January 24, 2024

Effects of radiofrequency radiation exposure on reproduction and development

(E)= effect; (NE)= no effect; First author in blue= study with exposure to a wireless device; Low SAR = <0.4 W/kg

AE= acute exposure; BE= behavioral effect; CE= long-term/repeated exposure; DE= developmental study; F= female reproduction component, e.g., ovary; FC= functional change including fertility; GE= genetic effect (DNA damage/gene expression); HU= human study (including tissues from humans); IU= in utero/in ovo exposure; IV= in vitro; IX= interaction with other entity; M= male reproduction component, e.g., testis; ME= morphological/cellular effect; MO= molecular/hormonal effect; NU= neurological effect, including electrophysiology; OX= oxidative effect; PN= post-natal exposure; VO= in vivo

E=280 (83%); NE=55 (17%)

SARs of low SAR (<0.4 W/kg) studies that reported effects:

0.009, 0.15, 0.14, 0.024, 0.025, 0.024, 0.0098, 0.1, 0.01, 0.00003, 0.025, 0.2986, 0.087, 0.025, 0.0067, 0.09, 0.0008, 0.1, 0.143, 0.15, 0.000011, 0.0054, 0.143, 0.023, 0.179, 0.016, 0.1, 0.0233, 0.087, 0.23, 0.15, 0.2221, 0.00242, 0.03, 0.018, 0.014, 0.014, 0.014, 0.014, 0.0516, 0.08, 0.0005, 0.0405, 0.00001, 0.018, 0.0146, 0.002, 0.027, 0.0623, 0.186, 0.31, 0.048, 0.001, 0.07, 0.18, 0.0625

N=56, mean= 0.069 W/kg, median= 0.026 W/kg

Studies with SAR ≤0.08 W/kg that reported effects:

0.009, 0.024, 0.025, 0.024, 0.0098, 0.01, 0.00003, 0.025, 0.025, 0.0067, 0.0008, 0.000011, 0.0054, 0.023, 0.016, 0.0233, 0.00242, 0.03, 0.018, 0.014, 0.014, 0.014, 0.014, 0.0516, 0.08, 0.0005, 0.0405, 0.00001, 0.018, 0.0146, 0.002, 0.027, 0.0623, 0.048, 0.001, 0.07, 0.0625

N=37, mean= 0.022 W/kg, median = 0.016 W/kg

(E) Afromeev VI, Tkachenko VN, [Change in the percent of lactate dehydrogenase isoenzyme level in testes of animals exposed to superhigh frequency radiation]. Biofizika 44(5):931-932, 1999. [Article in Russian] **(VO, M, ME)**

The content of six lactate dehydrogenase isoenzymes in testes of rats exposed to electromagnetic field of 3-cm wavelength range was studied. The changes in their percent contents were found to be inhomogeneous compared with control. It is assumed that

electromagnetic radiation affects the organs of the human urinogenital system. The results can be used for estimating the safety of persons professionally exposed to electromagnetic radiation of the industrial frequency range and in the therapy of diseases of the urinogenital system.

(E) Agarwal A, Deepinder F, Sharma RK, Ranga G, Li J. Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertil Steril. 89(1):124-128, 2008. (CE, HU, M, ME)

OBJECTIVE: To investigate the effect of cell phone use on various markers of semen quality. DESIGN: Observational study. SETTING: Infertility clinic. PATIENT(S): Three hundred sixty-one men undergoing infertility evaluation were divided into four groups according to their active cell phone use: group A: no use; group B: <2 h/day; group C: 2-4 h/day; and group D: >4 h/day. INTERVENTION(S): None. MAIN OUTCOME MEASURE(S): Sperm parameters (volume, liquefaction time, pH, viscosity, sperm count, motility, viability, and morphology). RESULT(S): The comparisons of mean sperm count, motility, viability, and normal morphology among four different cell phone user groups were statistically significant. Mean sperm motility, viability, and normal morphology were significantly different in cell phone user groups within two sperm count groups. The laboratory values of the above four sperm parameters decreased in all four cell phone user groups as the duration of daily exposure to cell phones increased. CONCLUSION(S): Use of cell phones decrease the semen quality in men by decreasing the sperm count, motility, viability, and normal morphology. The decrease in sperm parameters was dependent on the duration of daily exposure to cell phones and independent of the initial semen quality.

