ScienceDirect

Journal of Chemical Neuroanatomy
Volume 126, December 2022, 102168

Effects of 3.5 GHz radiofrequency radiation on ghrelin, nesfatin-1, and irisin level in diabetic and healthy brains

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https://doi.org/10.1016/j.jchemneu.2022.102168
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Abstract

Diabetes, mobile phone use, and obesity have increased simultaneously in recent years. The radiofrequency radiation (RFR) emitted from mobile phones is largely absorbed in the heads of users. With 5G, which has started to be used in some countries without the necessary precautions being taken, the amount of RFR to which living things are exposed will increase. In this study, the changes in energy homeostasis and redox balance caused by 5G (3.5 GHz, GSM-modulated) were explored. The effects of RFR on the brains of diabetic and healthy rats were investigated and histopathological analysis was performed. Twenty-eight Wistar albino rats weighing 200–250 g were divided into 4 groups as sham, RFR, diabetes, and RFR+diabetes groups (n=7). The rats in each group were kept in a plexiglass carousel for 2 h a day for 30 days. While the rats in the experimental groups were exposed to RFR for 2 h a day, the rats in the sham group were kept under the same experimental conditions but with the radiofrequency generator turned off. At the end of the experiment, brain tissues were collected from euthanized rats. Total antioxidant (TAS), total oxidant (TOS), hydrogen peroxide (H_2O_2), ghrelin, nesfatin-1, and irisin levels were determined. In addition, histopathological analyses of the brain tissues were performed. The specific absorption rate in the gray matter of the brain was calculated as 323 mW/kg and 195 mW/kg for 1 g and 10 g averaging, respectively. After RFR exposure among diabetic and healthy rats, decreased TAS levels and increased TOS and H_2O_2 levels were observed in brain tissues. RFR caused increases in ghrelin and irisin and a decrease in nesfatin-1 in the brain. It was also observed that RFR increased the number of degenerated neurons in the hippocampus. Our results indicate that 3.5 GHz RFR causes changes in the energy metabolism and appetite of both healthy and diabetic rats. Thus, 5G may not be innocent in terms of its biological effects, especially in the presence of diabetes.

Introduction

Rapid developments in wireless communication technologies, especially mobile phones, and the intensive use of these instruments by people of all ages have led scientists to focus their attention on the human health effects of the radiofrequency radiation (RFR) emitted by these technologies. While 2G, 3G, 4G, and 4.5G technologies use radiofrequency waves of 900 MHz, 1800 MHz, and 2100 MHz, the most preferred radiofrequency band for 5G technology, which has begun to be used in many countries in recent years, is 3.5 GHz (Dasgupta et al., 2020, Wang et al., 2022). With the innovations offered by 5G technology and the application of the internet of things, the RFR exposure time and intensity of living things are increasing. The RFR emitted from mobile phones is not sufficient for the ionization of molecules and the activation of orbital electrons. It is now known that the underlying mechanism of DNA and other cellular elements affected by RFR is oxidative stress (Dasdag and Akdag, 2016; Yakymenko et al., 2016). It has been suggested that RFR (2.45 GHz, with 217 Hz pulses, during 60 min/day for 30 days, whole-body SAR 0.1 W/kg) can change cation transitions by affecting voltage-dependent channels in DRG neurons and brains of Wistar Albino rats (Nazıroğlu et al., 2012). The use of 5G with other currently used generations of technology standards with different frequencies will lead to accumulative effects (Tan et al., 2017). Cumulative biological effects are strongly related to the intensity and duration of radiofrequency exposure. The current exposure limits are based on adverse health outcomes due to temperature rise (tissue warming and inducible tissue stimulation from short-term or acute exposures) (Belpomme et al., 2018). There are no precautions for chronic and/or cumulative health risks associated with radiofrequency energy at substandard levels (Dolan and Rowley, 2009). Changes mediated by reactive oxygen species (ROS) are the most convincing mechanisms put forward to explain the effects of RFR on living things (Dasdag and Akdag, 2016, Yakymenko et al., 2016). Because the brain, a vital organ, is particularly close to the source of RFR exposure, studies on the effects of RFR have mostly focused on the brain and the brain was shown to be affected by RFR (Kim et al., 2021, Tripathi et al., 2021). In addition, brain tissues are more vulnerable to oxidative damage due to their low levels of antioxidant enzyme activity and high oxygen consumption (Motawi et al., 2014). There are a number of studies reporting that exposure to RFR at various specific absorption rate (SAR) levels causes oxidative stress in the brain (Avci et al., 2012, Chauhan et al., 2017, Chen et al., 2011, Kesari et al., 2011, Shehu et al., 2016, Singh et al., 2020). Other studies have revealed that the basis of age-related neurodegenerative diseases is imbalance in redox mechanisms (Sahin et al., 2016).

Diabetes mellitus (DM) is a disease that is spreading rapidly around the world due to the living conditions of people today and it carries with it high risks of mortality and morbidity. Studies reported that ROS and lipid peroxidation are significantly increased in rats with experimentally induced diabetes and in human patients with diabetes, and oxidative stress has a role in the etiology and progression of diabetes (Wang et al., 2018). DM is associated with increased ROS production, inadequate antioxidant defense mechanisms, and, consequently, increased oxidative stress (Bathina and Das, 2021).

