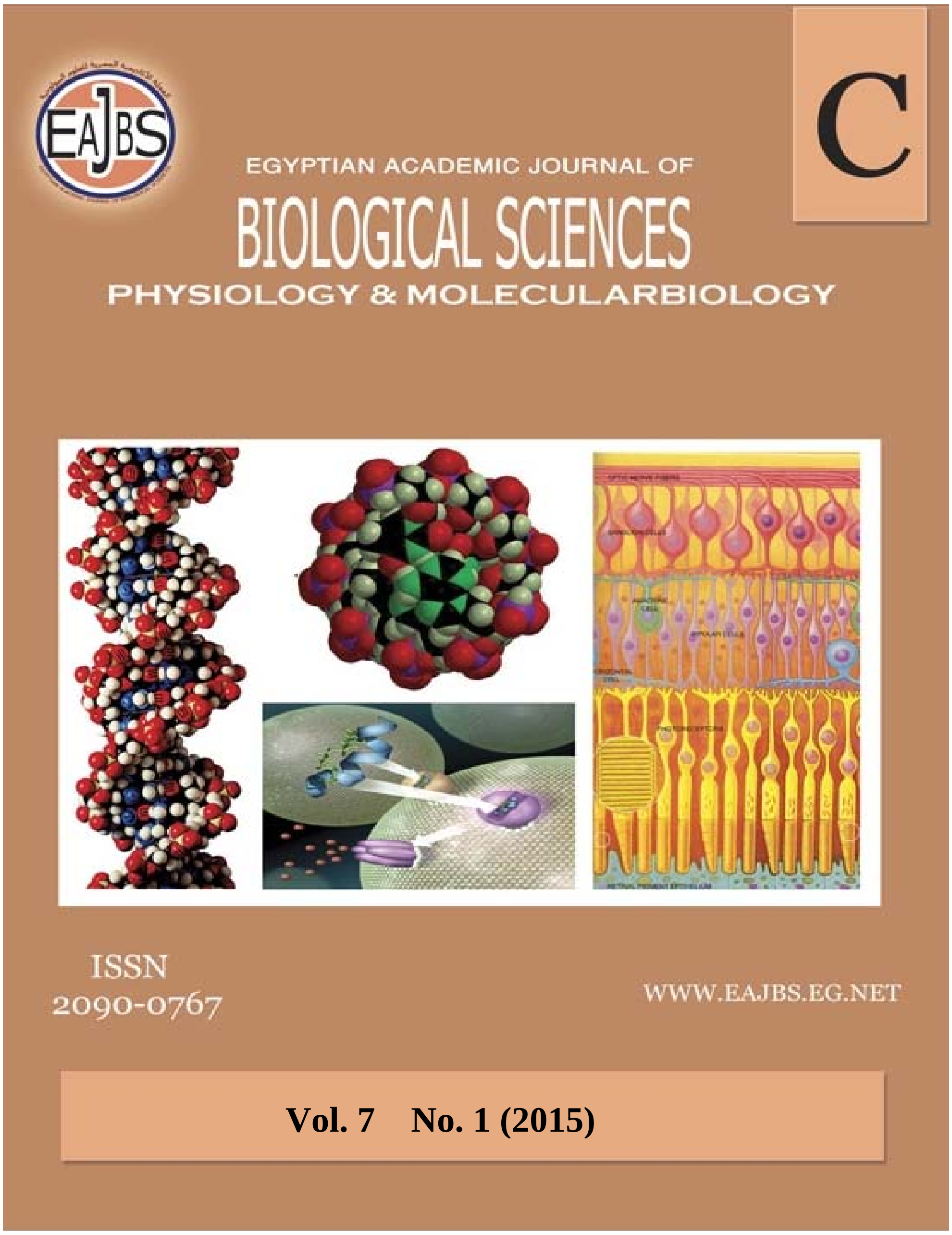

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Effect of Radiation on Heart Rate Variability Changes in Healthy Youth