(E) Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, Sharma R. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil Steril. 92(4) 1318-1325, 2009. (AE, IV, M, ME, OX)

OBJECTIVE: To evaluate effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed (neat) ejaculated human semen. DESIGN: Prospective pilot study. SETTING: Center for reproductive medicine laboratory in tertiary hospital setting. SAMPLES: Neat semen samples from normal healthy donors (n = 23) and infertile patients (n = 9). INTERVENTION(S): After liquefaction, neat semen samples were divided into two aliquots. One aliquot (experimental) from each patient was exposed to cellular phone radiation (in talk mode) for 1 h, and the second aliquot (unexposed) served as the control sample under identical conditions. MAIN OUTCOME MEASURE(S): Evaluation of sperm parameters (motility, viability), reactive oxygen species (ROS), total antioxidant capacity (TAC) of semen, ROS-TAC score, and sperm DNA damage. RESULT(S): Samples exposed to RF-EMW showed a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage showed no significant differences from the unexposed group. CONCLUSION(S): Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility.

(NE) Aït-Aïssa S, Billaudel B, Poulletier de Gannes F, Ruffié G, Duleu S, Hurtier A, Haro E, Taxile M, Athané A, Geffard M, Wu T, Wiart J, Bodet D, Veyret B, Lagroye I. In utero and early-life exposure of rats to a Wi-Fi signal: screening of immune markers in sera and gestational outcome. Bioelectromagnetics. 33(5):410-420, 2012. (CE, DE, IU, VO)

An experimental approach was used to assess immunological biomarkers in the sera of young rats exposed in utero and postnatal to non-ionizing radiofrequency fields. Pregnant rats were exposed free-running, 2 h/day and 5 days/week to a 2.45 GHz Wi-Fi signal in a reverberation chamber at whole-body specific absorption rates (SAR) of 0, 0.08, 0.4, and 4 W/kg (with 10, 10, 12, and 9 rats, respectively), while cage control rats were kept in the animal facility (11 rats). Dams were exposed from days 6 to 21 of gestation and then three newborns per litter were further exposed from birth to day 35 postnatal. On day 35 after birth, all pups were sacrificed and sera collected. The screening of sera for antibodies directed against 15 different antigens related to damage and/or pathological markers was conducted using enzyme-linked immunosorbent assay (ELISA). No change in humoral response of young pups was observed, regardless of the types of biomarker and SAR levels. This study also provided some data on gestational outcome following in utero exposure to Wi-Fi signals. Mass evaluation of dams and pups and the number of pups per litter was monitored, and the genital tracts of young rats were observed for abnormalities by measuring anogenital distance. Under these experimental conditions, our observations suggest a lack of adverse effects of Wi-Fi exposure on delivery and general condition of the animals.

(NE) Aït-Aïssa S, de Gannes FP, Taxile M, Billaudel B, Hurtier A, Haro E, Ruffié G, Athané A, Veyret B, Lagroye I. In Situ Expression of Heat-Shock Proteins and 3-Nitrotyrosine in Brains of Young Rats Exposed to a WiFi Signal In Utero and In Early Life. Radiat Res. 179:707-716, 2013. (CE, DE, IU, VO)

The bioeffects of exposure to Wireless High-Fidelity (WiFi) signals on the developing nervous systems of young rodents was investigated by assessing the in vivo and in situ expression levels of three stress markers: 3-Nitrotyrosine (3-NT), an oxidative stress marker and two heat-shock proteins (Hsp25 and Hsp70). These biomarkers were measured in the brains of young rats exposed to a 2450 MHz WiFi signal by immunohistochemistry. Pregnant rats were first exposed or sham exposed to WiFi from day 6 to day 21 of gestation. In addition three newborns per litter were further exposed up to 5 weeks old. Daily 2-h exposures were performed blind in a reverberation chamber and whole-body specific absorption rate levels were 0, 0.08, 0.4 and 4 W/kg. 3-NT and stress protein expression was assayed in different areas of the hippocampus and cortex. No significant difference was observed among exposed and sham-exposed groups. These results suggest that repeated exposure to WiFi during gestation and early life has no deleterious effects on the brains of young rats.

(E)Aitken RJ, Bennetts LE, Sawyer D, Wiklendt AM, King BV. Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. Inter J Androl 28:171-179, 2005. (CE, GE, M, VO)

Concern has arisen over human exposures to radio frequency electromagnetic radiation (RFEMR), including a recent report indicating that regular mobile phone use can negatively impact upon human semen quality. These effects would be particularly serious if the biological effects of RFEMR included the induction of DNA damage in male germ cells. In this study, mice were exposed to 900 MHz RFEMR at a specific absorption rate of approximately 90 mW/kg inside a waveguide for 7 days at 12 h per day. Following exposure, DNA damage to caudal epididymal spermatozoa was assessed by quantitative PCR (QPCR) as well as alkaline and pulsed-field gel electrophoresis. The treated mice were overtly normal and all assessment criteria, including sperm number, morphology and vitality were not significantly affected. Gel electrophoresis revealed no gross evidence of increased single- or double-DNA strand breakage in spermatozoa taken from treated animals. However, a detailed analysis of DNA integrity using QPCR revealed statistically significant damage to both the mitochondrial genome ($p < 0.05$) and the nuclear β-globin locus ($p < 0.01$). This study suggests that while RFEMR does not have a dramatic impact on male germ cell development, a significant genotoxic effect on epididymal spermatozoa is evident and deserves further investigation.

