

Seizures and Sensitivity to Man-made Radiofrequency Radiation (RFR), Electromagnetic Fields (EMFs) and Natural Geomagnetic Disturbances

All humans are sensitive to external electrical and magnetic fields. These include man-made, such as from mobile phones, phone masts, Wifi, laptops, smart meters, power cables and substations, and natural sunlight and the earth's magnetic field, which are inherent in the existence of life on earth.

Human sensitivity to man-made RFR/EMFs varies on a wide spectrum. Some people show no conscious symptoms but only subconscious effects. About 1.2 to 1.6 % of the population have severe sensitivity with disabling conscious symptoms.

Seizures are a well-known symptom of sensitivity to exposures from man-made and natural RFR/EMFs. Seizures as a sensitivity symptom have long been listed in the scientific literature. In 1998, declassified in 2006, the US military stated that seizures could be induced in all humans with sufficiently strong EMFs. Some studies have focused on magnetic fields pulses at a frequency of 7-15 Hz, close to the alpha brain wave of 8-14 Hz, and at a strength of >10 nT. Many mobile phone signals and Wifi standing signals use low frequency pulses from 10 to ≥ 217 Hz on their microwave carrier signals.

Mechanisms include glucose and glutamate. These can be affected by RFR /EMFs through calcium flux, ion flux generally and demyelination. Because of the established health risks, there do not seem to be any provocation studies specifically on people's sensitivity to RFR/EMFs and seizures. Therefore, much information comes from other types of studies. Some of these concern epilepsy, a term used for a variety of seizure conditions for which there is no single conclusive test.

Studies (with excerpts):

1. *Seizures associated with man-made RFR/EMFs, shown in human and animal studies* p.2
2. *Seizures associated with diagnostic and therapeutic Transcranial Magnetic Stimulation (TMS) and a TMS subset, Theta Burst Stimulation (TBS)* p.4
3. *Biological pathways and mechanisms associated with seizures, especially in patients with epilepsy or animals showing epileptic characteristics* p.5
4. *Seizures associated with fluctuations in the natural background geomagnetic levels, such as thunderstorms, atmospherics and full moon* p.8

1. Seizures caused by man-made RFR/EMFs, shown in human and animal studies

Significant increases in the frequency of seizures in some epileptic children when exposed to base-station radiation

there is an undeniable consistency between some of these non-thermal influences and the nature of many of the health problems reported, such as headache, sleep disruption, impairment of short term memory, and, more seriously, significant increases in the frequency of seizures in some epileptic children when exposed to base-station radiation, and of brain tumours amongst users of mobile phones

- Hyland G: "The Physiological and Environmental Effects of Nonionising Electromagnetic Radiation" Final Study, Scientific and Technological Options Assessment (STOA), Directorate A Division Industry, Research and Energy, Directorate General for Research, European Parliament, EP/IV/A/STOA/2000/07/03. (2001) [Article](#). p.18.

Man-made RFR/EMFs could cause seizures in everyone

From past work in evaluating the potential for electromagnetic pulse generators to affect humans, it is estimated that sufficiently strong internal fields can be generated within the brain to trigger neurons. ... essentially 100% of individuals would be susceptible to seizure induction.

- U.S. Department of the Army: "Bioeffects of Selected Nonlethal Weapons (Addendum to: Nonlethal Technologies – Worldwide: NGIC-1147-101-98)" (1998, declassified 2006). [Article](#).

Mobile phone radiation increased the risk of seizures in mice and caused seizures in seizure-prone rats

The present study was designed to evaluate the effects of mobile phone radiation on seizure threshold in mice. ... Although acute mobile radiation did not change seizure threshold, chronic radiation decreased the clonic and tonic seizure thresholds significantly. Conclusion: Our data suggests that the continued and prolonged contact with the mobile phone radiation might increase the risk of seizure attacks and should be limited.