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ABSTRACT

The rapid increase in the use of mobile phones (MPs) in recent years has raised the problem of health risk connected with high-frequency electromagnetic fields. There are reports of headache, dizziness, numbness in the thigh, and heaviness in the chest among MP users. This paper deals with the neurological effect of electromagnetic fields radiated from MPs, by studies on heart rate variability (HRV) of 50 male volunteers. As heart rate is modulated by the autonomic nervous system, study of HRV can be used for assessing the neurological effect. The time and frequency domain analysis of HRV were performed to assess the changes in sympathovagal balance in a group of 50 male volunteers with normal electrocardiogram (ECG) at rest. The frequency domain variables were computed using PowerLab ®acquisition system: very low frequency (VLF) power, low frequency (LF) power, high frequency (HF) power and LF/HF ratio was determined. ECG was recorded in standardized conditions: from 09:00 to 11:00 in the morning in a sitting position, within 15 min periods: before the telephone call (period I; control), during the call with use of mobile phone (period II), and after the telephone call (period III). Mobile phones (MP) are widely used especially by young people. It is possible that electromagnetic field (EMF) generated by MP may have an influence on the autonomic nervous system (ANS) and hence the heart rate variability (HRV). The aim of the study was to estimate the influence of the call with a mobile phone on HRV in young healthy people. Mean heart rate did not change significantly over 15 min period before the telephone call (period I, control), during 15 min telephone call (period II) and after the telephone call (period III) (respectively 96.62 ± 1.10; 126.80 ± 2.63; 106.21 ± 3.32). The analysis of the time domain HRV parameters for the period I, II and III showed that SDNN (Standard Deviation of Normal to Normal intervals) was significantly higher during the telephone call (period II, 214.72 ± 1.12) in comparison with period I (control, 195.49 ± 2.94) and period III (194.98 ± 4.77). The rest of the parameters of the time analysis did not differ significantly from each other. Frequency domain demonstrated that VLF, and HF parameters were significantly increased over the 15 minute period of the telephone call in comparison with the 15 min period before it. While LF was significantly decreased during 15 min period after the telephone calls in comparison with the time of the telephone call. LF/HF ratio was also significantly lower during the telephone call in comparison with the period before and after the telephone call. The increases in the parasympathetic tone concomitant with the decrease in the sympathetic tone, measured indirectly by analysis of heart rate variability, were observed during the mobile telephone call. HRV analysis may be used as a tool to monitor the effects of mobile phones on the cardiovascular system. Changes in heart rate variability during the call with a mobile phone could be affected by electromagnetic field, but the influence of speaking cannot be excluded.

INTRODUCTION

Heart rate is mainly controlled by autonomic nerve activity to the sinoatrial node. Sympathetic and parasympathetic drive can be non-invasively investigated using Heart Rate Variability (HRV) analysis.

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A low level of HRV associated with low vagal parasympathetic activity has been identified as a risk marker for all causes of mortality. Akselrod S. (1996) HRV can be altered by physiological factors, such as aging, gender and physical fitness. The aging process decreases HRV towards a lower parasympathetic modulation. Altamura G., *et al*., 1997 and Appel ML *et al*., 1989 Concerning gender, parasympathetic modulation of HRV seems to be generally higher in women than in men; Akselrod S, *et al* 1981 and Aubert A, *et al*., 2001 however, aging tends to attenuate this difference, the change apparently beginning at the menopause.[7] Radiofrequency (RF) electromagnetic fields (EMF) of mobile phones are widespread in the living environment. The potential health risk of electromagnetic field emitted by mobile phones is still under debate. Exposition to high-power RF energy may have negative thermal effects on eye, skin and pregnancy. Bigger J *et al*., 1992, 1995 Bortkiewicz A *et al*., 1996, 2006 and Dewhirst MW, *et al*., 2003 Such negative effects have never been demonstrated at the power levels associated with public exposure to RF energy emitted by mobile phones. In this case the produced power is too low to cause the dangerous heating but there are few reports of non-thermal effect exerted by standard Global System for Mobile Communication (GSM). Bigger J *et al.*, 1992,1995 Bortkiewicz A *et al*., 1996, 2006 and Dewhirst MW, *et al.,* 2003 Many reports suggest that electromagnetic fields emitted by cellular phones may interfere with work of cardiac pacemakers and other implantable medical devices.[15-19] There are some reports confirming so called non-thermic effect of mobile phones on humans that is not related to heat stress. Eaker ED, *et al*., 1993 and Elder JA. Ocular 2003. It was shown that occupational exposition to EMF can cause fluctuations in heart rate and heart rate variability (HRV). Foster KR. 2000 and Hillert 2006. It is possible that electromagnetic field emitted by cellular telephones may influence the autonomic tone, thus modifying the functioning of circulatory system. The aim of the present study was to determine the influence of the call with a mobile phone on HRV in healthy young male medical students with a non invasive, widely used method of autonomic function evaluation.