(E) Akakin D, Tok OE, Anil D, Akakin A, Sirvanci S, Sener G, Ercan F. Electromagnetic Waves from Mobile Phones may Affect Rat Brain During Development. Turk Neurosurg 31(3):412-421, 2021. (CE, IU, ME, OX, PN, VO)

Aim: To investigate the effects of electromagnetic waves (EMWs) from mobile phones (MPs) on rat brains of rats by morphological and biochemical analysis. **Material and methods:** EMW was applied for two hours/day until birth in stand-by fetal and EMW fetal groups and postnatal 60th day in stand-by and EMW groups. The control group was not exposed to MP. On postnatal 60th day, brain malondialdehyde (MDA) and glutathione (GSH) levels were measured, and western blot analysis was performed to determine glial fibrillary acidic protein (GFAP) content. Hematoxylin and eosin staining and GFAP immunohistochemistry were applied. Trigeminal nerves were examined using the transmission electron microscope. **Results:** In comparison to controls, rats exposed to MP in stand-by or talk modes had significantly increased neuronal damage in the cortex and hippocampus. Increased MDA levels in the EMW group and decreased GSH levels in the stand-by, EMW fetal and EMW groups were found compared with controls. Increased GFAP content in the EMW group and increased GFAP staining in the EMW fetal and EMW groups compared to controls were observed. EMW group had a significantly decreased number of myelinated axons than control animals. **Conclusion:** The results of this study suggests that 1800 MHz EMWs (SAR=1.79 W/kg) exposure in the prenatal and early postnatal life may lead to trigeminal nerve damage in addition to oxidative stress-induced neuronal degeneration and astroglial activation in the rat brain. Effects seem to be mode related, being more detrimental in groups exposed to MP during talk mode.

(E)Akdag MZ, Dasdag S, Canturk F, Karabulut D, Caner Y, Adalier N. Does prolonged radiofrequency radiation emitted from Wi-Fi devices induce DNA damage in various tissues of rats? J Chem Neuroanat. 75(pt B):116-122, 2016. (CE, GE, M, VO)

Wireless Internet (Wi-Fi) providers have become essential in our daily lives, as wireless technology is evolving at a dizzying pace. Although there are different frequency generators, one of the most commonly used Wi-Fi devices are 2.4GHz frequency generators. These devices are heavily used in all areas of life but the effect of radiofrequency (RF) radiation emission on users is generally ignored. Yet, an increasing share of the public expresses concern on this issue. Therefore, this study intends to respond to the growing public concern. The purpose of this study is to reveal whether long term exposure of 2.4GHz frequency RF radiation will cause DNA damage of different tissues such as brain, kidney, liver, and skin tissue and testicular tissues of rats. The study was conducted on 16 adult male Wistar-Albino rats. The rats in the experimental group (n=8) were exposed to 2.4GHz frequency radiation for over a year. The rats in the sham control group (n=8) were subjected to the same experimental conditions except the Wi-Fi generator was turned off. After the exposure period was complete the possible DNA damage on the rat's brain, liver, kidney, skin, and testicular tissues was detected through the single cell gel electrophoresis assay (comet) method. The amount of DNA damage was measured as% tail DNA value. Based on the DNA damage results determined by the single cell gel electrophoresis (Comet) method, it was found that the% tail DNA values of the brain, kidney, liver, and skin tissues of the rats in the experimental group increased more than those in the control group. The increase of the DNA damage in all tissues was not significant ($p > 0.05$). However the increase of the DNA damage in rat testes tissue was significant ($p < 0.01$). In conclusion, long-term exposure to 2.4GHz RF radiation (Wi-Fi) does not cause DNA damage of the organs investigated in this study except testes. The results of this study indicated that testes are more sensitive organ to RF radiation.

