IJCMBS

Original article

doi.org/ 10.5281/zenodo.10951953
IJCMBS 2024; 4(2):29-34

Long-term Exposure to 50 Hz Extremely Low Frequency Pulsed Electromagnetic Field Does not Alter the Electrocardiographic Parameters of Rats

50 Hz Aşırı Düşük Frekanslı Darbeli Elektromanyetik Alana Uzun Süre Maruz Kalmak, Sıçanların Elektrokardiyografik Parametrelerini Değiştirmez

Yasin Gokce[1*]

[1]Department of Biophysics, Harran University, Faculty of Medicine, Sanliurfa , Turkiye

Abstract

Background: The heart is a contractile organ with the ability to generate its own signals. Because of the excitable nature of heart cells, they may be impacted by external impulses or stimuli. The purpose of this research is to use electrocardiogram (ECG) measurements to ascertain the effects of exposure to an extremely low frequency pulsed magnetic field (ELF-PEMF) at 1 milli Tesla (mT) and 5 mT intensity on the heart's electrical stimulation system.

Materials and Methods: Eighteen Wistar Albino rats, weighing 200-250g and aged 8 weeks, were randomly allocated into three groups, with six rats in each group: sham, 1 milli Tesla (1 mT), and 5 mT exposure groups. Rats were subjected to ELF-PEMF for 4-hours each day, 5-days per week for 8-weeks. The rats in the sham group were kept under the same condition, but the exposure system was turned off.

Results: The findings indicate that ELF-PEMF exposure at 1 mT and 5 mT intensities did not affect common ECG parameters used to evaluate cardiac rhythmic activity, including heart rate, P-wave amplitude, PR interval, QRS interval, R amplitude, and QT interval.

Conclusion: The 8-week exposure to ELF-PEMF at the 1 mT and 5 mT intensities didn't show any effect on ECG parameters in rats, at least according to the design applied in this study. The effects of these magnetic fields are also directly related to exposure durations and intensity. Therefore, more research is required to ascertain how varied application intensities and durations affect cardiac function.

Keywords: Heart function; Electrocardiogram (ECG); Extremely Low Frequency Pulsed Electromagnetic Fields (ELF-PEMF)

ÖZ

Amaç: Kalp, kendi sinyallerini üretebilen kasılabilir bir organdır. Kalp hücrelerinin uyarılabilir doğası nedeniyle, dış etkenler veya uyarıcılardan etkilenebilirler. Bu araştırmanın amacı, elektrokardiyogram (EKG) ölçümlerini kullanarak, 1 mili Tesla (mT) ve 5 mT şiddetindeki aşırı düşük frekanslı darbeli manyetik alanın (ELF-PEMF) maruziyetinin kalbin elektriksel uyarı sistemine etkilerini belirlemektir.

Gereç ve Yöntem: 200-250 g ağırlığında ve 8 haftalık 18 Wistar Albino sıçan, altışarlı üç gruba rastgele ayrıldı: sham, 1 mili Tesla (1 mT) ve 5 mT maruziyet grupları. Sıçanlar her gün 4 saat boyunca ELF-PEMF'ye maruz bırakıldı ve bu işlem haftada 5 gün, 8 hafta boyunca tekrarlandı. Sham grup sıçanları aynı koşullarda tutuldu, ancak maruziyet sistemi kapatıldı..

Bulgular: 1 mT ve 5 mT yoğunluğundaki ELF-PEMF maruziyeti, kalp hızı, P dalga genliği, PR aralığı, QRS aralığı, R genliği ve QT aralığı gibi kalp ritmik aktivitesinin değerlendirilmesinde yaygın olarak kullanılan EKG parametreleri üzerinde hiçbir etki göstermedi. **Sonuç:** Bu çalışmada uygulanan tasarıma göre, 1 mT ve 5 mT yoğunluğundaki ELF-PEMF'ye 8 haftalık maruziyet, sıçanlarda EKG parametreleri üzerinde herhangi bir etki göstermedi. Bu manyetik alanların etkileri aynı zamanda maruziyet süreleri ve şiddetleri ile doğrudan ilgilidir. Bu nedenle, farklı manyetik alan şiddetlerinin ve sürelerinin kalp fonksiyonunu nasıl etkilediğini belirlemek için daha fazla araştırmaya ihtiyaç vardır.

