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Original Article

Electrical Activity of Heart During ECG For EMF And Non– EMF Trails.

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ABSTRACT

Background: The ubiquitous use of mobile phones has raised concerns about potential health impacts, particularly regarding the effects of electromagnetic fields (EMF) on the human brain and heart. Heart rate variability (HRV) is a critical measure of heart health, influenced by brain function and susceptible to disruption by mobile phone radiation.

Objective: This study aims to investigate the influence of mobile phone EMF on HRV, utilizing higher-order spectral analysis of ECG data to determine the functional relationship between the heart and brain under EMF exposure.

Methods: Twenty healthy subjects from the University of Sindh, Jamshoro, participated in this experiment. The subjects, with an average age of 27 years, underwent ECG and EEG recording under varying conditions of EMF exposure. Each session involved comparisons of EMF effects over different durations and positions relative to the heart.

Results: Statistically significant differences were observed in bicoherence values for chest positions V1 and V2, with non-EMF trials showing higher values compared to EMF trials. Coherence between ECG and EEG indicated significant changes in the 16-30 Hz frequency band during EMF exposure. Extended exposure of 40 minutes correlated with notable variations in HRV.

Conclusion: The findings suggest that mobile phone EMF can significantly affect HRV parameters, particularly with prolonged exposure and when the EMF source is close to the heart. These results underscore the importance of developing guidelines for safe mobile phone usage.

Keywords: Bicoherence, Coherence, Electromagnetic Field, Electrocardiogram, Electroencephalography, Heart Rate Variability, Mobile Phone Radiation

INTRODUCTION

The electrical activity of the heart is primarily governed by the sinoatrial (SA) and atrioventricular (AV) nodes, which form the cornerstone of the heart's conduction system. These nodes function as pacemakers, setting the heart's rhythm and ensuring its efficient operation. The SA node, a cluster of cells located in the right atrium, initiates each heartbeat by generating an electrical impulse that causes the right atrium to contract. This contraction facilitates a cascade of events that propel blood throughout the body as rhythmic waves, essential for circulation.

Following the initiation by the SA node, the electrical signals are transmitted to the AV node, strategically positioned at the juncture between the right atrium and the right ventricle. Serving as a secondary pacemaker, the AV node plays a critical role in cardiac regulation by delaying the electrical impulse briefly—approximately one-tenth of a second. This delay ensures that the atria have sufficient time to contract before the ventricles, a crucial aspect of effective cardiac function.

Both the SA and AV nodes are intricately connected to the autonomic nervous system (ANS), which modulates the physiological activities of various organs, including the heart. The ANS comprises sympathetic and parasympathetic nerves that dynamically adjust the heart rate in response to the body's needs. The parasympathetic nerves reduce the heart rate by signaling the SA node to slow down, while the sympathetic nerves increase the heart rate by enhancing the SA node's activity (24).

The objective of examining the electrical activity of the heart during electrocardiogram (ECG) tests for electromagnetic field (EMF) and non-EMF trials is to discern any potential influences of EMF exposure on cardiac function. This research aims to provide a clearer understanding of how external factors such as EMFs might interact with the heart's natural electrical conduction system, potentially affecting its rhythm and overall cardiac health.

MATERIAL AND METHODS

In this study, the performance of electroencephalogram (EEG) and electrocardiogram (ECG) methods was assessed, focusing on the evaluation of coherence and bicoherence functions. These functions were derived using Fourier transform techniques, a method that provides meaningful results when expressed as a weighted average. To obtain robust estimates, the original time series data was segmented according to protocols established in previous research (25). Each segment was then individually analyzed to estimate the desired functions.

Due to inherent limitations in the time and frequency resolution of data, the size and number of segments were carefully chosen to optimize frequency resolution while considering the adverse effects on time resolution. Larger data segments enhanced frequency resolution but at the expense of time resolution, and vice versa.

Additionally, the study employed a distribution-free Wilcoxon Rank-sum test to compare the bispectrum estimates between EMF exposure and non-exposure trials. This non-parametric approach was necessitated by the absence of a normal distribution in the bispectrum estimates, as confirmed by Shapiro-Wilk and Kolmogorov-Smirnov tests (26). This methodological choice ensured that the statistical analysis remained robust despite the non-normality of the data, providing a reliable comparison of the effects of EMF exposure on the cardiac and cerebral functions measured by ECG and EEG.

