



Cellphone Radio Frequency Radiation Studies

Cellphones are used by 97% of American adults.¹ Given the large number of users, any harmful effects associated with cellphone use could be a significant public health concern.

Cellphones use radio frequency radiation (RFR) to transmit signals. The U.S. Food and Drug Administration (FDA) nominated RFR for study by the National Toxicology Program (NTP), due to widespread human exposure and limited information about the potential health effects of long-term cellphone use.

What did NTP study?

NTP conducted toxicology studies in rats and mice to help clarify potential health hazards, including cancer risk, from exposure to RFR used in 2G and 3G cellphones. 2G and 3G networks were standard when the studies were designed and are still used for phone calls and texting.

The NTP studies, completed in 2018, are the most comprehensive assessment, to date, of health effects in animals exposed to RFR.



What did the studies find?

In studies of high levels of RFR, like that used in 2G and 3G cellphones, NTP found:

- **Clear evidence of an association with tumors in the hearts of male rats.** The tumors were malignant schwannomas.
- **Some evidence of an association with tumors in the brains of male rats.** The tumors were malignant gliomas.
- **Some evidence of an association with tumors in the adrenal glands of male rats.** The tumors were benign, malignant, or complex combined pheochromocytoma.

For female rats, and male and female mice, it was unclear, also known as equivocal, whether cancers observed in the studies were associated with exposure to RFR.

The conclusions were based on NTP's four categories of evidence that a substance may cause cancer:

- Clear evidence (highest)
- Some evidence
- Equivocal evidence
- No evidence (lowest)

If you are concerned about potential health risks from RFR, the FDA suggests the following tips:²

- Use speaker mode, headset, headphones, or earbuds to place more distance between your head and the cellphone.
- Reduce the amount of time spent using your cellphone.
- Consider texting rather than talking – but don't text while you are driving.





Do the rat and mouse findings apply to humans?

The findings in animals cannot be directly applied to humans for two key reasons:

- The exposure levels and durations were greater than what people may receive from cellphones.
- The rats and mice received RFR across their whole bodies, which is different from the more localized exposures humans may receive, like from a cellphone in their pocket or next to their head.

However, the studies question the long-held assumption that RFR is of no concern as long as the energy level is low and does not significantly heat the tissues.

Still, the effects observed in the animals were relatively rare. NTP scientists are not sure why male rats appear to be at greater risk for developing tumors compared to female rats.

How do the RFR levels used in the studies compare to typical human exposures?

The lowest exposure level used in the studies was equal to the maximum exposure to the local tissue (cells) currently allowed for cellphone users. This power level rarely occurs with typical cellphone use. The highest exposure level in the studies was four times higher than the maximum power level permitted for local tissues.



Did NTP find health effects other than cancer?

NTP found lower body weights among newborn rats and their mothers, especially when exposed to high levels of RFR during pregnancy and lactation, yet these animals grew to normal size. They also found that RFR exposure was associated with an increase in DNA damage. DNA damage, if not repaired, can potentially lead to tumors. Specifically, they found RFR exposure was linked with significant increases in DNA damage in the frontal cortex of the brain in male mice, the blood cells of female mice, and the hippocampus of male rats.

What factors contributed to the NTP conclusions?

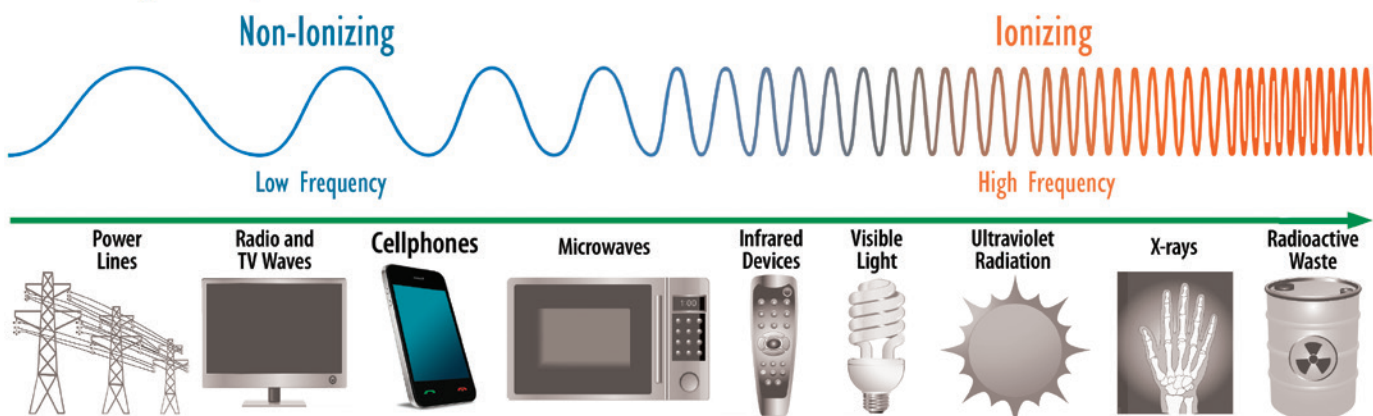
In addition to seeing tumors in the male rats with higher exposures to RFR, NTP scientists also observed other changes in the hearts of exposed male and female rats that supported their conclusions.

