

5G: Probable and Possible Adverse Effects of Radiofrequency Electromagnetic Fields on Humans

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Abstract

5G communication elicits radiofrequency electromagnetic fields, which will compound those being emitted by 2G, 3G and 4G, proving potentially harmful to humans and the environment. Radiofrequency electromagnetic fields stimulate and conduce cancers in humans. Also, radiofrequency electromagnetic fields pose risks to the eyes, skin, reproductive and neurologic systems, gene expression, energy metabolism and protein synthesis (metabolic effects), cell membranes, and superficial tissues. They also cause non-specific symptoms (such as headaches, insomnia, dizziness, nausea, lack of concentration, heart palpitations, depression, and sleep disturbances). Radiofrequency electromagnetic fields contribute to oxidative stress, increasing reactive oxygen species production and oxidative damage to DNA bases. The radiation attacks the superficial layers of the skin. Recognizing the potential dangers and presumed adverse effects of 5G radiation, the World Health Organization recommends exposure limits and drafting policies for reducing risk levels in the exposed population. Governments, militaries, and industries have been supporting rapid 5G implementation without, however, determining its safety and establishing preventive measures. This research explores recent peer-reviewed studies on the biological effects of radiofrequency electromagnetic fields on humans.

Keywords: Cancer; Gene Expression; Free Radicals; Oxidative Stress; Radiofrequency Electromagnetic Fields; Wireless Communication

Abbreviations

1G: First Generation; 2G: Second Generation; 3G: Third Generation; 4G: Fourth Generation; 5G: Fifth Generation; *ERα*: Estrogen Receptor Alpha; IARC: International Agency for Research on Cancer; ICNIRP: International Commission on Non-Ionizing Radiation Protection; K+: Potassium; MMW: Millimeter Wave; RF-EMF: Radiofrequency Electromagnetic Field

Introduction

Worldwide, communication through wireless devices has been increasing at an egregious rate. The first generation (1G) of handheld mobile devices were introduced in a few countries in the late 1980s. Subsequently, the 2G, 3G, and 4G mobile devices spread to numerous countries. The next generation, 5G mobile networks, are being deployed, representing a further transformation in telecommunication technology [1].

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The biological and corporal effects of 5G communication—utilizing exceptionally high-frequency microwaves (millimeter waves [MMWs] of 1–10 mm)—are significant and legitimate public health concerns. 5G devices (along with the existing devices and networks) are likely to compound hazardous radiofrequency electromagnetic fields (RF-EMF), adversely affecting humans and the ecosystem. For more detailed comparisons of 5G to prior 2G, 3G, or 4G technology, see the Supplementary Information section.

Studies, reviewed by the International Agency for Research on Cancer (IARC), have suggested that exposure to RF-EMF (in Group 2B) may cause cancer in humans [2]. Recent studies have also linked RF-EMF to possible risks of reproductive [3], neurologic [4,5], and metabolic diseases [6,7].

RF-EMF precipitates oxidative stress [8,9] primarily through the elevated production of reactive oxygen species [10,11] and oxidative damage to DNA bases [12].

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has described the adverse reactions caused by RF radiation in humans and the environment—based, however, on a thermic model, exclusively.

There are no reports regarding the effect of exposure to RF emissions below the guideline levels (100 kHz to 300 GHz) on other health parameters, whereas few studies have published non-carcinogen-related findings falling below-guideline-level RF exposure [13,14].

Discussion

Ophthalmologic and dermatologic effects

In humans, MMWs are absorbed within 1–2 mm of the skin and the corneal surface layer. The skin contains nerve endings and capillaries. Thus, the biological effects of MMWs are posited as being transmitted through the skin's nervous system or molecular mechanisms [15].

Any adverse effects of 5G radiation are attributed to the radiation's inherent nature and its relation to tissues and other target structures. At these wavelengths, resonance phenomena with superficial human structures [16] and insect or insect components can be observed.