- Kouchaki E et al.: "Effect of mobile phone radiation on pentylentetrazole-induced seizure threshold in mice" *Iran J Basic Med Sci.* (2016) [PMID: 27635206](#). [PMC5010854](#).

This study investigated the effects of mobile-phone-type radiation on the cerebral activity of seizure-prone animals. When rats transformed into an experimental model of seizure-proneness by acute subconvulsive doses of picrotoxin were exposed to 2 h GSM-modulated 900 MHz radiation at an intensity similar to that emitted by mobile phones, they suffered seizures and the levels of the neuronal activity marker c-Fos in neocortex, paleocortex, hippocampus and thalamus increased markedly. Non-irradiated picrotoxin-treated rats did not suffer seizures, and their cerebral c-Fos

counts were significantly lower. Radiation caused no such differences in rats that had not been pretreated with picrotoxin.

- López-Martín E et al.: "GSM radiation triggers seizures and increases cerebral c-Fos positivity in rats pretreated with subconvulsive doses of picrotoxin" *Neurosci Lett.* (2006) [PMID: 16448750](#).

2. Seizures associated with diagnostic and therapeutic Transcranial Magnetic Stimulation (TMS) and a TMS subset, Theta Burst Stimulation (TBS)

Transcranial Magnetic Stimulation (TMS)

TMS-induced seizures in healthy individuals and patients with neurological conditions

Among the 41 cases, 13 were healthy individuals (32%) and 28 were patients with clinical conditions (68%). Of the 28 patients with clinical conditions ([Figure 1](#)), the majority were psychiatric disorders (16/28 = 57%) and stroke (6/28 = 21%). The remaining clinical conditions included migraine, brain tumor, pain, hydrocephalus, tinnitus, and multiple sclerosis (1 seizure event for each clinical condition).

- Chou Y-H et al.: "TMS-induced seizure cases stratified by population, stimulation protocol, and stimulation site: A systematic literature search" *Clin Neurophysiol.* (2020) [PMID: 32193163](#). [PMC7646466](#).

TMS-related seizures risk is <1% overall, and <2% for epileptic patients

The risk of TMS-related seizures is <1% overall. ... the risk of a seizure in temporal association with TMS is less than 2% in epilepsy patients

- Stultz DJ et al.: "Transcranial Magnetic Stimulation (TMS) Safety with Respect to Seizures: A Literature Review" *Neuropsychiatr Dis Treat.* (2020) [PMID: 33324060](#). [PMC7732158](#).

TMS-related seizures risk is higher for some treatments

generic Brainsway H-coil treatment appears to be associated with a higher relative risk than generic figure- 8 coil treatment.

- Taylor JJ et al.: "Seizure risk with repetitive TMS: Survey results from over a half-million treatment sessions" *Brain Stimul.* (2021) [PMID: 34133991](#).

TMS subset: theta burst stimulation (TBS) caused adverse events in 5% of subjects

Theta burst stimulation (TBS) protocols have recently emerged as a method to transiently alter cortical excitability in the human brain through repetitive transcranial magnetic stimulation. TBS involves applying short trains of stimuli at high frequency repeated at intervals of 200 milliseconds. Because repetitive transcranial magnetic stimulation is known to carry a risk of seizures, safety guidelines have been established. TBS has the theoretical potential of conferring an even higher risk of seizure than other repetitive transcranial magnetic stimulation protocols because it delivers high-frequency bursts. ... The majority of adverse events attributed to TBS were mild and occurred in 5% of subjects.

- Oberman L et al.: "Safety of theta burst transcranial magnetic stimulation: a systematic review of the literature" *J Clin Neurophysiol.* (2011) [PMID: 21221011](#). [PMC3260517](#).

3. Biological pathways and mechanisms associated with seizures, especially in patients with epilepsy or animals showing epileptic characteristics.