(E)Akefe IO, Nyan ES, Adegoke VA, Lamidi IY, Ameh MP, Chidiebere U, Ubah SA, Ajayi IE.Myrtenal improves memory deficits in mice exposed to radiofrequency-electromagnetic radiation during gestational and neonatal development *via* enhancing oxido-inflammatory, and neurotransmitter functions. Heliyon 9(4):e15321, 2023. (BE, CE, IU, MO, OX, NU. PN, VO) (145 μW/cm^2)

Objective: Radiofrequency-electromagnetic radiation (RF-EMR) exposure during gestational and neonatal development may interact with the foetus and neonate considered hypersensitive to RF-EMR, consequently resulting in developmental defects associated with neuropsychological and neurobehavioral disorders, including learning and memory impairment. This study assessed the potential of Myrtenal (Myrt) to improve memory deficits in C57BL/6 mice exposed to RF-EMR during gestational and neonatal development.**Method:** Thirty-five male mice were randomly allocated into 5 cohorts, each comprising of 7 mice. Group I was administered vehicle, Group II: RF-EMR (900 MHz); Group III: RF-EMR (900 MHz) + 100 mg/kg Myrt; Group IV: RF-EMR (900 MHz) + 200 mg/kg Myrt; and Group V: RF-EMR (900 MHz) + donepezil 0.5 mg/kg. **Results:** Myrt treatment improved short-term memory performance in RF-EMR (900 MHz)-exposed mice by augmenting activities of endogenous antioxidant enzymes and proinflammatory cytokines, thereby protecting the brain from oxido-inflammatory stress. Additionally, Myrt restored the homeostasis of neurotransmitters in RF-EMR-exposed animals. **Conclusion:** Results from the present study shows that exposure to RF-EMR impaired short-term memory in animals and altered the response of markers of oxido-inflammatory stress, and

neurotransmitters. It is therefore conceivable that the recommendation of Myrt-enriched fruits may offer protective benefits for foeti and neonates prone to RF-EMR exposure.

Akimoto S, Nagaoka T, Saito K, Watanabe S, Takahashi M, Ito K. Comparison of SAR in realistic fetus models of two fetal positions exposed to electromagnetic wave from business portable radio close to maternal abdomen. Conf Proc IEEE Eng Med Biol Soc. 2010:734-737, 2010. (Dosimetry)

Since the diversification of the electromagnetic (EM) environment is spreading, it is essential to estimate the EM energy absorption rate [specific absorption rate (SAR)] of a pregnant woman's body and her fetus under various exposure situations. For example, if pregnant women work in jobs where they might wear business portable radios around their abdomens, they should also be concerned about this issue, because the fetuses are in their abdomens. In this paper, in order to evaluate the SAR in the pregnant woman and her fetus when wearing the wireless radio terminal on her abdomen, the SAR distribution in the fetus is calculated using the numerical model of the pregnant woman by exposed to near-field of a normal mode helical antenna (NHA) with a metallic case at 150 MHz. In addition, the SAR in the fetus will be evaluated under two fetal positions. It was found that the fetal SARs are greatly affected by the distance and penetration path from the antenna to the fetal surface. In addition, the fetal SARs are lower than the RF safety guidelines for occupational exposure.

(E)Al-Ali BM, Patzak J, Fischereder K, Pummer K, Shamloul R. Cell phone usage and erectile function. Cent European J Urol. 66(1):75-77, 2013. (CE, HU, M)

INTRODUCTION: The objective of this pilot study was to report our experience concerning the effects of cell phone usage on erectile function (EF) in men. MATERIAL AND METHODS: We recruited 20 consecutive men complaining of erectile dysfunction (ED) for at least six months (Group A), and another group of 10 healthy men with no complaints of ED (Group B). Anamnesis, basic laboratory investigations, and clinical examinations were performed. All men completed the German version of the Sexual Health Inventory for Men (SHIM) for evaluation of the International Index of Erectile Function (IIEF), as well as another questionnaire designed by our clinicians that assessed cell phone usage habits. RESULTS: There was no significant difference between both groups regarding age, weight, height, and total testosterone (Table 1). The SHIM scores of Group A were significantly lower than that of Group B, 11.2 ±5 and 24.2 ±2.3, respectively. Total time spent talking on the cell phone per week was not significantly higher in Group A over B, 17.6 ±11.1 vs. 12.5 ±7 hours. Men with ED were found to carry their 'switched on' cell phones for a significantly longer time than those without ED, 4.4 ±3.6 vs. 1.8 ±1 hours per day. CONCLUSIONS: We found a potential correlation with cell phone usage and a negative impact on EF. Further large-scale studies confirming our initial data and exploring the mechanisms involved in this phenomenon are recommended.