The current literature and media point out that 5G radiation mainly affects surface structures, leading to skin neoplasm, other skin conditions, and cataracts. However, further evidence reveals that biological responses to MMWs commence in the skin, and the subsequent molecular mechanisms in the skin can lead to physiological effects on the nervous, cardiovascular, and immune systems [17].

Carcinogenic effects

Bortkiewicz, *et al.* (2014), in a meta-analysis involving 24 case-control studies (cases: 26,846; controls: 50,013), reported a higher risk of the intracranial tumor (in those using mobile phone for > 10 years) and glioma in the ipsilateral location [18].

Lerchl, *et al.* (2015) reported that RF-EMF affected the lungs and livers of mice at levels of 0.04 and 0.4W/kg SAR, below the current exposure limits of 10 mW/cm² over a 30-min period [19].

In another rat study, exposure to RF radiation from a GSM device for about 4h adversely affected methylation by the estrogen receptor alpha (*ERα*), associated with cancer of the colon and rectum [20].

Reproductive effects

In 2017, Lewis, *et al.* conducted a longitudinal cohort study involving 153 men attending a fertility clinic. Their findings suggested that

the duration of mobile phone use and headphone use did not undermine the quality of the semen samples [21].

Houston, *et al.* (2016) identified 21 out of 27 studies documenting specific adverse effects (i.e., impaired sperm motility, heightened ROS promotion and damage to DNA, and reduced antioxidant level) due to mobile phone exposure [22].

Metabolic effects

Wang, *et al.* (2016) investigated 1073 power plant personnel, determining that exposure to a combination of RF-EMF and low-frequency EMF resulted in a positive correlation with abnormal serum low-density-lipid-cholesterol levels; however, total cholesterol and high-density lipid and triglyceride levels were essentially unaffected [23].

Shahbazi-Gahrouei, *et al.* (2016) determined that there were no effects on insulin release when rats were exposed to RF radiation (SAR 2 W/kg) at 6 h/day for 1 week. Liver and pancreas damage were noted, such as inflammatory changes in the portal spaces and damaged cells in the islet of Langerhans, respectively, based on the length of radiation exposure [24].

In an *in vitro* study, researchers found that RF-EMF from a GSM mobile phone lessened the viability of cells and propagation of human mesenchymal adipose-derived stem cells, correlating with length of radiation exposure [25].

Neurologic effects

In an animal study, adolescent rats exposed to RF-EMF did not incur damage to brain tissues compared to sham-exposed control animals [26]. Also, there were no harmful effects following long-term RF-EMF exposure on neurological development, learning skills, and behavior in female Wistar rats [26]. Nevertheless, exposure to 835MHz of RF-EMF greatly diminished specific brain structures in mice [27].

In a murine model, the subjects were exposed to RF-EMF at 0, 1.5, or 6 W/kg SAR for 15 min propagation. Long-term memory was reduced in the animals due to the RF-EMF-induced astrogliosis [5].

In another rat study, the RF-EMF-exposed animals exhibited spatial memory loss compared to unexposed rats [28]. Mice exposed to RF-EMF for 5 h/day during 12 weeks demonstrated myelin sheath damage and corresponding aberrant behaviors [29].

A Dutch cohort study revealed abnormal behavior in specific children due to mobile phone use by the mothers [30]. A similar but larger study showed a heightened incidence of behavioral issues in children of cell phone-using mothers during pregnancy compared to offspring of mothers who were not cell phone users during pregnancy. Residual concerns, however, derive from certain uncontrolled confounding factors [31].

A separate study revealed aberrations in sleep patterns and other sleep-cycle parameters relative to the proximity to mobile phone base stations [32].

In a cross-sectional survey involving 2150 students, increased headaches, fatigue, and sleep disturbance were noted in mobile phone users. These effects demonstrated a dose-response relationship. In the same study, limited associations with vicinity to base stations and lack of relationships with measured EMF levels were noted [33].

A murine-familial Alzheimer's disease model was used to study the long-term effects of RF-EMF exposure on Alzheimer's disease. RF-EMF at 1950 MHz and 5.0 W/kg SAR for 2 h/day and 5 days/week for 8 months improved cognitive deficits in the exposed mice [34].

