Use of cellular telephones and risk for brain tumors: a case control study. *Int J Oncology* 1999; 15: 113.
27. Jancke L. The plastic human brain. *RestorNeurosci* 229; 27(5): 521-38.
28. May A. Experience dependent structural plasticity in adult human brain. *Trends Cogn Sci* 2011; 15 (10): 475-82.