Mechanisms of seizures: glutamate and glucose

Seizures induce elevations in extracellular glutamate, which then contribute to excitotoxic damage. Chronic seizures can alter neuronal and glial expression of glutamate receptors and uptake transporters, further contributing to epileptogenesis. Evidence points to a shared glutamate pathology for epilepsy and other central nervous system (CNS) disorders, including depression, which is often a comorbidity of epilepsy.

- Barker-Haliski M et al.: "Glutamatergic Mechanisms Associated with Seizures and Epilepsy" *Cold Spring Harb Perspect Med.* (2015) [PMID: 26101204](#). [PMC4526718](#).

In healthy participants and compared with no exposure, 50-minute cell phone exposure was associated with increased brain glucose metabolism in the region closest to the antenna.

- Volkow ND et al.: (2011) "Effects of cell phone radiofrequency signal exposure on brain metabolism" *JAMA.* (2011) [PMID: 21343580](#).

These findings demonstrate that modulation of the glycemic index can modify the outcome of brain injury in the kainate model of seizure induction.

- Schauwecker PE: "The effects of glycemic control on seizures and seizure-induced excitotoxic cell death" *BMC Neurosci.* (2012) [PMID: 22867059](#). [PMC3465215](#).

Brain hypometabolism is a common epilepsy-related finding in both patients and animal models. Fluorodeoxyglucose positron emission tomography studies have shown that recurrent seizures lead to reduced glucose metabolism in certain brain regions, but no studies have definitively determined whether this induces epileptogenesis. ... Our findings suggest that hippocampal glucose hypometabolism elevates ASIC2a expression by suppressing TFCP2 expression, which further enhances the intrinsic excitability of CA1 pyramidal neurons and increases seizure susceptibility in patients with temporal lobe epilepsy.

- Zhang H et al.: "Glucose Deficiency Elevates Acid-Sensing Ion Channel 2a Expression and Increases Seizure Susceptibility in Temporal Lobe Epilepsy" *Sci Rep.* (2017) [PMID: 28725010](#). [PMC5517604](#).

Glutamate is the principal excitatory neurotransmitter in the brain and, as such, it inevitably plays a role in the initiation and spread of seizure activity. It also plays a critical role in epileptogenesis. The process of "kindling" limbic seizures in rodents by repeated electrical stimulation is dependent on activation of N-methyl-D-aspartate (NMDA) receptors. The function of these receptors is enhanced in the hippocampus of kindled rats and in the cerebral cortex of patients with focal epilepsy.

- Meldrum BS: "The role of glutamate in epilepsy and other CNS disorders" *Neurology.* (1994) [PMID: 7970002](#).

An imbalance between excitation and inhibition has been a longstanding proposed mechanism regarding ictogenesis and epileptogenesis. This imbalance is related to increased extracellular glutamate in the brain and/or reduction in GABA concentrations, leading to excitotoxicity, seizures,

and cell death. ... The majority of microdialysis studies demonstrated increased glutamate in epileptic regions either compared to control regions or to baseline levels; ... For the MRS research, two of six studies reported significant changes in glutamate levels compared to controls, though the results were mixed, with one reporting increased and the other reporting decreased glutamate levels. Eleven of 20 studies reported significant changes in Glx (glutamate + glutamine) or Glx ratios, with most reporting increased levels, except for a few epilepsy syndromes where reduced levels were reported. Few studies investigated GABA concentrations, with one microdialysis and four spectroscopy studies reporting increased GABA levels, and one study reporting decreased GABA in a different brain region.

- Sarlo GL et al.: "Brain concentrations of glutamate and GABA in human epilepsy: A review" *Seizure*. (2021) [PMID: 34233236](#).

Mechanisms of seizures: membrane voltage changes through ion fluxes

Changes in membrane voltage brought about by ion fluxes through voltage and transmitter-gated channels represent the basis of neural activity. As such, electrochemical gradients across the membrane determine the direction and driving force for the flow of ions and are therefore crucial in setting the properties of synaptic transmission and signal propagation. ... In this review we explore how the transmembrane concentration gradient of the six major ions (K(+), Na(+), Cl(-), Ca(2+), H(+)) and [Formula: see text] is altered during an epileptic seizure.