However, in a meta-analysis, no distinction was noted regarding the impact of electromagnetic radiation emitted by GSM phones on working memory in humans compared to sham-exposed individuals [35]. Thus, further studies on this topic are indicated.

Effects on the cell membrane and superficial tissues

Studies have reported that the extensive surface effects of low-intensity MMWs can result in numerous biological changes, including cell membrane effects, at non-thermal levels. MMWs in the range of 95 GHz affect cutaneous nociceptors and function as a threatening stimulus without causing heating or thermal damage.

Sweat glands, filled with a conductive aqueous solution, may be a conduit of MMWs, affecting adjacent vessels and tissues [36].

Effects on gene expression

Another study indicated that MMWs may not effect genes [37]. However, MMWs altered specific genes mechanisms in human keratinocytes treated with a glycolysis inhibitor (2-deoxyglucose). The findings highlighted concerns about the negative long-term effects of MMW exposure on metabolically-stressed cells [38].

Effects on bacteria

Cohen., *et al.* (2010) investigated MMWs and the viability of specific bacteria, finding bacterial activity unaffected. Moreover, exposure to MMWs did not elicit any adverse effects on bacterial metabolic activity [39].

Another study demonstrated that altered (depressed) bacterial growth and activity following exposure to MMWs positively affected microorganisms' sensitivity to active chemicals, including antibiotics [40], indicating unrelated thermic effects [41].

Effects on energy metabolism and protein synthesis

MMWs promote extracellular matrix synthesis and cell proliferation in chondrocytes, increasing their energy metabolism and protein synthesis by possibly modulating the voltage-gated potassium (K⁺) channel [42]. On the contrary, MMW exposure had anti-proliferative effects on cultured erythromyeloid leukemia cells (K562). The effect was associated with an increase in the glycolytic aerobic pathway activity [43]; however, other specific cells were unaffected [44,45].

Non-specific effects

The 5G spectrum may induce electromagnetic sensitivity, characterized by a myriad of symptoms. In a healthy mice study, researchers concluded that MMWs have a profound effect on non-specific immunity [46].

Lushnikov., *et al.* (2004) investigated cell-mediated immunity and non-specific inflammatory response in mice exposed to low-intensity EHF EMR (42.0 GHz, 0.1 mW/cm², 20 min daily). The researchers reported that radiation suppresses both non-specific and cell-mediated immune responses [47].

Prevention or amelioration of the probable and possible adverse effects of 5G

According to the World Health Organization principle, "New RF-EMF communication network development must be paralleled by the adequate, active involvement of public environmental health institutions by providing recommendations on exposure limits and drafting policies for reducing risk levels in the exposed population" [48].

A practical understanding of RF-WMF relating to health risks (including cancer and non-communicable diseases) is fundamental for any clinician [49,50]. The additional exposure of 5G to an already complex amalgamation of wireless frequencies may further compromise the global population's physical and mental health.

Governments, militaries, and industries have been supporting rapid 5G implementation. However, these organizations must first demonstrate that 5G (and previous generations of mobile networking technology) is safe and trustworthy.

Conclusion

Extensive laboratory and epidemiological data currently exist, demonstrating significant health impacts of the previous generations of wireless networking technology. Most of these data were obtained under non-real-world conditions. The adverse effects would be significantly increased if real-world data, including information content of signals, carrier frequencies, and other toxic stimuli combined with the wireless radiation, were considered.

The addition of 5G radiation with existing toxic wireless radiation is bound to exacerbate adverse health effects. Moreover, further studies are needed to confirm potential 5G-related health effects before its complete and inevitable enactment.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Supplementary Information

The reader is referred to a comprehensive article and resource, entitled "5G Telecommunications Science", published in *Physicians for Safe Technology*. Scientific Literature Updated 10/9/20. According to this encyclopedic report, 5G technology differs from 2G, 3G, or 4G technology as follows:

- "Frequencies (Cycles per second): One MHz is 1 million cycles per second. One GHz is 1 billion cycles per second. 4G uses several different frequencies from 750MHz to about 2,400-5,000 MHz(2.4 GHz to 5 GHz- typical Wi Fi and cell phone) – 5G (proposed 5th generation) uses 10GHz to 300GHz, but lower frequencies will also be used and the frequencies and speed will vary with each carrier i.e. 600 MHz will be used by T Mobile. Sprint will use 2.5GHz, called mid-band, which will penetrate walls. PC Magazine on April 16, 2019 notes, 'The actual 5G radio system, known as 5G-NR, isn't compatible with 4G. But all 5G devices in the US, to start, will need 4G because they'll lean on it to make initial connections before trading up to 5G where it's available. That's technically known as a *non standalone*, or NSA, network.' <https://www.pcmag.com/article/345387/what-is-5g>
- Length of the Wave: 4G electromagnetic wavelengths are inches to feet long – 5G (6 to 300GHz) frequencies are very short and measured in centimeters to millimeters, but again lower frequencies will also be used, creating a mix of frequencies and therefore wavelengths.
- Depth of Skin and Body Absorption: 4G microwave radiation (2.4GHz and 5 GHz) passes through bodies and the energy is absorbed by anything that contains water (can't cook dry rice in a microwave oven), while 5G (6 to 300GHz) penetrates

only the outer layers of the skin in humans. Again the mix of frequencies in cell towers and cell phones will have a mix of skin and body penetration

- Distance Radiation Travels: 4G can travel dozens of miles in a line of sight and if poles are placed high. In experiments 5G (6 to 300GHz) can travel a few miles but is easily blocked by objects, trees and plants thus poles are planned for every 300 feet in cities
- Mechanisms of Harm: 4G and low band 5G (600MHz) emissions can cause oxidation of tissues (93 of 100 studies), 5G (6 to 300GHz) millimeter wavelengths can have their effect through heat (tissue destruction), through a resonance effect of increased vibration in an object the size of the wavelengths, and at low power levels through signaling of skin structures that can affect metabolism, the nervous system, the endocrine system, the reproductive system (Declassified Military studies)
- Amount of Testing Done: 4G technology has been tested by the military and by international scientists with an abundance of studies showing broad harm to animals, humans, plants, insects and bacteria. 5G (6 to 300GHz) technology has been studied by some in the military showing broad harm and some newer studies are showing damage to insects, tissue burns and overheating with streaming of data, but there has been no independent safety testing of 5G before it is rolled out.” [51]

The *Physicians for Safe Technology* article continues with risks from 5G, which include:

- “Damage to the eyes- cataracts, retina
- Immune system disruption
- Metabolic disruption
- Damage to sperm
- Skin damage
- Collapse of insect populations, the base of food for birds and bats
- Rise in bacterial resistance and bacterial shifts on skin and in ecosystems
- Damage to plants and trees” [51]

The entire article can be viewed by accessing this link: <https://mdsafetech.org/5g-telecommunications-science/>.

References

1. Kostoff RN and Lau CGY. “Modified Health Effects of Non-ionizing Electromagnetic Radiation Combined with Other Agents Reported in the Biomedical Literature”. In: Geddes C, (eds) *Microwave Effects on DNA and Proteins*. Springer, Cham (2017): 99-157. https://link.springer.com/chapter/10.1007/978-3-319-50289-2_4
2. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields”. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* 102.2 (2013): 1-460. <https://pubmed.ncbi.nlm.nih.gov/24772662/>
3. Sepehrimanesh M., *et al.* “Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure”. *Environmental Science and Pollution Research* 24.15 (2017): 13666-13673. <https://pubmed.ncbi.nlm.nih.gov/28397118/>