(E) Alchalabi ASH, Aklilu E, Aziz AR, Malek F, Ronald SH, Khan MA. Different periods of intrauterine exposure to electromagnetic field: Influence on female rats' fertility, prenatal

and postnatal development. Asian Pacific Journal of Reproduction 5: 14-23, 2016. (CE, DE, IU, ME, VO) (low SAR 0.048 W/kg)

To assess the intrauterine irradiation of 1 800 MHz Global System of Mobile telecommunication on pre- and postnatal development in Sprague–Dawley rats. Methods: The whole-body irradiation 1 h/day and 2 h/day was applied to the pregnant rats in three different intervals (one week, two weeks and three weeks) at SAR 0.048 W/ Kg and control groups. Post-Morton findings and growth markers were monitored. Sera were collected for biochemical analysis. Results: Prenatal development findings showed uterine congestion, haemorrhage, dead and reabsorbed fetuses were observed in exposure groups during 2nd and 3rd week of pregnancy unlike to control. 1st and 2nd week in-utero irradiation showed significant reduction with unequal and asymmetrical distribution of implantation sites and embryos in exposure groups except the control group. A number of live embryos were significantly reduced with an increasing number of dead and reabsorbed embryos in the 2 h/day of the 2nd-week exposure group in compared to control group. Malformation, haematoma, and oedematous foetuses in experimental groups were observed unlike control foetuses. A significant decrease in live foetuses and a significant decrease in body mass of foetuses at gestation day 20, unlike control group. Postnatal observations showed haematoma, congestion, short tail, malformation and growth restriction and delay in some growth markers were observed. In-utero irradiation for 2 and three weeks induced oxidative stress in pregnant rats. Conclusion: Results suggest that long-term exposure to EMF during the pregnancy lead to chronic stress, which has detrimental effects on pre-& postnatal development and for that more studies to clarify such harmful effects are recommended.

(E)Alchalabi AS, Aklilu E, Aziz A, Rahim H, Ronald S, Malek M, Khan M. Impact of electromagnetic radiation exposure during pregnancy on embryonic skeletal development in rats. Asian Pacific Journal of Reproduction 6: 104-111, 2017. (CE, DE, IU, ME, VO)

Objective: To evaluate the teratogenic effect of mobile phone radiation exposure during pregnancy on embryonic skeletal development at the common used mobile phone frequency in our environment. Methods: Sixty female Sprague-Dawley rats were distributed into three experiment groups; control and two exposed groups (1 h/day, 2 h/day exposure groups) (n=20/ each group) and exposed to whole body radiation during gestation period from day 1- day 20. Electromagnetic radiofrequency signal generator was used to generate 1 800 MHz GSM-like signals at specific absorption rate value 0.974 W/kg. Animals were exposed during experiment in an especial designed Plexiglas box (60 cm × 40 cm × 30 cm). At the end of exposure duration at day 20 of pregnancy animals were sacrificed and foetuses were removed, washed with normal saline and processed to Alizarin red and Alcian blue stain. Skeleton specimens were examined under a stereo microscope and skeleton's snaps were being carefully captured by built in camera fixed on the stereo microscope. Results: Intrauterine exposure to electromagnetic radiation lead to variation in degree of ossification, mineralization, formation of certain parts of the skeleton majorly in head and lesser in other parts. Deformity and absence of formation of certain bones in the head, ribs, and coccygeal vertebrae were recorded in skeleton of foetuses from exposed dams compare to control group. Conclusions: The electromagnetic radiation exposure during pregnancy alter the processes of bone

mineralization and the intensity of bone turnover processes, and thus impact embryonic skeleton formation and development directly.

(E)Aldad TS, Gan G, Gao XB, Taylor HS. Fetal radiofrequency radiation exposure from 800-1900 MHz-rated cellular telephones affects neurodevelopment and behavior in mice. Sci Rep. 2:312, 2012. (BE, CE, DE, IU)

Neurobehavioral disorders are increasingly prevalent in children, however their etiology is not well understood. An association between prenatal cellular telephone use and hyperactivity in children has been postulated, yet the direct effects of radiofrequency radiation exposure on neurodevelopment remain unknown. Here we used a mouse model to demonstrate that in-utero radiofrequency exposure from cellular telephones does affect adult behavior. Mice exposed in-utero were hyperactive and had impaired memory as determined using the object recognition, light/dark box and step-down assays. Whole cell patch clamp recordings of miniature excitatory postsynaptic currents (mEPSCs) revealed that these behavioral changes were due to altered neuronal developmental programming. Exposed mice had dose-responsive impaired glutamatergic synaptic transmission onto layer V pyramidal neurons of the prefrontal cortex. We present the first experimental evidence of neuropathology due to in-utero cellular telephone radiation. Further experiments are needed in humans or non-human primates to determine the risk of exposure during pregnancy.