- Raimondo JV et al.: "Ion dynamics during seizures" *Front Cell Neurosci*. (2015) [PMID: 26539081](#). [PMC4612498](#).

Voltage-gated Ca²⁺ channels are of central relevance in these processes. In particular, they are key elements in the etiopathogenesis of numerous seizure types and epilepsies.

- Wormuth C et al.: "Review: Cav2.3 R-type Voltage-Gated Ca²⁺ Channels - Functional Implications in Convulsive and Non-convulsive Seizure Activity" *Open Neurol J*. (2016) [PMID: 27843503](#). [PMC5080872](#).

EEG changes including seizure activity following sensory provocation.

- Pall ML: "Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression" *J Chem Neuroanat*. (2015) [PMID: 26300312](#). [Article](#).

Mechanisms of seizures: demyelination, which can be caused by EMF exposure, is associated with seizures

Multiple sclerosis (MS) patients are three to six times more likely to develop epilepsy compared to the rest of the population. Seizures are more common in patients with early onset or progressive forms of the disease and prognosticate rapid progression to disability and death. Gray matter atrophy, hippocampal lesions, interneuron loss, and elevated juxtacortical lesion burden have been identified in MS patients with seizures; ... Here, we report that cuprizone-mediated chronically demyelinated (9-12 weeks) mice exhibit marked changes to dorsal hippocampal electroencephalography (EEG) and evidence of overt seizure activity.

- Lapato AS et al.: "Chronic demyelination-induced seizures" *Neuroscience*. (2017) [PMID: 28153692](#). [PMC5394933](#).

Mechanisms of seizures: TLR signaling

Recent breakthroughs in understanding the molecular organization of the innate immune system first in macrophages, then in the different cell types of the CNS, together with pharmacological and genetic studies in epilepsy models, showed that the activation of IL-1 receptor/Toll-like receptor (IL-1R/TLR) signaling significantly contributes to seizures.

- Vezzani A et al.: "IL-1 receptor/Toll-like receptor signaling in infection, inflammation, stress and neurodegeneration couples hyperexcitability and seizures" *Brain Behav Immun.* (2011) [PMID: 21473909](#).

Mechanisms of seizures: bystander signaling

We hypothesize that cell stress-caused bystander signaling induced by certain exogenous and endogenous stressors, such as ionizing radiation exposure, chemicals, tumor, or senescent cells, might contribute to neuronal excitability and synchronization, specifically to initiation of hyperexcitability, excessive synchronization and seizure generation in epileptic brain/epileptogenesis. It is suggested that bystander-induced interconnected variations in cytosolic Ca²⁺, cytokines, and reactive oxygen/nitrogen species, and in activity of mitogen-activated protein kinases and nuclear factor κB pathways might affect neurotransmitter system, neuronal receptors and ion channels implicated in seizure generation/epileptogenesis, or modulate expression of genes associated with epileptogenesis.

- Zakhvataev VE et al.: "Stress-induced bystander signaling as a possible factor contributing to neuronal excitability and seizure generation/epileptogenesis" *Med Hypotheses.* (2016) [PMID: 27063087](#).

In this study we report on the capability of the culture medium from SH-SY5Y neuroblastoma cells exposed to 1950 MHz to elicit, in recipient non-exposed cells, a reduction of menadione-induced DNA damage ($P < 0.05$; comet assay), indicating the capability of non-ionizing radiation to elicit a bystander effect.

- Zeni O et al.: "Evidence of bystander effect induced by radiofrequency radiation in a human neuroblastoma cell line" *Environ Res.* (2021) [PMID: 33647301](#).