Anahtar Kelimeler: Kalp Fonksiyonu, Elektrokardiyogram (EKG); Son Derece Düşük Frekanslı Darbeli Elektromanyetik Alanlar (ELF-PEMF)

Highlights

- 8-week exposure to 1mT and 5 mT did not affect rat cardiac electrical activity.
- Further studies are needed to explore effects of varying intensities and durations of ELF-PEMF on cardiac function.
- This study suggests that even at high intensities, ELF-PEMF exposure appears safe for the heart's electrical activity.

***Corresponding author:** Yasin Gökçe. Department of Biophysics, Harran University, Faculty of Medicine, Sanliurfa, TÜRKIYE.
E-mail: ygokce@harran.edu.tr

Received: 08 March 2024
Accepted: 28 March 2024

Cite as: GOKCE.Y. Long-term Exposure to 50 Hz Extremely Low Frequency Pulsed Electromagnetic Field Does not Alter the Electrocardiographic Parameters of Rats. .IJCMBS 2024; 4(2):29-34 doi.org/ 10.5281/zenodo.10951953

Introduction

The exposure to electromagnetic fields is increasingly becoming prevalent in our daily lives' day by day. However, its effects on human health are highly debatable and draw attention to a controversial issue. A greater number of people have been exposed to weak electric or magnetic fields at home and at work due to a variety of electrical gadgets, industrial equipment, and household appliances. Extremely low-frequency electromagnetic fields (ELF-EMFs) are among the most prevalent components of the environment that can have an impact on biological systems. ELF part of the electromagnetic spectrum is often defined as 0 - 300 Hz (1). Magnetic fields produced by electrical or electronic devices used in our surroundings and electrical power lines have frequency ranges of 50 Hz in a large portion of the world and 60 Hz in North America (2). The biological effects of ELF-EMF and their harmful implications on human health have become a subject of intense discussion, according to the results obtained (3–5). The heart plays a crucial role in maintaining organismal homeostasis by pumping blood throughout the body. Any disruption in heart function can cause atherosclerosis, heart failure and sudden death (6,7).

Exposures to ELF-EMF are rising with the increasing use of electrical devices and technological products in our daily lives. However, it is noteworthy that there are very few studies showing the effects of these exposures on the cardiovascular system. A study conducted in 1999 showed that there was a parallel increase in the development of heart diseases as the duration of ELF-EMF exposure increased in electrical service workers (8). Long-term magnetic field (MF) treatment was demonstrated in another investigation to generate oxidative stress and, as a result, apoptosis and morphological abnormalities in rat cardiomyocytes (9). On the other hand, many studies have looked into the therapeutic benefits of extremely low frequency pulsed-magnetic field (ELF-PEMF) (10–12). Using a myocardial infarction model, Peng et al. demonstrated that pulsed magnetic field exposure, particularly at 30 Hz 3 milli Tesla (mT) intensity improved heart function in mice by inducing angiogenesis (13). In a different study, Wang et al. demonstrated that using a pulsed magnetic field in conjunction with adipose-derived stem cell treatment prevented cardiomyocyte death by controlling the miR-20a-5p/E2F1/p73 signaling pathway in a mouse model of myocardial infarction (14). Despite these findings, several other investigations have found that ELF-EMF exposure has no effect on heart function (15–17). In another study, Wang et al. showed that, short-term exposure to ELF-PEMF altered the RR interval slightly but had no influence on other intervals in human ECG measurements (18). In summary, it is noted that the duration, intensity, and waveform of applied ELF-EMF result in substantial variations.

PEMF is a form of collected electrical energy that is discharged in very short bursts (19). PEMF was first utilized for medicinal purposes in 1980, after it was licensed by the US Food and Drug Administration (20). Although the therapeutic properties of ELF-PEMF applications have been proven, more research is needed to show their potential impacts on the functioning of the heart. Additionally, to our best knowledge, the possible effects of long-term exposures of pulsed magnetic field on the electrical activity of the heart are not fully known. Thus, the effects of long-term (8-week) ELF-PEMF exposure at different strengths of 1 mT and 5 mT at a frequency of 50 Hz on rat electrocardiograms were investigated in that study.