(E)Al-Damegh MA. Rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone and the protective effects of the antioxidants vitamins C and E. Clinics (Sao Paulo). 67(7):785-792, 2012. (CE, M, ME, OX, VO)

OBJECTIVE: The aim of this study was to investigate the possible effects of electromagnetic radiation from conventional cellular phone use on the oxidant and antioxidant status in rat blood and testicular tissue and determine the possible protective role of vitamins C and E in preventing the detrimental effects of electromagnetic radiation on the testes. MATERIALS AND METHODS: The treatment groups were exposed to an electromagnetic field, electromagnetic field plus vitamin C (40 mg/kg/day) or electromagnetic field plus vitamin E (2.7 mg/kg/day). All groups were exposed to the same electromagnetic frequency for 15, 30, and 60 min daily for two weeks. RESULTS: There was a significant increase in the diameter of the seminiferous tubules with a disorganized seminiferous tubule sperm cycle interruption in the electromagnetism-exposed group. The serum and testicular tissue conjugated diene, lipid hydroperoxide, and catalase activities increased 3-fold, whereas the total serum and testicular tissue glutathione and glutathione peroxidase levels decreased 3-5 fold in the electromagnetism-exposed animals. CONCLUSION: Our results indicate that the adverse effect of the generated electromagnetic frequency had a negative impact on testicular architecture and enzymatic activity. This finding also indicated the possible role of vitamins C and E in mitigating the oxidative stress imposed on the testes and restoring normality to the testes.

(E)Almášiová V, Holovská K, Andrašková S, Cigánková V, Ševčíková Z, Raček A, Zuza na Andrejčáková Z, Beňová K, Tóth S, Tvrdá E, Molnár J, Račeková E. Potential influence of prenatal 2.45 GHz radiofrequency electromagnetic field exposure on Wistar albino rat testis. Histol Histopathol 36(6):685-696, 2021. (CE, IU, M, ME, VO)

An ever-increasing use of wireless devices over the last decades has forced scientists to clarify their impact on living systems. Since prenatal development is highly sensitive to numerous noxious agents, including radiation, we focused on the assessment of potential adverse effects of microwave radiation (MR) on testicular development. Pregnant Wistar albino rats (3 months old, weighing 282±8 g) were exposed to pulsed MR at a frequency of 2.45 GHz, mean power density of 2.8 mW/cm², and a specific absorption rate of 1.82 W/kg for 2 hours/day throughout pregnancy. Male offspring were no longer exposed to MR following birth. Samples of biological material were collected after reaching adulthood (75 days). In utero MR exposure caused degenerative changes in the testicular parenchyma of adult rats. The shape of the seminiferous tubules was irregular, germ cells were degenerated and often desquamated. The diameters of the seminiferous tubules and the height of the germinal epithelium were significantly decreased (both at $**p<0.01$), while the interstitial space was significantly increased ($**p<0.01$) when compared to the controls. In the group of rats prenatally exposed to MR, the somatic and germ cells were rich in vacuoles and their organelles were often altered. Necrotizing cells were more frequent and empty spaces between Sertoli cells and germ cells were observed. The Leydig cells contained more lipid droplets. An increased Fluoro Jade - C and superoxide dismutase 2 positivity was detected in the rats exposed to MR. Our results confirmed adverse effects of MR on testicular development.

Altun G, Deniz ÖG, Yurt KK, Davis D, Kaplan S. Effects of mobile phone exposure on metabolomics in the male and female reproductive systems. Environ Res 167:700-707, 2018. (Review)

With current advances in technology, a number of epidemiological and experimental studies have reported a broad range of adverse effects of electromagnetic fields (EMF) on human health. Multiple cellular mechanisms have been proposed as direct causes or contributors to these biological effects. EMF-induced alterations in cellular levels can activate voltage-gated calcium channels and lead to the formation of free radicals, protein misfolding and DNA damage. Because rapidly dividing germ cells go through meiosis and mitosis, they are more sensitive to EMF in contrast to other slower-growing cell types. In this review, possible mechanistic pathways of the effects of EMF exposure on fertilization, oogenesis and spermatogenesis are discussed. In addition, the present review also evaluates metabolomic effects of GSM-modulated EMFs on the male and female reproductive systems in recent human and animal studies. In this context, experimental and epidemiological studies which examine the impact of mobile phone radiation on the processes of oogenesis and spermatogenesis are examined in line with current approaches.