Studies on mediators that have effects on nutrition in humans and animals have led researchers to focus on nesfatin and ghrelin. These are hormones that influence food intake, while irisin is one of the hormones that are effective in regulating energy metabolism (Price et al., 2007). It is accepted that appetite is controlled by the brain and eating is regulated by complex mechanisms in the central nervous system and particularly in the hypothalamus (Druce and Bloom, 2003). The level of ghrelin is increased by fasting and it decreases within 60–120 min following food intake (Tschop et al., 2001). In rats, it was shown that fasting increased ghrelin release, while carbohydrate intake decreased ghrelin release (Cummings et al., 2001). It is thought that adipose tissue and appetite-enhancing effects of ghrelin are regulated by special neurons in the central nervous system (Tschop et al., 2001).

It is known that nesfatin plays roles in the brain not only in the regulation of food intake but also in the regulation of some brain functions, autonomic regulation, stress, mood, and REM sleep (Jego et al., 2012).

Irisin is a hormone attracting the attention of researchers since its recent discovery; it is thought to have potential in the treatment of many metabolic diseases in the future, especially obesity and diabetes, and it is a highly effective peptide in neurodegeneration (Moreno-Navarrete et al., 2013).

In a recent human study, 15 normal-weight young individuals (23.47±0.68 years) were exposed to sham radiation and two different types of mobile phones emitting 900 MHz RFR (0.97 W/kg and 1.33 W/kg) under fasting conditions for 25 min. Afterwards, spontaneous food intake was determined by an ad libitum standard buffet test and cerebral energy homeostasis was monitored by phosphorus-magnetic resonance spectroscopy measurements. It was reported that exposure to both types of mobile phones strikingly increased the overall caloric intake by 22–27 % compared to the sham condition (Wardzinski et al., 2022). Moreover, measurement results of cerebral energy contents, such as the ratios of adenosine triphosphate and phosphocreatine to inorganic phosphate, showed increases with cell phone radiation exposure (Wardzinski et al., 2022). These researchers argued that RFR is a potential contributor to the overeating that underlies the obesity epidemic (Wardzinski et al., 2022). Furthermore, pulsed and amplitude modulated microwaves were shown to affect brain energy homeostasis in rats (Sanders et al., 1985). It was also demonstrated that both the brain and energy homeostasis are affected by RFR (Tripathi et al., 2021). Based on these previous findings, we hypothesized that 3.5 GHz RFR exposure affects irisin, ghrelin, and nesfatin-1 levels via oxidant and antioxidant redox systems in the brain.

The present study was designed to determine the effects of exposure to 3.5 GHz RFR (GSM, 217 Hz modulation frequency, pulse width 577 μs) emitted from 5 G technologies on total antioxidant (TAS), total oxidant (TOS), hydrogen peroxide (H_2O_2), nesfatin, ghrelin, and irisin levels in the brains of healthy and diabetic rats and possible histological changes.

Section snippets

Animal care

This experimental study was carried out in the Experimental Research and Application Center of Van Yuzuncu Yil University. All stages of the study were designed and performed according to the guidelines of the Animal Experiments Local Ethics Committee of Van Yuzuncu Yil University (Protocol No: 2021/05–10).

A total of 28 healthy male Wistar albino rats (8–10 weeks old and weighing 200–250 g) were obtained from the Experimental Animal Research Center of Van Yuzuncu Yil University. The rats were…

Results of body weight

While the average initial weight of the healthy rats was 233.5 g, it was increased to 302.5 g at the end of the RFR exposure ($p = 0.004$). There was no significant change in the weights of the diabetic rats after 5 G exposure (Table 1).…

SAR results

SAR calculations based on the IEEE/IEC 62704-1 method were used to evaluate the SAR distribution. Whole-body SAR was found to be 37 mW/kg. SAR of the gray matter of the brain was calculated as 323 mW/kg and 195 mW/kg for 1 g and 10 g averaging, respectively. The…

Discussion

There is growing concern about increasing electromagnetic pollution due to RFR emitted from wireless devices. Exposure to RFR varies from individual to individual according to the length of time and frequency of use of such devices. The 3.5 GHz band is one of the frequency bands used in 5 G technology (Dasgupta et al., 2020, Wang et al., 2022) and it was consequently selected for the present study. Older wireless telephones use frequencies in the 900, 1800, and 2100 MHz ranges. The mechanisms…

Conclusion

The data obtained in this study showed that 3.5 GHz RFR caused changes in energy metabolism and appetite in both diabetic and healthy rats. In addition, it was shown that 3.5 GHz can cause degenerative effects via oxidative damage in the brain. It was demonstrated that these effects may be more dangerous for diabetics according to the TAS, TOS, H_2O_2, ghrelin, nesfatin, and irisin levels and cresyl violet staining results. The results of this research reveal that 3.5 GHz RFR has the potential to …

Ethical statement

All experiments were performed in accordance with the guidelines provided by the Experimental Animal Laboratory and approved by the Animal Experiments Local Ethics Committee of Van Yuzuncu Yil University, Turkey (approval number: 2021/05-10). All experimental procedures were appropriate to the Guide for the Care and Use of Laboratory Animals of National Institutes of Health (NIH Publication No. 80-23; reformulated in 1996)....

Author statement

All authors read and approved the final and revised manuscript. They warrant that the article is the authors' original work, has not received prior publication and is not under consideration for publication elsewhere....

Authors' contributions

HB and **SD** designed the study. **HB** and **SA** performed the in vivo study. **HB** and **SA** performed the biochemical analysis. **FA** performed the histopathology analysis. **KY** performed SAR simulation. **HB, SD** and **ZA** wrote the manuscript, **SD** supervised all the step of the study, All authors read and approved the final manuscript....

Conflict of interests

The authors have no conflict of interest....

Acknowledgements

This work was supported by Van Yuzuncu Yil University Scientific Research Foundation (BAP, Turkey, grant number: TYD-2021-9598). The authors would like to thank Dr. Mustafa Cakir and Yusuf Emir Bektaş for their valuable contribution....

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