The evidence for tumors in the brain and adrenal glands was not as strong as what NTP scientists saw in the heart. However, the type of brain cancer observed is similar to a type of brain tumor linked to heavy cellphone use in some human studies.³

Why did NTP expose the animals' whole bodies to RFR?

Although many previous studies focused on exposure to the brain, NTP scientists wanted to make sure that they were considering health effects to the whole body, especially since many people do not hold their phones next to their head much of time.

Electromagnetic Spectrum



RFR used in cellphones is at the lower frequency and lower energy end of the electromagnetic spectrum.



What is the difference between electric and magnetic fields and RFR?

RFR is a subcategory of electric and magnetic fields (EMF), which are the invisible waves of force that surround any electrical device. The different types of EMF are distinguished by their frequencies. RFR is a form of low frequency, non-ionizing radiation that was thought to be relatively harmless.

How were the studies conducted?

Rats and mice were exposed to RFR in special chambers for up to two years, or most of their natural lives. NTP scientists looked for a range of cancers and noncancer health effects.

Exposure to RFR began in the womb for rats and at 5-6 weeks old for mice. The RFR exposure was intermittent, 10 minutes on and 10 minutes off, totaling about nine hours each day. The RFR levels ranged from 1.5 to 6 watts per kilogram of body weight in rats, and 2.5 to 10 watts per kilogram in mice.

The chambers were shielded rooms with a transmitting antenna that radiated RFR fields, plus rotating stirrers that generated a uniform field.^{4,5} Pilot studies established field strengths that did not raise animal body temperatures excessively.⁶

The rats and mice were exposed to whole body RFR at frequencies of 900 and 1,900 megahertz, respectively, from two technologies – Code Division Multiple Access (CDMA) and Global System for Mobile Communications (GSM).

NTP and RFR experts from the National Institute of Standards and Technology (NIST) and the IT'IS Foundation designed and built the chambers specifically for these studies.



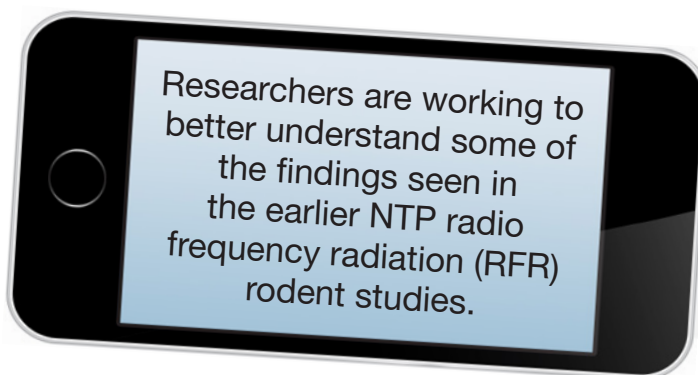
Chambers at the IIT Research Institute in Chicago where the studies took place.

What is the difference between CDMA and GSM?

CDMA and GSM are two common ways of transmitting cellphone signals in the U.S. and Europe. There are substantial differences in signal structure that may result in different RFR exposures, so NTP wanted to expose the animals to both modulations.

How do the NTP studies relate to 4G, 5G, or Wi-Fi?

NTP studies of RFR used in 2G and 3G cellphones do not apply to 4G or 5G technologies. These newer technologies use different methods of signal modulation than NTP used in the studies. The NTP studies also did not investigate frequencies and modulations used for Wi-Fi.



What are the future plans for studying cellphone RFR?