RESULTS

In the analysis of heart rate variability (HRV) using bicoherence, no significant differences were observed in the ECG data from 10-minute exposures, irrespective of whether the mobile phone was placed at the chest or ear. Consequently, data from these conditions were excluded from further consideration. Notably, significant alterations were detected in the bicoherence measures from 40-minute exposure trials with the mobile phone positioned at the chest, warranting further investigation (27).

For these extended exposure trials, bicoherence analysis indicated larger peaks at various chest electrode positions from V1 to V4 in the non-EMF trials compared to the EMF trials. However, significant differences between EMF and non-EMF trials were predominantly observed within the frequency range of 0 to 7 Hz. This specific finding was visually represented in the bicoherence plot for electrode position V3, where changes were denoted by a color scale—red indicating a marked increase and blue a decrease in bicoherence values. Despite the overall spectrum showing visible differences, meaningful distinctions in bicoherence values were primarily confined to the stated frequency range (28).

To quantitatively assess these differences, the average bicoherence for ECG across both exposure and non-exposure trials was computed using the formula $Bx(f) = 1/N \sum f1 \sum f2\ Bx(f1,f2)$, where N represents the number of bicoherence estimates for each segment. This analysis revealed that while the bicoherence values for electrodes V1 and V2 in non-EMF trials were significantly higher than those in EMF trials, with p-values of 0.003 and 0.024 respectively, no significant differences were found for electrodes V3 and V4, where the p-values were 0.234 and 0.742 respectively (28).

Further, the study explored the correlation between ECG and electroencephalogram (EEG) data under EMF influence. Except for the chest electrodes V1 and V2, no significant effects of EMF trials were observed on the coherence between ECG and EEG data at other chest positions. The coherence analysis focused on the chest position V1 and the corresponding frontal and occipital electrode positions in EEG. The coherence values were calculated first by averaging individual coherence measures and then taking an average across the 16-30 Hz frequency region. This method revealed a statistically significant difference in coherence between EMF and non-EMF trials at the frontal electrode position, with a p-value of 0.0031. However, no significant differences were found at parietal and temporal electrodes, with p-values of 0.596 and 0.601 respectively (29-31). This detailed analysis underlines the localized impact of EMF on the correlation between cardiac and brain electrical activities, emphasizing the need for further research in this area.

The Bi-coherence of ECG for EMF and Non-EMF trails								The Coherence Between ECG and EEG							
chest electrode V1 P value is 0.003		chest electrode V2 P value is 0.024		Chest Position electrode V3 P value is 0.234		Chest Position Electrode V4 P value is 0.742		V1 and Occipital electrodes P value is 0.363		V1 and Frontal electrodes P value is 0.0031		V1 and Parietal electrode P value is 0.596		V1 and temporal electrodes P value is 0.601	
Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials	Non-EMF Trials	EMF Trials
0.224	0.603	0.631	0.447	0,295	0342.	0.563	o.533	0.341	0.412	0.762	0.783	0.517	0.477	0.734	0.670
0.318	0.772	0.453	0.375	0,337	0.451	0.326	0.392	0.531	0.438	0.522	0.574	0.135	0.108	0.376	0.037
0.112	0.54	0.555	0.322	0,447	0.637	0.233	0.452	0.875	0.896	0.717	0.921	0.752	0.760	0.252	0.253
0.008	0.099	0.673	0.544	0,854	0.662	0.174	0.295	0.341	0.367	0.277	0.326	0.688	0.588	0.861	0.796
0.209	0.004	0.492	0.451	0,337	0.253	0.295	0.361	0.713	0.691	0.543	0.944	0.146	0.058	0.249	0.229
0.336	0.813	0.449	0.422	0,443	0.225	0.215	0.227	0.365	0.344	0.763	0.775	0.127	0.167	0.449	0.698
0.117	0.604	0.437	0.216	0,632	0.497	0.342	0.482	0.461	0.399	0.764	0.792	0384	0.579	0.581	0.673
0.111	0.224	0.445	0.345	0,255	0.135	0.223	0.265	0.844	0.795	0.296	0.726	0.222	0.225	0.750	0.451
0.003	0.475	0.411	0.475	0,436	0.224	0.365	0.332	0.241	0.292	0.362	0.427	0.421	0.430	0.224	0.258
0.303	0.775	0.447	0.442	0.264	0.225	0.148	0.223	0.432	0.462	0.216	0.451	0.571	0.571	0.713	0.714
0.4	0.342	0.473	0.395	0.442	0.525	0.547	0.472	0.588	0.611	0.495	0.689	0.338	0.301	0.211	0.176
0.301	0.395	0.572	0.462	0.662	0.631	0.422	0.651	0.347	0.333	0.323	0.795	0.721	0.705	0.406	0.388
0.009	0.325	0.337	0.553	0.493	0.452	0.533	0.435	0.714	0.751	0.514	0.579	0.518	0.639	0.416	0.491
0.005	0.334	0.537	0.374	0.772	0.659	0.424	0.454	0.314	0.411	0.242	0.416	0.244	0.109	0.473	0.464
0.113	0.482	0.648	0.633	0.447	0.435	0.586	0.613	0.341	0.375	0.845	0.553	0.251	0.267	0.704	0.718
0.137	0.583	0.375	0.242	0.273	0.331	0.755	0.715	0.161	0.199	0.352	0.852	0.654	0.697	0.327	0.312
0.11	0.664	0.496	0.336	0.511	0.462	0.523	0.496	0.577	0.654	0.315	0.535	0.111	0.077	0.614	0.577
0.005	0.588	0.528	0.462	0.354	0.361	0.144	0.241	0.494	0,624	0.643	0.666	0.028	0.146	0.163	0.971
0.333	0.547	0.442	0.434	0.522	0.442	0.532	0.497	0.743	0.714	0.254	0.713	0.262	0.202	0.545	0.553
0.216	0.775	0.352	0.639	0.443	0.417	0.626	0.621	0.712	0.771	0.264	0.369	0.134	0.170	0.877	0.526