Materials and Methods

Preparation of animals

For this study, 18 Wistar-Albino rats were employed. Rats were divided into three groups at random (each with 6-rats): sham, ELF-PEMF at 1mT and 5 mT intensities. Akdeniz University Local Ethics Committee's guidelines for the use of animals in experimentation were strictly adhered to (Date: 07.08.2023; Protocol Number: 1615/2023.08.001). A maximum of 3 animals were housed in each cage while the animals were maintained at 22±2 °C room temperature. Additionally, the experimental procedure was carried out on animals with free access to food and water and 12-second light/dark cycles.

Pulsed Magnetic Field Application

A pair of Helmholtz Bobin coils (copper wire with 120 turns, 2 mm2 cross-section area of each bobbin), each 50 cm in diameter, were placed in a Faraday cage along with a programmable signal generator power source (ILFA Electronics, Adana, Turkey) capable of adjusting the number of repeats, pulse frequency, pulse duration, and pulse number. **(Figure 1A)**.

In this investigation, a pulsed magnetic field of 1 mT or 5 mT magnitude was delivered to two experimental groups for 4 hours each day, five days a week, for eight weeks. The program consisted of 96 consecutive pulse trains, each lasting 2 minutes with a 30-second interval (**Figure 1B)**.

The coils generated magnetic fields peaking at 1 mT and 5 mT. The waveform of the magnetic field's time-varying component was quasi-triangular. Additionally, the device generated a horizontal homogeneous magnetic field in the desired way. A Gauss meter (Bell 5170, SYPRIS, USA) with a Hall effect probe was used to verify the appropriate magnetic field amplitude (in milliTesla) on each experimental day. The magnetic field in the magnetic field exposure area was found to be 95% homogeneous using the tesla meter as well.
Three rats were placed in a plexiglass container (40 x 15 x 20) for the administration of PMF. Magnetic field application was accomplished by positioning plexiglass in the center of the coils. PMF application was applied continuously at certain time intervals (9 am to 1 pm, for four hours each day, five days a week, for eight weeks) in order not to disturb the circadian rhythm of the animals. For the sham group, which differed from the 1 mT and 5 mT treatments, the rats were once more placed in plexiglass and left in the application area for 4 hours, but the power supply was left disconnected. Again, this routine was followed for 4 hours per day, 5 days per week, for a total of 8 weeks.

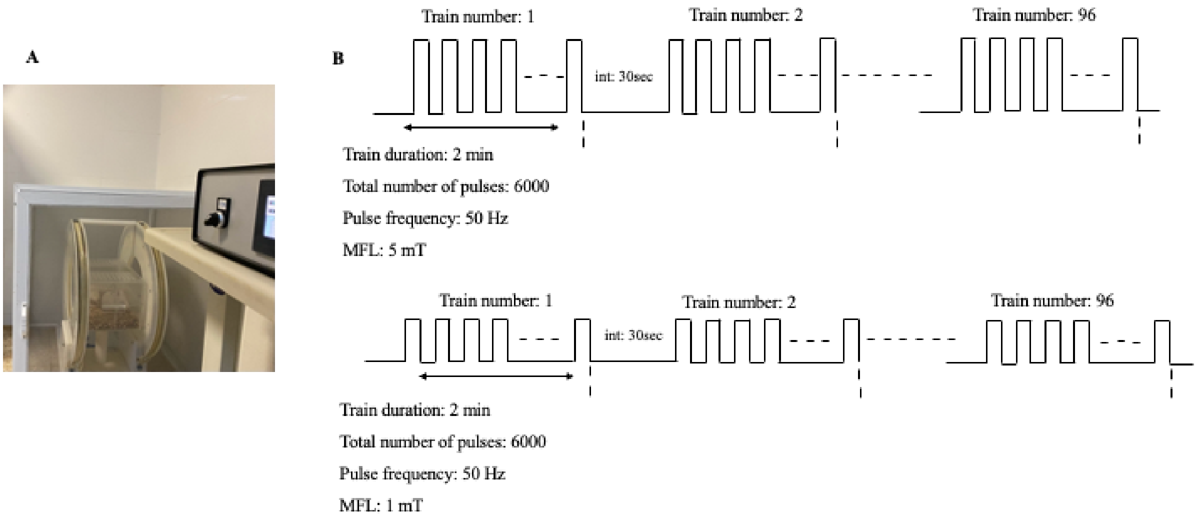

Figure 1: Pulsed magnetic field exposure system. (A) Signal generator and Helmhotz bobbin coils. **(B)** The pulse trains used in PMF application. Int: interval.