NIEHS scientists in the Division of Translational Toxicology, which supports the NTP, are working to better understand findings reported in its earlier RFR studies.^{7,8}

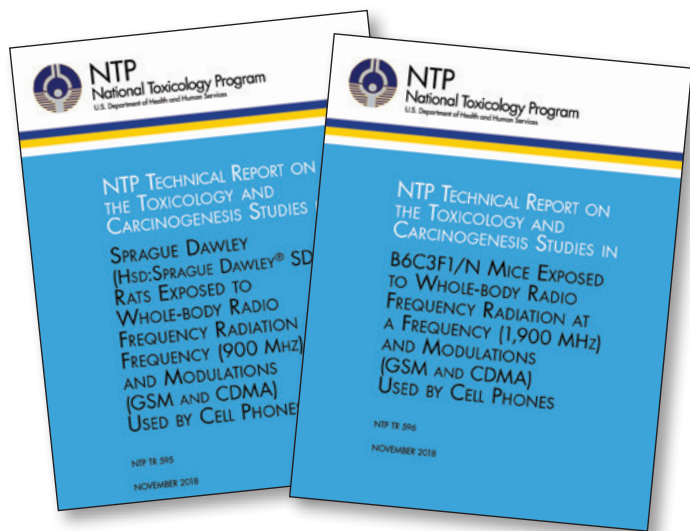
The researchers have overcome several technical issues while developing a new RFR exposure system for the planned rodent studies and are now making progress in accomplishing the following research goals:

- **Determine the impact of RFR exposure on behavior and stress, including the real-time assessment of activity and response to system-generated noise and RFR signals.**
- **Conduct physiological monitoring, including evaluation of heart rate.**
- **Investigate whether RFR induces heating.**
- **Further evaluate whether RFR exposure causes DNA damage.**



Several short-term studies have already been conducted to evaluate approaches to assess physiological changes using real-time monitoring of animals during RFR exposure and to evaluate whether RFR exposure causes DNA damage.

Data from these studies are being evaluated and interpreted, and once complete, manuscripts will be written and submitted for peer review.



Final reports and data tables are available on the NTP website at <https://ntp.niehs.nih.gov/go/cellphone>.

Where can I go for more information?

For more information on what the NTP and federal agencies are doing to determine whether RFR used in cellphones may affect human health, visit the following websites:

National Toxicology Program

<https://ntp.niehs.nih.gov/go/cellphone>

National Cancer Institute

<https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/cell-phones-fact-sheet>

U.S. Food and Drug Administration

<https://go.usa.gov/B5tx>

Federal Communications Commission

<https://fcc.gov/consumers/guides/wireless-devices-and-health-concerns>

The National Toxicology Program is an interagency program headquartered at the **National Institute of Environmental Health Sciences** that tests and evaluates chemicals in our environment.

For more information on NTP, go to <https://ntp.niehs.nih.gov>.

¹ Pew Research Center. 2021. Mobile Fact Sheet. Available: <https://pewinternet.org/fact-sheet/mobile> [accessed February 6, 2023].

² FDA (U.S. Food and Drug Administration). 2020. Reducing Radio Frequency Exposure from Cell Phones. Available: <https://www.fda.gov/radiation-emitting-products/cell-phones/reducing-radio-frequency-exposure-cell-phones> [accessed February 6, 2023].

³ IARC (International Agency for Research on Cancer). 2013. Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields. IARC Monogr Eval Carcinog Risks Hum 102:1-481.

⁴ Capstick MH, Kuehn S, Berdinas-Torres V, Gong Y, Wilson PF, Ladbury JM, Koepke G, McCormick DL, Gauger J, Melnick RL, Kuster N. 2017. A radio frequency radiation exposure system for rodents based on reverberation chambers. IEEE T Electromagn C 59(4):1041-1052.

⁵ Gong Y, Capstick MH, Kuehn S, Wilson PF, Ladbury JM, Koepke G, McCormick DL, Melnick RL, Kuster N. 2017. Life-time dosimetric assessment for mice and rats exposed in reverberation chambers for the two-year NTP cancer bioassay study on cell phone radiation. IEEE T Electromagn C 59(6):1798-1808.

⁶ Wyde ME, Horn TL, Capstick MH, Ladbury JM, Koepke G, Wilson PF, Kissling GE, Stout MD, Kuster N, Melnick RL, Gauger J, Bucher JR, McCormick DL. 2018. Effect of cell phone radiofrequency radiation on body temperature in rodents: Pilot studies of the National Toxicology Program's reverberation chamber exposure system. Bioelectromagnetics 39(3):190-199.

⁷ NTP Technical Report on the Toxicology and Carcinogenesis Studies in Sprague Dawley (Hsd:Sprague Dawley® SD®) Rats Exposed to Whole-body Radio Frequency Radiation at a Frequency (900 Mhz) and Modulations (GSM and CDMA) Used by Cell Phones. Technical Report 595. November 2018.

⁸ NTP Technical Report on the Toxicology and Carcinogenesis Studies in B6C3F1/N Mice Exposed to Whole-body Radio Frequency Radiation at a Frequency (1,900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones. Technical Report 596. November 2018.