4. Kim JH., *et al.* "Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice". *Scientific Reports* 7.1 (2017): 1-2. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5247706/>
5. Barthélémy A., *et al.* "Glial markers and emotional memory in rats following acute cerebral radiofrequency exposures". *Environmental Science and Pollution Research* 23.24 (2016): 25343-25355. <https://pubmed.ncbi.nlm.nih.gov/27696165/>
6. Lin KW., *et al.* "Exposure of ELF-EMF and RF-EMF increase the rate of glucose transport and TCA cycle in budding yeast". *Frontiers in Microbiology* 7 (2016): 1378. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5005349/>
7. Shahbazi-Gahrouei D., *et al.* "Effects of RF-EMF exposure from GSM mobile phones on proliferation rate of human adipose-derived stem cells: An in-vitro study". *Journal of Biomedical Physics and Engineering* 6.4 (2016): 243. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5219575/>
8. Dasdag S and Akdag MZ. "The link between radiofrequencies emitted from wireless technologies and oxidative stress". *Journal of Chemical Neuroanatomy* 75 (2016): 85-93. <https://pubmed.ncbi.nlm.nih.gov/26371078/>
9. Yakymenko I., *et al.* "Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation". *Electromagnetic Biology and Medicine* 35.2 (2016): 186-202. <https://pubmed.ncbi.nlm.nih.gov/26151230/>
10. Chauhan P., *et al.* "Microwave radiation (2.45 GHz)-induced oxidative stress: Whole-body exposure effect on histopathology of Wistar rats". *Electromagnetic Biology and Medicine* 36.1 (2017): 20-30. <https://pubmed.ncbi.nlm.nih.gov/27362544/>
11. Houston BJ., *et al.* "The effects of radiofrequency electromagnetic radiation on sperm function". *Reproduction* 152.6 (2016): R263-R276. <https://pubmed.ncbi.nlm.nih.gov/27601711/>
12. Duan W., *et al.* "Comparison of the genotoxic effects induced by 50 Hz extremely low-frequency electromagnetic fields and 1800 MHz radiofrequency electromagnetic fields in GC-2 cells". *Radiation Research* 183.3 (2015): 305-314. <https://pubmed.ncbi.nlm.nih.gov/25688995/>
13. Scientific Committee on Emerging Newly Identified Health Risks. Opinion on potential health effects of exposure to electromagnetic fields". *Bioelectromagnetics* 36.6 (2015): 480-484. <https://pubmed.ncbi.nlm.nih.gov/26179386/>
14. Simkó M and Mattsson MO. "5G wireless communication and health effects—a pragmatic review based on available studies regarding 6 to 100 GHz". *International Journal of Environmental Research and Public Health* 16.18 (2019): 3406. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6765906/>
15. Moskowitz J. "5G wireless technology: millimeter wave health effects". *Electromagnetic Radiation Safety* 3 (2017): 3-6. https://ecf-sapi.fcc.gov/file/10504289508154/200420_SaferEMR%20Millimeter%20Wave%20Studies.pdf
16. Betzalel N., *et al.* "The human skin as a sub-THz receiver—Does 5G pose a danger to it or not?" *Environmental Research* 163 (2018): 208-216. <https://www.sciencedirect.com/science/article/abs/pii/S0013935118300331>
17. Russell CL. "5 G wireless telecommunications expansion: Public health and environmental implications". *Environmental Research* 165 (2018): 484-495. <https://www.sciencedirect.com/science/article/abs/pii/S0013935118300161>
18. Bortkiewicz A., *et al.* "Mobile phone use and risk for intracranial tumors and salivary gland tumors-A meta-analysis". *International Journal of Occupational Medicine and Environmental Health* 30.1 (2017): 27-43. <http://ijomeh.eu/Mobile-phone-use-and-risk-for-intracranial-tumors-and-salivary-gland-tumors-A-meta-analysis,63713,0,2.html>
19. Lerchl A., *et al.* "Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans". *Biochemical and Biophysical Research Communications* 459.4 (2015): 585-590. <https://pubmed.ncbi.nlm.nih.gov/25749340/>

