



Cellphone Radio Frequency Radiation Studies

Cellphones are used by 95% 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 \$30 million NTP studies took more than 10 years to complete and are the most comprehensive assessment, to date, of health effects in animals exposed to RFR. The results will help guide other studies of newer technologies.



What did the studies find?

NTP studies found that exposure to high levels of RFR, like that used in 2G and 3G cellphones, was associated with:

- **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 or a headset to place more distance between your head and the cellphone.
- Reduce the amount of time spent using your cellphone.





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 radio frequency radiation is of no concern as long as the energy level is low and does not significantly heat the 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

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?

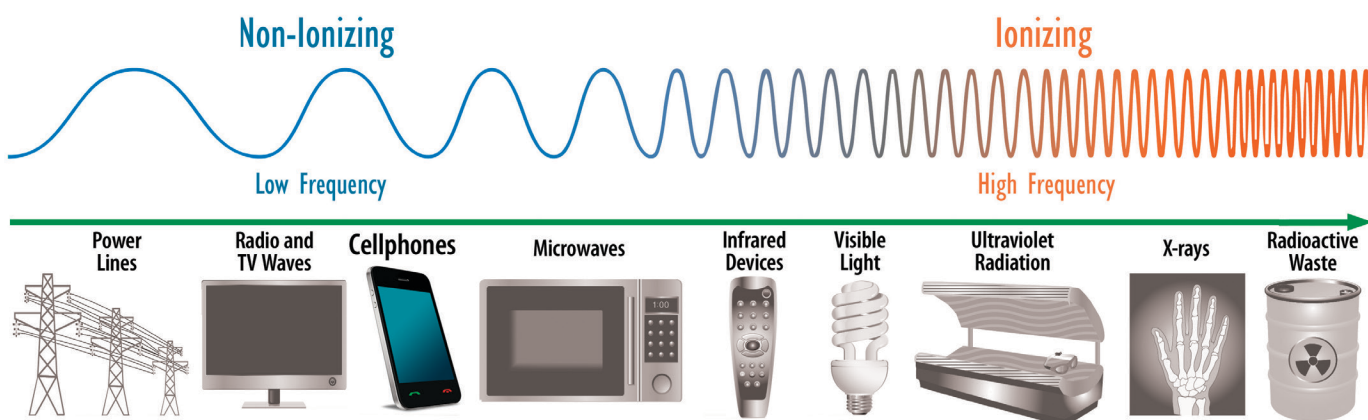
The lowest exposure level used in the studies was equal to the maximum local tissue exposure currently allowed for cellphone users. This power level rarely occurs with typical cellphone use. The highest exposure level in the studies was four times higher than the maximum power level permitted for local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



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 1900 megahertz, respectively, from two technologies – Code Division Multiple Access (CDMA) and Global System for Mobile Communications (GSM).

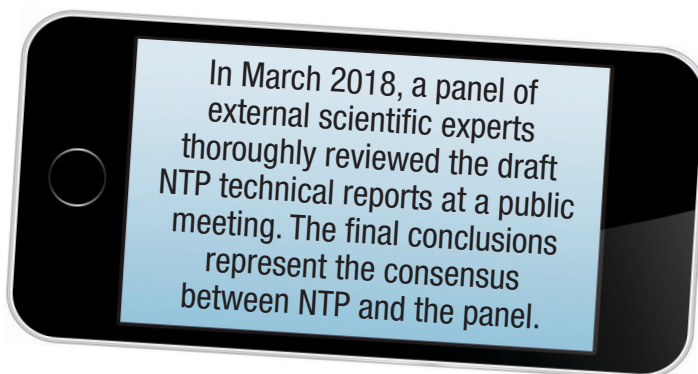
NTP and RFR experts from the National Institute of Standards and Technology (NIST) and the IT'IS Foundation designed and built the chambers specifically for these studies.



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 were the studies' strengths?

NTP was able to control exactly how much RFR the animals received — something that is not possible when studying human cellphone use.

Were there any surprise findings?

NTP found longer lifespans among the exposed male rats. This may be explained by an observed decrease in chronic kidney problems that are often the cause of death in older rats.

What will NTP do with the results of the studies?

NTP will provide these studies to the FDA and Federal Communications Commission. The agencies will review the information as they continue to monitor new research on the potential health effects of RFR.

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



What are NTP's future plans for studying cell phone RFR?

NTP is working to better understand the biological basis for the cancer findings reported in its earlier RFR studies. The program has developed smaller RFR exposure chambers for additional short-term studies that will take weeks and months to complete rather than years. NTP aims to better understand the underlying effects of RFR on biological systems, such as looking at biomarkers of damage. The biomarkers are measurable physical changes, such as DNA damage, that can be seen in shorter amounts of time than it takes to develop cancer and that might be predictive of disease. NTP scientists also want to know if heat or exposure-related stress plays a role in cancer development.

With 5G technology on the horizon, many questions have been raised about what this means with respect to human exposures to RFR. One significant difference between 5G networks and the current networks is that 5G will utilize a broader range of frequencies, including those much higher than NTP previously evaluated (> 6000 MHz). The lower frequency ranges that are currently in use (700-2700 MHz) remain relevant since they will continue to be used in the existing cellular communication networks, as well as the 5G network. The higher frequencies, known as millimeter waves, can rapidly transmit enormous amounts of data with increased network capacity compared with current technologies. Millimeter waves do not travel as far and do not penetrate the body as deeply as do the wavelengths of the lower frequencies. Since these millimeter waves are likely to penetrate no deeper than the skin, there is less concern that these frequencies can cause harmful effects in the heart and brain. However, scientists do not know if millimeter waves may cause toxicity in the skin and other human tissues. Since the NTP's studies have demonstrated that there is some interaction between RFR exposure at the tested frequencies and cancers of certain tissues, there is

a need to understand the interaction between RFR and biological tissues and the factors that affect that interaction.

The exposure system is also designed to allow NTP to conduct studies with various RFR frequencies and modulations used by cell phones to keep up with changing technologies in the telecommunications industry. In general, NTP scientists want to understand the impact of exposure to RFR on biological tissues, regardless of generation, or G.

Where can I go for more information?

For more information on what 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://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. 2018. Mobile Fact Sheet. Available: <https://pewinternet.org/fact-sheet/mobile> [accessed 24 October 2018].

² FDA (U.S. Food and Drug Administration). 2017. Reducing Exposure: Hands-free Kits and Other Accessories. Available: <https://fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116293.htm> [accessed 30 October 2018].

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.