Materials and Methods

Subjects:

A total 50 male volunteers (21.0 ± 1.5 year) participants were included in the study. All participants were healthy and none of them were on treatment. The following exclusion criteria were accepted for the investigation: presence of any serious cardiovascular disease, including arterial hypertension, metabolic and neurological disorders that could influence heart rate variability and serious arrhythmias. All participants had used mobile phones for 3 to 6 yr prior to the study.

The mean number of telephone calls was 125 per month; mean total duration of calls was 850 min per month. The written informed consent was obtained from all students taking part in the study. The study was approved by the local ethical committee. All subjects got up between 4:30 a.m. and 7:00 a.m. and were asked to abstain from consuming caffeinated beverages and excessive physical activity including gymnastics within 10 hr preceding data collection. They were also requested not to eat and drink on the morning of the experiment. Students were fully habituated to equipment, protocols, and experimenters. Our investigation was performed in a semi-darkened, temperature-controlled quiet laboratory at room temperature (22°C). Before the experiment participants had rested in a laboratory room in a sitting posture for about 15 min. The students are advised to speak their friends and relatives only in happy mood during the experiments. Records were performed between 09:00 and 11:00 in the morning in similar conditions (the same place of the experiment and sitting position) over 15 min periods. Throughout the 15 min period of the investigation the subjects were exposed to a RF field emitted by 1,900 MHz frequency band GSM mobile phone held in the right hand. The GSM Nokia E90 model was used in all cases. Heart rate variability indices includes, (mean HR, mean R-R intervals, RMSSD and SDRR) as well as power spectral analysis (VLF, LF, HF, TP (total power), and LF/HF ratio) were obtained from short term (15 minutes) recording of ECG using PowerLab ®acquisition system.

ECG data analysis: The ECG was sampled at 1000 Hz with the PowerLab ® acquisition system (ADInstruments Pty Ltd, Castle Hill ‹Australia) installed on IBM computer. Thus the accuracy of the measurements was 1 ms. The first minute of each ECG recording was disregarded to allow for stabilization of the data prior to analysis. The detection of the QRS complex was conducted using the Gritzali's algorithm. RR interval sequence was defined by the duration between two consecutive R-peaks. These data were edited to eliminate any glitches, due to premature cardiac contraction. Each RR interval was visually validated by two experts before temporal and spectral analysis. Definitions and abbreviations for time domain analysis are shown in Table 1. For each RR sequence, three classical temporal parameters were then extracted : the mean RR, which represents mean HR; Standard deviation of RR intervals (SDRR), which reflects all the cyclic components responsible for variability in the period of recording, and RMSSD (Root mean square of successive RR intervals difference) between adjacent RR intervals, which is considered as an index of parasympathetic modulation of HR. Prior to power spectrum density estimation, the RR sequence, which is intrinsically non-evenly spaced data, was linearly interpolated in order to obtain a series of uniformly sampled data. An interpretation of frequency contents of HRV was therefore possible independently of the mean RR value.

Table 1: Definitions and abbreviations for time domain analysis of heart rate variability.