20. Mokarram P, *et al.* "Effect of exposure to 900 MHz GSM mobile phone radiofrequency radiation on estrogen receptor methylation status in colon cells of male sprague dawley rats". *Journal of Biomedical Physics and Engineering* 7.1 (2017): 79. <https://pubmed.ncbi.nlm.nih.gov/28451581/>
21. Lewis RC, *et al.* "EARTH Study Team. Self-reported mobile phone use and semen parameters among men from a fertility clinic". *Reproductive Toxicology* 67 (2017): 42-47. <https://pubmed.ncbi.nlm.nih.gov/27838386/>
22. Houston BJ, *et al.* "The effects of radiofrequency electromagnetic radiation on sperm function". *Reproduction* 152.6 (2016): R263-R276. <https://pubmed.ncbi.nlm.nih.gov/27601711/>
23. Mortazavi SM, *et al.* "GSM 900 MHz microwave radiation-induced alterations of insulin level and histopathological changes of liver and pancreas in rat". *Journal of Biomedical Physics and Engineering* 6.4 (2016): 235. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5219574/>
24. Shahbazi-Gahrouei D, *et al.* "Effects of RF-EMF exposure from GSM mobile phones on proliferation rate of human adipose-derived stem cells: An in-vitro study". *Journal of Biomedical Physics and Engineering* 6.4 (2016): 243. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5219575/>
25. Stasinopoulou M, *et al.* "Effects of pre-and postnatal exposure to 1880–1900 MHz DECT base radiation on development in the rat". *Reproductive Toxicology* 65 (2016): 248-262. <https://www.sciencedirect.com/science/article/abs/pii/S0890623816303185>
26. Klose M, *et al.* "Effects of early-onset radiofrequency electromagnetic field exposure (GSM 900 MHz) on behavior and memory in rats". *Radiation Research* 182.4 (2014): 435-447. <https://pubmed.ncbi.nlm.nih.gov/25251701/>
27. Kim JH, *et al.* "Changes in numbers and size of synaptic vesicles of cortical neurons induced by exposure to 835 MHz radiofrequency-electromagnetic field". *PLoS One* 12.10 (2017): e0186416. <https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0186416.g001>
28. Tang J, *et al.* "Exposure to 900 MHz electromagnetic fields activates the mmp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats". *Brain Research* 1601 (2015): 92-101. <https://pubmed.ncbi.nlm.nih.gov/25598203/>
29. Kim JH, *et al.* "Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice". *Scientific Reports* 7.1 (2017): 1-2. <https://www.nature.com/articles/srep41129>
30. Guxens M, *et al.* "Maternal cell phone and cordless phone use during pregnancy and behaviour problems in 5-year-old children". *Journal of Epidemiology and Community Health* 67.5 (2013): 432-438. <https://pubmed.ncbi.nlm.nih.gov/23386674/>
31. Birks L, *et al.* "Maternal cell phone use during pregnancy and child behavioural problems in five birth cohorts". *Environment International* 104 (2017): 122-131. <https://pubmed.ncbi.nlm.nih.gov/28392066/>
32. Martens AL, *et al.* "Modeled and perceived exposure to radiofrequency electromagnetic fields from mobile-phone base stations and the development of symptoms over time in a general population cohort". *American Journal of Epidemiology* 186.2 (2017): 210-219. <https://pubmed.ncbi.nlm.nih.gov/28398549/>
33. Durusoy R, *et al.* "Mobile phone use, school electromagnetic field levels and related symptoms: a cross-sectional survey among 2150 high school students in Izmir". *Environmental Health* 16.1 (2017): 1-4. <https://pubmed.ncbi.nlm.nih.gov/28577556/>
34. Son Y, *et al.* "Long-term RF exposure on behavior and cerebral glucose metabolism in 5xFAD mice". *Neuroscience Letters* 666 (2018): 64-69. https://www.researchgate.net/publication/321927308_Long-term_RF_exposure_on_behavior_and_cerebral_glucose_metabolism_in_5xFAD_mice
35. Zubko O, *et al.* "Effects of electromagnetic fields emitted by GSM phones on working memory: a meta-analysis". *International Journal of Geriatric Psychiatry* 32.2 (2017): 125-135. <https://pubmed.ncbi.nlm.nih.gov/27645289/>