(E)Andrašková S, Holovská K, Ševčíková Z, Andrejčáková Z, Tóth S, Martončíková M, Račeková E, Almášiová V. The potential adverse effect of 2.45 GHz microwave radiation on the testes of prenatally exposed peripubertal male rats. Histol Histopathol 37(3):287-299, 2022. (CE, DE, IU, M, ME, VO)

In utero development of organs is easily influenced by many environmental factors. The aim of this study was to elucidate the effect of microwave radiation (MR) at a frequency of 2.45 GHz and a specific absorption rate of 1.73 W/kg on intrauterine development of testis. Pregnant albino rats were exposed to whole-body MR for 2 hours per day throughout the pregnancy. Male

offspring (n=12, age 35 days) were not exposed to MR after birth. The study revealed that MR applied in utero induced apparent structural changes in the testes, such as irregular shape of seminiferous tubules, significant decrease in the diameter of seminiferous tubules ($p<0.05$) and in the height of the germinal epithelium ($p<0.01$), disorganisation of germ cells, desquamations of immature germ cells, formation of giant multinucleated cells, and significant ($p<0.01$) expansion of the interstitium. At the level of transmission electron microscopy, there were observed basement membrane irregularities in seminiferous tubules, vacuolation of the cytoplasm and adversely affected organelles in Sertoli cells, germ cells, Leydig cells, peritubular and endothelial cells. The tight junctions between adjacent Sertoli cells were often incomplete, and necrotizing germ cells were more numerous in experimental animals compared to controls. Enhanced necrotizations of germ cells proved by a Fluoro Jade C method, and declined germ cells proliferation confirmed by proliferating cell nuclear antigen analysis, were detected in MR exposed animals. Our results revealed that the prenatal exposure to MR had an adverse effect on the postnatal testicular development in rats.

Asghari A, Khaki AA, Rajabzadeh A, Khaki A. A review on Electromagnetic fields (EMFs) and the reproductive system. Electron Physician 8(7):2655-2662, 2016. (Review)

Environmental factors, such as electromagnetic waves, induce biological and genetic effects. One of the most important physiological systems involved with electromagnetic fields (EMFs) is the genital system. This paper reviews the effects of EMFs on human reproductive organs, female animals, fetus development and the importance of two types of natural antioxidants, i.e., vitamin E and fennel. The studies presented in this review referred to the effects of different exposures to EMFs on the reproductive system, and we tried to show the role of natural antioxidants in reducing the effects of the exposures. Many studies have been done on the effects of ionizing and non-ionizing electromagnetic waves on the cell line of spermatogenesis, sexual hormones, and the structure of the testes. Also, about the hormonal cycle, folliculogenesis and female infertility related to EMF have been given more consideration. In particular, attention is directed to pregnant women due to the importance of their fetuses. However, in addition to the studies conducted on animals, further epidemiological research should be conducted.

Ashrafinia F, Moeindarbari S, Razmjouei P, Ghazanfarpour M, Najafi MN, Moodi Ghalibaf AAM, Abdi F. Can Prenatal and Postnatal Cell Phone Exposure Increase Adverse Maternal, Infant and Child Outcomes? Rev Bras Ginecol Obstet 43(11):870-877, 2021. (Review)

Objective: To determine the association between maternal mobile phone use and adverse outcomes in infants, children, and mothers. **Method:** In March 202, we conducted a search on the MEDLINE, Embase, and Scopus databases. Data extraction and an assessment of the quality of the studies were performed by two authors. The quality of the studies was assessed using the checklist of the Newcastle-Ottawa scale. **Results:** Studies assessing behavioral problems in infants aged 6 to 18 months reported null findings. However, an increased risk of emotional and behavioral disorders was observed in children aged between 7 and 11 years whose mothers had been exposed to cell phones. The findings regarding the association between maternal cell phone exposure and adverse outcomes in children aged 3 to 5 are controversial. A study found a significant association between the call time ($p = 0.002$) or the history of mobile phone use (in

months) and speech disorders in the children ($p = 0.003$). However, another study found that maternal cell phone use during pregnancy was not significantly associated with child psychomotor and mental developments. Inconclusive results were observed about the adverse outcomes in fetuses, such as fetal growth restriction or t scores for birth weight in cell phone users as opposed to non-users. On the contrary, the children of mothers who were cell phone users had a lower risk of scoring low on motor skills. Similar results were observed regarding the adverse outcomes of cell phone use in infants, such as fetal growth restriction or low birth weight, and the risk of preeclampsia was lower among subjects with medium and high cell phone exposure, as opposed to those with low exposure. **Conclusion:** Studies on behavioral problems have reported different postnatal results, such as null findings among infants and a positive association in children.