Variable	Units	Definition
SDRR	Ms	Standard deviation of normal RR intervals
MHR	Beats/min	Mean Heart rate
SNN50	Ms	The number of time that the difference between adjacent normal RR intervals greater than 50 ms, computed over the entire 24-hour recording
RMSSD	Ms	Root mean square of successive RR intervals difference: the square root of the mean of the sum of the squares of the differences between adjacent normal RR intervals over the entire 24-hour ECG recording

The retained sampling rate was then set to 2 Hz. Using a sliding window of 64s duration, time-varying auto-regressive (TVAR) modelling of the interpolated RR sequence was performed to estimate its power spectrum (ms2) in order to eliminate the slight non-stationarities of the sequence. On the basis of the well-known Akaike information criteria, the order of the TVAR model was set to 12. The spectrum is divided into three bands as the following: very low frequency (0 – 0.05 Hz), low frequency (0.05 – 0.15 Hz), high frequency (0.15 – 0.5 Hz) and total power (0 – 0.5 Hz).

Statistical analysis

The values are expressed as mean ± SD. The statistical comparisons were performed by one way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT), using SPSS version 15.0 for windows (SPSS Inc. Chicago; http://www.spss.com). The values are considered statistically significant if the p value was less than 0.05.

RESULTS

Mean heart rate did not change significantly over 15 min period before the telephone call (period I, control), during 15 min telephone call (period II) and after the telephone call (period III) (Table 2). No arrhythmias were noted in the analyzed records before, during and after the telephone call. The analysis of the time domain HRV parameters in for the period I, II and III showed that SDNN was significantly higher during the telephone call (period II; 210.72 ± 1.12) in comparison with period I (165.49 ± 2.94) and period III (174.98 ± 4.77). The rest of the parameters of the time analysis measured within the particular periods of the investigation did not differ significantly from each other (Table 2).

Table 2: Time domain heart rate variability (HRV) parameters in 15-min intervals before mobile phone call (period I), during mobile phone call (period II) and after mobile phone call (period III.

Parameters	**Period I (Control)**	**Period II**	**Period III**	*p* values
MHR	66.62 ± 1.10	96.80 ± 2.63	116.21 ± 3.32$^{\wedge}$	$p < 0.05$
SDNN	165.49 ± 2.94	210.72 ± 1.12*	174.98 ± 4.77$^{\wedge}$	$p < 0.05$
RMSSD	204.92 ± 3.05	224.81 ± 1.09*	202.54 ± 1.51**	$p < 0.05$
NN50	40.67 ± 0.30	43.54 ± 0.32*	37.48 ± 0.40**	$p < 0.05$

Values are expressed as mean SD for 25 young healthy subjects in each period. Different superscript denotes for significant differences between periods as analyzed by one-way ANOVA followed by DMRT ($p < 0.05$) The analysis of the frequency domain HRV parameters demonstrated that VLF, and HF parameters were significantly increased over the 15 minute period of the telephone call in comparison with the 15 min period before it (Table 3). LF was significantly decreased during 15 min period after the telephone calls (5265.17 ± 122.67; period II) compared with period I (6256.83 ± 65.45) and III (12578.67 ± 74.67). LF/HF ratio was also significantly lower during the telephone call in comparison with the period before and after the telephone call (Period I, 0.76 ± 0.04; period II, 0.65 ± 0.03; period III, 1.90 ± .03) (Table 3).

Table 3: Frequency domain heart rate variability (HRV) parameters in 15-min intervals before mobile phone call (period I), during mobile phone call (period II) and after mobile phone call (period III).

Parameters	**Period I (Control)**	**Period II**	**Period III**	*p* values
TP	36758.50 ± 151.94$^{\#}$	48411.50 ± 248.71*	42411.33 ± 75.69$^{\wedge}$	$p < 0.05$
VLF	8343.83 ± 34.75$^{\#}$	27421.00 ± 39.43*	23540.17 ± 68.86$^{\wedge}$	$p < 0.05$
LF	6256.83 ± 65.45$^{\#}$	5265.17 ± 122.67*	12578.67 ± 74.67$^{\wedge}$	$p < 0.05$
HF	9457.67 ± 60.25$^{\#}$	10366.33 ± 61.19*	7722.83 ± 120.66$^{\wedge}$	$p < 0.05$
LF/HF	0.76 ± 0.04$^{\#}$	0.65 ± 0.03*	1.90 ± .03$^{\wedge}$	$p < 0.05$

Values are expressed as mean SD for 25 young healthy subjects in each period. Different superscript denotes for significant differences between periods as analyzed by one-way ANOVA followed by DMRT ($p < 0.05$).