ECG Recordings

At the end of of the 8-week experiment, electrocardiographic measures were performed. To keep the anesthetic state, 10 mg/kg xylazine and 90 mg/kg ketamine were administered intramuscularly. All animals were given a 3-minute anesthetic before having their ECGs (lead II) measured. The MP150 (Biopac Systems) device was used to record changes in electrocardiographic activity. All data were shown as RR interval, heart rate (HR), PR interval, P duration, QRS interval, QT interval, corrected QT interval (QTc), P amplitude and R amplitude, which are commonly used ECG parameters. Lab Chart application was employed to analyze the ECG parameters. Relevant ECG recordings for each group are given in **Figure 2.**

Figure 2. Electrocardiogram recordings of rats from three groups: (**A**) Sham, (**B**) 1 mT, (**C**) 5 mT exposure.

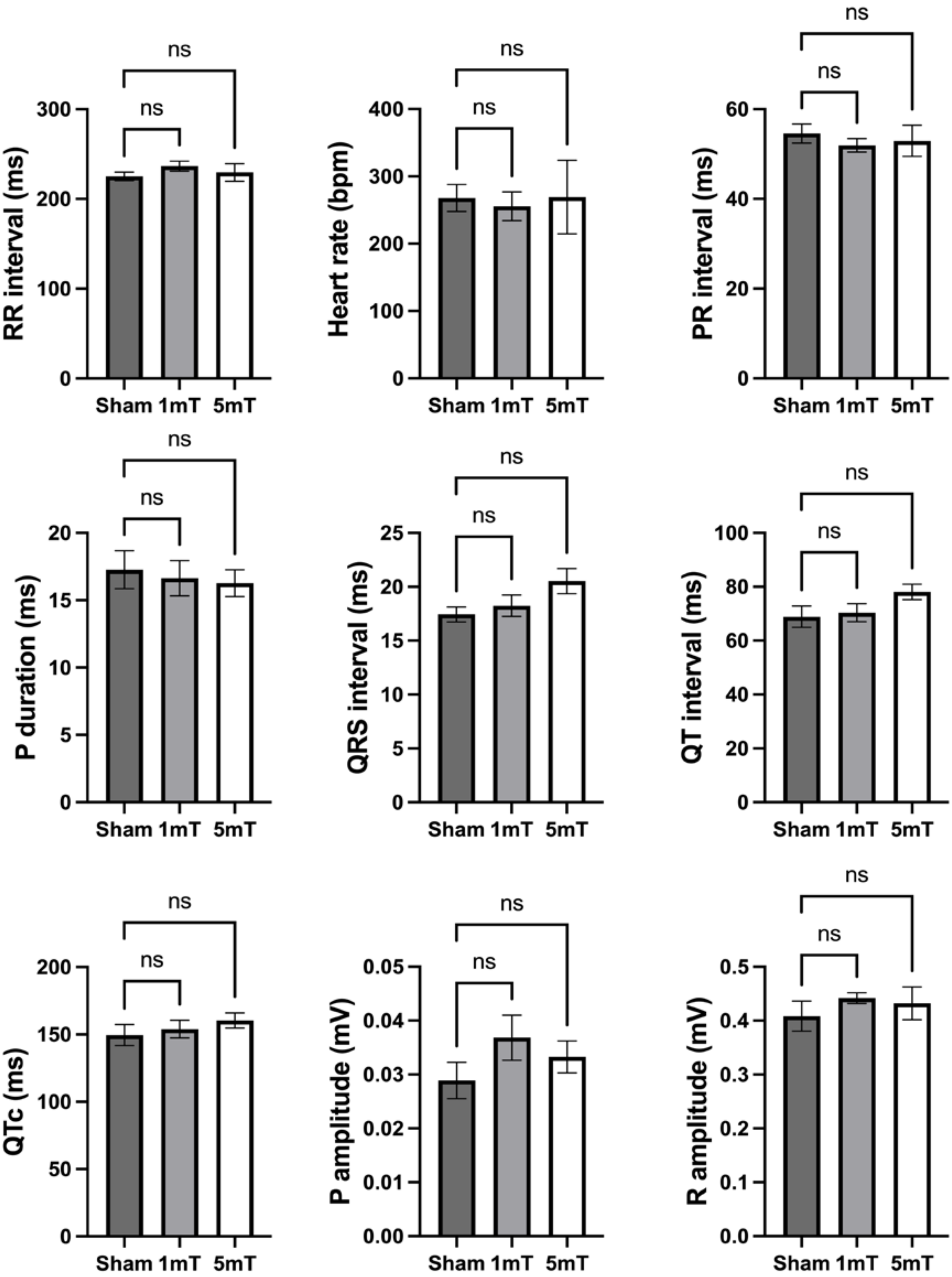

Figure 3. Graphs showing changes in ECG parameters following exposure.

Statistical analysis

The GraphPad Prism program was used to conduct the statistical analysis. All experimental results are shown as mean ± SEM. All parameters were compared via one way ANOVA followed by post hoc (Dunnett) test to determine the difference between groups. P values less than 0.05 was considered to be significant.

Results

The electrical activity of the heart, originating from the sinoatrial node, is crucial for normal cardiac function. The effects of ELF-PEMF at 1 mT and 5 mT intensities on cardiac electrical activity were examined utilizing electrocardiogram (ECG) measurements. As shown in Figure 3, ELF-PEMF exposure at 1mT and 5mT intensities had no effect on rat ECG values when compared to the sham group ($P > 0.05$).

Discussion

This study aimed to investigate the effects of 50-Hz PMF exposure at 1 mT and 5 mT intensities on rat ECG. We found that exposure to 1 mT and 5 mT for four hours per day, five days a week, for 8 weeks did not affect ECG parameters such as HR, P wave amplitude, PR interval, QRS interval, R amplitude and QT interval.

The effects of ELF-EMF exposure on cardiac function have been studied in other previous studies (21). In 1996, Korpinen and Partanen showed for the first time that ELF-EMF (1h exposure and < 6.6μT) had no effect on human systolic and diastolic blood pressure (22). Another investigation on humans found that exposure to ELF-EMF at 40 μT and 80 μT levels for 90 minutes had no effect on HR (23). Many other investigations have found that ELF-EMF exposure has no effect on heart functions (24,25). However, there are studies showing that ELF-EMF exposure has harmful effects on cardiovascular systems specifically on the HR (26,27). The reasons for these disparities in results may include differences in magnetic field exposure setup, intensity differences, and changes in the applied waveform. Especially in the results showing that ELF-EMF is effective on cardiac function, the magnitude of the applied field strength draws attention which are even above the occupational limit determined by the ICIRP (26). Although high ELF-PEMF field exposures of 1 mT and 5 mT were employed in this study, the major goal was to determine the probable effects of PEMF applications, particularly those used for therapy, on the rhythmic activity of the heart.