36. Feldman Y, *et al.* "The electromagnetic response of human skin in the millimetre and submillimetre wave range". *Physics in Medicine and Biology* 54.11 (2009): 3341. https://www.researchgate.net/publication/24415748_The_electromagnetic_response_of_human_skin_in_the_millimetre_and_submillimetre_wave_range
37. Koyama S, *et al.* "Effects of long-term exposure to 60 GHz millimeter-wavelength radiation on the genotoxicity and heat shock protein (HSP) expression of cells derived from human eye". *International Journal of Environmental Research and Public Health* 13.8 (2016): 802. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4997488/>
38. Soubere Mahamoud Y, *et al.* "Additive effects of millimeter waves and 2-deoxyglucose co-exposure on the human keratinocyte transcriptome". *PloS one* 11.8 (2016): e0160810. <https://pubmed.ncbi.nlm.nih.gov/27529420/>
39. Cohen I, *et al.* "Effect of 99 GHz continuous millimeter wave electro-magnetic radiation on E. coli viability and metabolic activity". *International Journal of Radiation Biology* 86.5 (2010): 390-399. <https://pubmed.ncbi.nlm.nih.gov/20397844/>
40. Torgomyan H and Trchounian A. "The enhanced effects of antibiotics irradiated of extremely high frequency electromagnetic field on Escherichia coli growth properties". *Cell Biochemistry and Biophysics* 71.1 (2015): 419-424. <https://pubmed.ncbi.nlm.nih.gov/25164112/>
41. Soghomonyan D, *et al.* "Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria?" *Applied Microbiology and Biotechnology* 100.11 (2016): 4761-4771. <https://europemc.org/article/med/27087527>
42. Li X, *et al.* "Millimeter wave promotes the synthesis of extracellular matrix and the proliferation of chondrocyte by regulating the voltage-gated K⁺ channel". *Journal of Bone and Mineral Metabolism* 32.4 (2014): 367-377. <https://pubmed.ncbi.nlm.nih.gov/24202060/>
43. Chidichimo G, *et al.* "Selective inhibition of tumoral cells growth by low power millimeter waves". *Anticancer Research* 22.3 (2002): 1681-1688. <https://pubmed.ncbi.nlm.nih.gov/12168854/>
44. Beneduci A. "Evaluation of the potential in vitro antiproliferative effects of millimeter waves at some therapeutic frequencies on RPMI 7932 human skin malignant melanoma cells". *Cell Biochemistry and Biophysics* 55.1 (2009): 25-32. <https://pubmed.ncbi.nlm.nih.gov/19536459/>
45. Yaekashiwa N, *et al.* "Investigation of the non-thermal effects of exposing cells to 70–300 GHz irradiation using a widely tunable source". *Journal of Radiation Research* 59.2 (2018): 116-121. <https://pubmed.ncbi.nlm.nih.gov/29281029/>
46. Kolomytseva MP, *et al.* "Suppression of nonspecific resistance of the body under the effect of extremely high frequency electromagnetic radiation of low intensity". *Biofizika* 47.1 (2002): 71-77. <https://pubmed.ncbi.nlm.nih.gov/11855293/>
47. Lushnikov KV, *et al.* "Effects of low-intensity ultrahigh frequency electromagnetic radiation on inflammatory processes". *Bulletin of Experimental Biology and Medicine* 137.4 (2004): 364-366. <https://link.springer.com/article/10.1023/B:BEBM.0000035131.54215.ca>
48. Hardell L. "World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review)". *International Journal of Oncology* 51.2 (2017): 405-413. <https://pubmed.ncbi.nlm.nih.gov/28656257/>
49. Wu S, *et al.* "Substantial contribution of extrinsic risk factors to cancer development". *Nature* 529.7584 (2016): 43-47. <https://www.nature.com/articles/nature16166>
50. Prüss-Ustün A, *et al.* "Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health". *Journal of Public Health* 39.3 (2017): 464-475. <https://pubmed.ncbi.nlm.nih.gov/27621336/>
51. 5G Telecommunications Science. (updated 2020 Oct 9). Physicians for Safe Technology. Retrieved 02/07/21 from <https://mdsafetech.org/5g-telecommunications-science/>

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