DISCUSSION

In this study demonstrated that the call with use of a mobile phone may cause the increase in parasympathetic tone (the highest values of HF parameter were noted during the telephone call) and the decrease in sympathetic tone (the lowest values of LF/HF ratio during the telephone call). It is known that the efferent vagal activity is a major contributor to the HF component. Kuo TBJ *et al*., 1999 , Lerma C, *et al*., 2006 Malliani A *et al.,* 19991 and Pickard W,*et al*., 2001. On the other hand, LF is a marker reflecting both sympathetic and vagal activity Malliani A *et al*., 19991 and Pickard W,*et al*., 2001and the LF/HF ratio is considered to mirror sympathovagal balance or reflect the sympathetic modulations. SDNN parameters were the highest during the telephone call. SDNN represents joint sympathetic and parasympathetic modulation of heart rate. Huikuri H *et al* 1996 These results were in agreements with previous published data. Heynick L, *et al*., 2003.

In our study, VLF increased during the telephone call. The increase in very low frequency in the exposed subjects could be related to parasympathetic activation as VLF is very much dependent on parasympathetic tone. Pomeranz M, *et al*., 1985. Taylor *et al.* suggested that parasympathelic nervous system is the dominant determinant of VLF. Pomeranz M, *et al*., 1985 In studies on atrial fibrillation (AF) the increase in VLF component together with other parasympathetic markers predicted the early recurrence of AF after cardioversion. Schwartz JB. *et al*., 1991. However, the physiologic interpretation of VLF oscillations is still a subject of debate. Reduction in VLF is associated with increased risk for sudden cardiac death. Szmigielski S, *et al*., 1998. Different physiological mechanisms for VLF have been proposed: physical activity, thermoregulation, renin-angiotensin-aldosterone system, slow respiratory patterns and parasympathetic mechanisms. Pomeranz M, *et al.,* 1985.

Regarding widespread use of mobile phones closer attention should be paid to a problem of workers who use mobile phones for a long time and are occupationally exposed to electromagnetic field. On the other hand, it is important to evaluate whether the extensive use of mobile phones in various types of jobs could exert influence on heart that is not only related to mental stress. Task Force 1996 Taylor J,*et al*., 1998, Tropea and Lee 1992, Tsuji H,*et al.,* 1994, Vikman S. *et al.,* 2003 and Wranicz J, *et al.,* 2004. Results of our investigation suggest that a call with use of a mobile phone may exert a noticeable effect on autonomic balance, though the pattern it represents is not typical for the dexterous effect on HRV, i.e. lack of a typical decrease in parasympathetic activity with the domination of sympathetic system. The increase in vagal activity can be beneficial in cardiovascular diseases. However, it has not been elucidated yet how much vagal activity or its markers have to increase in order to provide adequate protection or how the proper balance between parasympathetic and sympathetic tone should be expressed. Wranicz J, *et al.,* 2004. Thus, results of our investigation do not show that EMF can have a positive health effect. This is a preliminary study to demonstrate that the call with a mobile phone may cause changes in autonomic balance probably related to a non-thermal bioeffect. Further study may be needed to investigate the how much increase in HRV can be beneficial in cardiovascular diseases.

CONCLUSIONS

In conclusion, the above results showed that the call with a mobile phone may influence heart rate variability and change the autonomic balance. The increases in the parasympathetic tone concomitant with the decrease in the sympathetic tone measured indirectly by analysis of heart rate variability were observed during the mobile telephone call. Changes in heart rate variability during the call could be affected by electromagnetic field, but the influence of speaking cannot be excluded.