DISCUSSION

The effect of electromagnetic fields (EMF) emitted by mobile phones on electrocardiogram (ECG) data has been a subject of ongoing research, with previous studies predominantly focusing on lower-order statistical characteristics such as power spectral density and coherence functions (31, 56, 57, 59). These studies, however, have yielded inconsistent results, underscoring the complexity of assessing the impact of EMF on heart rate variability (HRV) and the need for further investigation. This study employed bicoherence analysis of HRV activities to explore how mobile phones might influence the cardiac function when positioned at various chest locations.

The findings indicated that the position of the EMF source relative to the heart plays a significant role in influencing ECG data. Notably, larger bicoherence values were observed for non-EMF trials compared to EMF trials, particularly at electrode positions closer to the heart, such as V1 and V2. This phenomenon suggests a nonlinear effect, potentially attributable to a decrease in cortical connectivity during EMF exposure, which may induce an increase in the number of oscillations and resonance, leading to enhanced bicoherence values in non-EMF trials (32).

Interestingly, the significant differences in bicoherence were confined to lower frequency intervals (0 to 7 Hz), suggesting that EMF's impact on HRV is frequency-dependent. This aligns with the findings of Fang et al., who reported changes in root mean square values of ECG at extremely low frequency ranges during EMF exposure (34). Moreover, the study by Erica et al. supported the notion that the duration of EMF exposure could be crucial, with longer exposures (e.g., 40 minutes) showing more pronounced effects on HRV parameters compared to shorter durations (e.g., 10 minutes) (35).

This research contributes novel insights into the interplay between brain activities and heart function under EMF exposure, particularly through the observed coherence between ECG and electroencephalogram (EEG) data in the frequency band of 16-30 Hz, which is associated with active or anxious cognitive states. Such findings highlight a potentially significant impact of EMF on the relationship between cardiac and cerebral functions, suggesting a linear as well as a possible nonlinear interaction between the heart and EEG signals under the influence of mobile phone EMF (36).

Despite these advancements, the study is not without limitations. The sample size and specific conditions of mobile phone usage, such as the exact distance from the heart and the orientation of the device, could influence the generalizability of the results. Additionally, while the study sheds light on the effects of mobile phone EMF on cardiac and brain functions, it leaves open questions regarding the long-term health implications of these interactions, necessitating further comprehensive studies to better understand these dynamics.

In conclusion, the findings indicate that the effects of mobile phone EMF on HRV are both duration-dependent and influenced by the proximity of the EMF source to the heart. These insights pave the way for developing guidelines for safer mobile phone use, particularly in terms of limiting duration and maintaining distance from vital body organs to mitigate potential adverse effects on cardiac health (37).

CONCLUSION

In conclusion, this study substantiates the duration-dependent effects of mobile phone electromagnetic fields (EMF) on heart rate variability (HRV), with significant changes observed particularly after prolonged exposure. The findings suggest that the proximity of the EMF source to the heart critically influences cardiac function, highlighting a potential nonlinear interaction between cardiac and cerebral activities under EMF influence. These insights are crucial for framing guidelines on safer mobile phone usage, emphasizing the need to limit usage duration and maintain a safe distance from vital organs to mitigate adverse health impacts.

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