PEMF has been studied for its therapeutic effects in conditions such as insomnia, accelerated bone repair, and pain management. (10–12). However, relatively few research has been conducted to investigate the effects of PEMF applications on ECG parameters. According to the findings of this study, PEMF exposure at 1 mT and 5 mT had no effect on rat heart rate, P and R wave amplitude, PR and QRS time interval values, as well as corrected QT interval values.

On the other hand, the magnetic field intensity produced by the increasing number of electrical devices used in our daily lives is also increasing rapidly. As a result, it is critical to research the effects of high intensities and assess their potential effects. Furthermore, because it is a contractile organ, the heart can create its own electrical activity. This process, known as cardiac excitation-contraction coupling, involves the electrical activation of the myocyte followed by heart contraction (28). Because of its electrical characteristics, each cell alters its resting membrane potential during this process, allowing the entire heart to contract in a coordinated manner (29). The excitation-coupling system that results from this electrical activity of the heart might be influenced by both magnetic field exposure from the growing number of electronic devices around us and even by therapeutic devices. Although the negative or positive effects of the field intensities used in this study have been shown in other tissues and organs (30,31), it appears that they have no effect on the electrical activity of the heart. Interestingly, while studies demonstrate that short-term EMF exposure causes drops in heart rate, such effects vanish in prolonged exposure (32). This is due to the heart's ability to compensate for alterations generated by such exposures. The results obtained in this study need to be supported by different studies. Additionally, a magnetic field with a frequency of 50 Hz was selected in this study. Although similar intensities are used for therapeutic purposes, differences between the applied frequencies are noteworthy (12). Therefore, it is necessary to examine both the effects of ELF-PEMF at different frequencies and the effects of different exposure times. Moreover, it is thought that there may be different effects between PEMF and continuous EMF exposure applications. As a result, it is evident that more research is needed to properly understand whether ELF-EMF exposures are causal factors or therapeutic and diagnostic instruments in the development of disorders.