Mechanisms of seizures: iron deficiency and decreased seizure threshold

Iron deficiency (ID) ... Disruptions in the excitation and inhibition (E/I) balance can be uncovered by the brain's response to seizure inducing insults. ... We found that mice which were postnatally exposed to ID (and were acutely ID) had a decreased seizure threshold and increased susceptibility to certain seizure types.

- Rudy M et al.: "Iron Deficiency Affects Seizure Susceptibility in a Time- and Sex-Specific Manner" *ASN Neuro.* (2017) [PMID: 29243938](#). [PMC5734468](#).

4. Seizures associated with fluctuations in the natural background geomagnetic levels, such as thunderstorms, atmospheric and full moon

Seizures in primed rats caused by natural magnetic fluctuations above 20-25 nT

[Humans can react at about: above 7 nT]

A decrease in the latency for the overt display of limbic seizures following the systemic injection of lithium and pilocarpine is weakly associated with enhanced global geomagnetic activity (in nanoTesla; nT). To determine the optimal threshold in global geomagnetic activity that is required for this effect, the seizure onset times for over 300 rats were dichotomized according to successive 5 nT increments. The results suggested that the seizure process occurred about 12% more quickly when the average daily global geomagnetic activity exceeded 20-25 nT and is commensurate with the observations by other researchers.

- Bureau YR et al.: "Decreased latencies for limbic seizures induced in rats by lithium-pilocarpine occur when daily average geomagnetic activity exceeds 20 nanoTesla" *Neurosci Lett.* (1995) [PMID: 7675323](#).

This experiment was designed to simulate experimentally the specific parameters of geomagnetic activity that evoke epileptic seizures. ... The partial regression coefficients from the analysis indicated that either the presence of the 'synthetic' geomagnetic activity or increased magnitudes of the daily, natural geomagnetic activity (regional range approximately 10-70 nT) during the observational period significantly ($P < 0.05$) increased the proportion of nightly seizures. The effect sizes (6-8%) for both magnetic sources were comparable and additive.

- Michon AL et al.: "Experimental simulation of the effects of increased geomagnetic activity upon nocturnal seizures in epileptic rats" *Neurosci Lett.* (1997) [PMID: 9132690](#).

Seizures linked with geomagnetic activity (> 40 nT) and suppressed nocturnal melatonin

The combined effects of the experimental field and ambient geomagnetic activity (> 40 nT) explained approximately 12 to 15% of the variance in the daily incidence of seizures. Implications for the transient disinhibition of electrical lability within the limbic system following suppression of nocturnal melatonin are discussed.

- Persinger MA: "Enhancement of limbic seizures by nocturnal application of experimental magnetic fields that simulate the magnitude and morphology of increases in geomagnetic activity" *Int J Neurosci.* (1996) [PMID: 8884398](#).

Seizures in humans linked with full moon and full moon EMF disturbances

A significant clustering of seizures around the full moon period was observed,

- Polychronopoulos P et al.: "Lunar phases and seizure occurrence: just an ancient legend?" *Neurology.* (2006) [PMID: 16682684](#).

Since ancient times evidence for human effects has been strongest for epileptic seizures, with increases of over 1.5 times

- Bevington M: "Lunar biological effects and the magnetosphere" *Pathophysiology* (2015) [PMID: 26462435](#).

Seizures linked with Very Low Frequency (VLF) 1-100 kHz atmospheric disturbances

the correlation between onsets and "atmospherics" of 28 KHz (positive) and 10 KHz (negative) impulses, are significant

- Ruhenstroth-Bauer G et al.: "Epilepsy and weather: a significant correlation between the onset of epileptic seizures and specific atmospheric--a pilot study" *Int J Biometeorol.* (1984) [PMID: 6511121](#). [Abstract](#).

Occurrence of seizures associated with succeeding weather patterns

All of the analyzed weather-related parameters seem to be associated with daily numbers of seizures on the previous day.

- Tomasović S et al.: "Weather patterns and occurrence of epileptic seizures" *BMC Neurol.* (2022) [PMID: 35062900](#). [PMC8780718](#).

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