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ARABIC SUMMARY

تأثير الاشعاع على التغيرات فى ضربات القلب للشباب الاصحاء

السيد احمد محمد شكر
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إنه من الممكن أن يكون للمجال الكهرومغناطيسي الناتج عن الهواتف النقالة تأثيرا على الجهاز العصبي اللاإرادي ومن هنا على تغير معدل أداء القلب. إن الهدف من الدراسة هو تقدير تأثير مكالمات الهواتف النقالة على تغير معاملات معدل أداء القلب للشباب اليافعين. لقد أجريت تحاليل مجال الزمن والتردد لاختبار تغير معدل أداء القلب لتقدير التغيرات التي تحدث في التوازن بين الجهازين السمبثاوي والبارا سمبثاوي في مجموعة من 50 طالبا من الأصحاء الذين بينوا رسومات طبيعية للقلب في حالة الإسترخاء. ولقد حسبت متغيرات مجال التردد باستخدام نظام PowerLab acquisition® المعتمد على مدى التردد المنخفض جدا (VLF) والتردد المنخفض (LF) والتردد المرتفع (HF) وكذلك حسبت نسبة التردد المنخفض إلى المرتفع. كما أجريت رسومات القلب الكهربائية في ظروف قياسية في وضع الإسترخاء في الفترة من التاسعة حتى الحادية عشرة صباحا. وقد أجريت القياسات خلال فترة زمنية قدرها ١٥ دقيقة قبل استخدام الهاتف وأثناء استخدام الهاتف النقال وبعد استخدام الهاتف. لقد وجد أن متوسط معدل أداء القلب لم يتغير بصورة ملحوظة خلال خمسة عشرة دقيقة قبل استخدام الهاتف النقال وكذلك خلال خمسة عشرة دقيقة أثناء استخدام الهاتف وأيضا في الخمسة عشرة دقيقة التي تلت استخدام الهاتف . أما باقي المعاملات الخاصة بتحليل الزمن فإنها لم تبين تغيرا بالنسبة لبعضها البعض. ولقد بينت دراسة مجال التردد أن المعاملات المحسوبة في حالة الترددات المنخفضة جدا وكذلك العالية قد زادت بصورة ملحوظة خلال الخمسة عشرة دقيقة أثناء المكالمة مقارنة مع الخمسة عشرة دقيقة التي سبقت إجراء المكالمة. بينما تناقصت المعاملات الخاصة بمنطقة التردد المنخفض بصورة ملحوظة خلال الخمسة عشرة دقيقة التي تلت استخدام الهاتف مقارنة مع فترة إجراء المكالمة. إن نسبة الترددات المنخفضة إلى العالية قد بينت أيضا قيما منخفضة أثناء إجراء المكالمة مقارنة مع الفترات الزمنية قبل وبعد استخدام الهاتف.

_لقد وجد أن هناك زيادة في نشاط الجهاز الباراسمبثاوي مصاحبة للنقص في نشاط الجهاز السمبثاوي والتي قيست بصورة غير مباشرة عن طريق إجراء تحليل لتغير معدل أداء القلب. إن التغير في معاملات أداء القلب أثناء المكالمة الهاتفية يمكن أن يتأثر بالمجال الكهرومغناطيسي، لكن تأثير التحدث لا يمكن تجاهله أيضا.

ولقد بينت دراسة مجال التردد أن المعاملات المحسوبة في حالة الترددات المنخفضة جدا وكذلك العالية قد زادت بصورة ملحوظة خلال الخمسة عشرة دقيقة أثناء المكالمة مقارنة مع الخمسة عشرة دقيقة التي سبقت إجراء المكالمة. بينما تناقصت المعاملات الخاصة بمنطقة التردد المنخفض بصورة ملحوظة خلال الخمسة عشرة دقيقة التي تلت استخدام الهاتف مقارنة مع فترة إجراء المكالمة. إن نسبة الترددات المنخفضة إلى العالية قد بينت أيضا قيما منخفضة أثناء إجراء المكالمة مقارنة مع الفترات الزمنية قبل وبعد استخدام الهاتف.

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