Study limitations

This experimental study has some limitations. The effects of ELF-PEMF exposure on rat cardiac functions were discussed through ECG evaluations. However, there is a need for the evaluation of the effects of pulsed magnetic field exposure on cardiac functions through histological and biochemical analyses as well.

Conclusion

The effects of long-term ELF-PEMF exposure of 1 mT and 5 mT on cardiac functions in rats were investigated using electrocardiogram (ECG) recordings in this study. Although such exposure has been shown to have both positive and negative effects on various tissues and organ systems, it has been found that it is ineffective against the heart's highly protected rhythmic electrical stimulation mechanism. Even if it has an effect, it is assumed that the body system can suppress it. However, special attention should be paid to long-term ELF-EMF exposures, whose effects on human health are still controversial. New studies evaluating the activities of ELF-PEMF, chronic or short-term exposures, under a range of situations, in conjunction with common real-life stressors, may aid in understanding their sincere biological consequences.

Acknowledgements: *Thanks for the comments and support on the study, Prof. Dr. Nazmi Yaraş.*

Ethical Approval: *This study was approved by Akdeniz University Local Ethics Committee. (Date: 07.08.2023; Protocol Number: 1615/2023.08.001).*

Author Contributions: *Concept: YG. Literature Review: YG. Design: YG. Data acquisition: YG. Analysis and interpretation: YG. Writing manuscript: YG. Critical revision of manuscript: YG..*

Conflict of Interest: *The author(s) do not have any potential conflict of interest regarding the research. authorship and/or publication of this article.*

Financial Disclosure: *This research received no specific grant from any funding agency in the public. commercial. or not-for-profit sectors*

References

1. Zhao Q-R, Lu J-M, Yao J-J, et al. Neuritin reverses deficits in murine novel object associative recognition memory caused by exposure to extremely low-frequency (50 Hz) electromagnetic fields. Sci Rep 2015; 5:11768.
2. Touitou Y, Selmaoui B. The effects of extremely low-frequency magnetic fields on melatonin and cortisol, two marker rhythms of the circadian system. Dialogues Clin Neurosci 2012; 14:381–99.
3. Giorgi G, Lecciso M, Capri M, et al. An evaluation of genotoxicity in human neuronal-type cells subjected to oxidative stress under an extremely low frequency pulsed magnetic field. Mutat Res Toxicol Environ Mutagen 2014;775–776:31–7.
4. de Groot MWGDM, Kock MDM, Westerink RHS. Assessment of the neurotoxic potential of exposure to 50Hz extremely low frequency electromagnetic fields (ELF-EMF) in naïve and chemically stressed PC12 cells. Neurotoxicology 2014; 44:358–64.
5. Golbach LA, Philippi JGM, Cuppen JJM, et al. Calcium signalling in human neutrophil cell lines is not affected by low-frequency electromagnetic fields. Bioelectromagnetics 2015; 36:430–43.
6. Foks AC, Bot I. Preface: Pathology and Pharmacology of Atherosclerosis. Eur J Pharmacol 2017; 816:1–2.
7. Schwinger RHG. Pathophysiology of heart failure. Cardiovasc Diagn Ther 2021; 11:263–76.
8. Savitz DA, Liao D, Sastre A, et al. Magnetic Field Exposure and Cardiovascular Disease Mortality among Electric Utility Workers. Am J Epidemiol 1999; 149:135–42.
9. Kiray A, Tayefi H, Kiray M, et al. The effects of exposure to electromagnetic field on rat myocardium. Toxicol Ind Health 2013; 29:418–25.
10. Pelka RB, Jaenicke C, Gruenwald J. Impulse magnetic-field therapy for insomnia: A double-blind, placebo-controlled study. Adv Ther 2001; 18:174–80.
11. Bassett CAL. Beneficial effects of electromagnetic fields. J Cell Biochem 1993; 51:387–93.
12. Coskun C, Ocal I, Gunay I. A Low-Frequency Pulsed Magnetic Field Reduces Neuropathic Pain by Regulating NaV 1.8 and NaV 1.9 Sodium Channels at the Transcriptional Level in Diabetic Rats. Bioelectromagnetics 2021; 42:357–70.
13. Peng L, Fu C, Liang Z, et al. Pulsed Electromagnetic Fields Increase Angiogenesis and Improve Cardiac Function After Myocardial Ischemia in Mice. Circ J 2020; 84:186–93.
14. Wang Y, Chen L, Wang L, et al. Pulsed Electromagnetic Fields Combined with Adipose-Derived Stem Cells Protect Ischemic Myocardium by Regulating miR-20a-5p/E2F1/p73 Signaling. Stem Cells 2023; 41:724–37.
15. Whittington CJ, Podd JV., Rapley BR. Acute effects of 50 Hz magnetic field exposure on human visual task and cardiovascular performance. Bioelectromagnetics 1996; 17:131–7.
16. Zhou L, Wan B, Liu X, et al. The effects of a 50-Hz magnetic field on the cardiovascular system in rats. J Radiat Res 2016; 57:627–36.
17. Wang Y, Liu X, Zhang Y, et al. Exposure to 50 Hz magnetic field at 100 μT exert no DNA damage in cardiomyocytes. Biol Open 2019;8.
18. Fang Q, Mahmoud S, Yan J, et al. An Investigation on the Effect of Extremely Low Frequency Pulsed Electromagnetic Fields on Human Electrocardiograms (ECGs). Int J Environ Res Public Health 2016; 13:1171.
19. Waldorff EI, Zhang N, Ryaby JT. Pulsed electromagnetic field applications: A corporate perspective. J Orthop Transl 2017; 9:60–8.
20. Martiny K, Lunde M, Bech P. Transcranial Low Voltage Pulsed Electromagnetic Fields in Patients with Treatment-Resistant Depression. Biol Psychiatry 2010; 68:163–9.
21. McNamee DA, Legros AG, Krewski DR, et al. A literature review: the cardiovascular effects of exposure to extremely low frequency electromagnetic fields. Int Arch Occup Environ Health 2009; 82:919–33.
22. Korpinen L, Partanen J. Influence of 50-Hz electric and magnetic fields on human blood pressure. Radiat Environ Biophys 1996; 35:199–204.
23. Ghione S, Seppia C Del, Mezzasalma L, et al. Effects of 50Hz electromagnetic fields on electroencephalographic alpha activity, dental pain threshold and cardiovascular parameters in humans. Neurosci Lett 2005; 382:112–7.
24. Zhang Y, Li L, Liu X, et al. Examination of the Effect of a 50-Hz Electromagnetic Field at 500 μT on Parameters Related with the Cardiovascular System in Rats. Front Public Heal 2020; 8:1–9.
25. Elmas O, Comlekci S, Koylu H. Effects of Short-Term Exposure to Powerline-Frequency Electromagnetic Field on the Electrical Activity of the Heart. Arch Environ Occup Health 2012; 67:65–71.
26. Korpinen L, Partanen J. Influence of 50 Hz electric and magnetic fields on the pulse rate of human heart. Bioelectromagnetics 1994; 15:503–12.
27. Okano H, Fujimura A, Kondo T, et al. A 50 Hz magnetic field affects hemodynamics, ECG and vascular endothelial function in healthy adults: A pilot randomized controlled trial. PLoS One 2021;16: e0255242.
28. Bers DM. Cardiac excitation–contraction coupling. Nature 2002; 415:198–205.
29. Alonso S, dos Santos RW. Modelling the Electrical Activity of the Heart, 2019, p. 211–29.
30. Carter CS, Huang SC, Searby CC, et al. Exposure to Static Magnetic and Electric Fields Treats Type 2 Diabetes. Cell Metab 2020; 32:561-74.
31. Sert C, Delin M, Eren MA, et al. Investigation of Fetuin-A pathway in diabetes mellitus formation in rats exposed to elf magnetic fields. Electromagn Biol Med 2022; 41:402–8.
32. Jeong JH, Kim JS, Lee BC, et al. Influence of exposure to electromagnetic field on the cardiovascular system. Auton Autacoid Pharmacol 2005; 25:17–23.