(E)Atasoy HI, Gunal MY, Atasoy P, Elgun S, Bugdayci G. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. J Pediatr Urol. 9(2):223-229, 2013. (CE, GE, M, OX, VO)

OBJECTIVE: To investigate effects on rat testes of radiofrequency radiation emitted from indoor Wi-Fi Internet access devices using 802.11.g wireless standards. METHODS: Ten Wistar albino male rats were divided into experimental and control groups, with five rats per group. Standard wireless gateways communicating at 2.437 GHz were used as radiofrequency wave sources. The experimental group was exposed to radiofrequency energy for 24 h a day for 20 weeks. The rats were sacrificed at the end of the study. Intracardiac blood was sampled for serum 8-hydroxy-2'-deoxyguanosine levels. Testes were removed and examined histologically and immunohistochemically. Testis tissues were analyzed for malondialdehyde levels and prooxidant-antioxidant enzyme activities. RESULTS: We observed significant increases in serum 8-hydroxy-2'-deoxyguanosine levels and 8-hydroxyguanosine staining in the testes of the experimental group indicating DNA damage due to exposure ($p < 0.05$). We also found decreased levels of catalase and glutathione peroxidase activity in the experimental group, which may have been due to radiofrequency effects on enzyme activity ($p < 0.05$). CONCLUSIONS: These findings raise questions about the safety of radiofrequency exposure from Wi-Fi Internet access devices for growing organisms of reproductive age, with a potential effect on both fertility and the integrity of germ cells.

(E)Augustianath T, Evans DA, Anisha GS. Teratogenic effects of radiofrequency electromagnetic radiation on the embryonic development of chick: A study on morphology and hatchability. Res Vet Sci 159:93-100, 2023. (CE, DE, IU)

The present study was aimed at studying the effects of RF-EMR in causing teratogenic changes in the embryonic development of organisms using chick embryo as a model. The fertilized eggs of the hen were incubated in a digital humidified incubator and exposed to RF-EMR from 2G and 4G mobile phones by ringing at regular time intervals. The dose of RF-EMR was varied by increasing the call duration and number of calls per day, with the lower dose being a call duration of 50 min/day and the higher dose being 90 min/day. The phone kept had a range of radiofrequency between 900 and 1800 MHz and SAR (Specific Absorption Rate) 1.355 (2G) and

1.12 (4G) watts/ kg respectively. The batch of eggs incubated without any exposure to RF-EMR was taken as control. The hatchability of 2G and 4G experimental groups were respectively, 65% and 75% at lower radiation exposure and 40% and 55% at higher radiation exposure. The teratogenic effects of RF-EMR on the morphology of chick embryos manifested as the cross beak, non-retracted yolk sac, macrocephaly, malformed legs and toes, disability in standing and balancing the body and variations in body weight, body length and beak length. The results indicate that the RF-EMR poses potential threats to the developing stages of organisms.

(E)Avendaño C, Mata A, Sanchez Sarmiento CA, Doncel GF. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. Fertil Steril. 97(1):39-45, 2012. (AE, FC, GE, HU, IV)

OBJECTIVE: To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa. **DESIGN:** Prospective in vitro study. **SETTING:** Center for reproductive medicine. **PATIENT(S):** Semen samples from 29 healthy donors. **INTERVENTION(S):** Motile sperm were selected by swim up. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to an internet-connected laptop by Wi-Fi for 4 hours, whereas the second aliquot (unexposed) was used as control, incubated under identical conditions without being exposed to the laptop. **MAIN OUTCOME MEASURE(S):** Evaluation of sperm motility, viability, and DNA fragmentation. **RESULT(S):** Donor sperm samples, mostly normozoospermic, exposed ex vivo during 4 hours to a wireless internet-connected laptop showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation. Levels of dead sperm showed no significant differences between the two groups. **CONCLUSION(S):** To our knowledge, this is the first study to evaluate the direct impact of laptop use on human spermatozoa. Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility. Further in vitro and in vivo studies are needed to prove this contention.

(E)Azimipour F, Zavareh S, Lashkarbolouki T. The Effect of Radiation Emitted by Cell Phone on The Gelatinolytic Activity of Matrix Metalloproteinase-2 and -9 of Mouse Pre-Antral Follicles during In Vitro Culture. Cell J 22(1):1-8, 2020. (AE, DE, F, IV, ME, MO)

Objective: The unfavorable effects of electromagnetic radiation (EMR) emitted by the cell phone on reproduction health are controversial. Metalloproteinases play a vital role in ovarian follicle development. This study was designed to investigate the effects of exposure to the cell phone on the gelatinolytic activity of *in vitro* cultured mouse pre-antral follicle. **Materials and methods:** In this experimental study, pre-antral follicles were isolated from ovaries of immature mice (n=16) and cultured with or without exposure to the cell phone in talking mode for 60 minutes. The gelatinolytic activity was evaluated through the zymography method, as well as the gene expression of matrix metalloproteinases (MMPs) namely *MMP-2* and -9 and tissue inhibitors of metalloproteinases (TIMPs) namely, *TIMP-1* and -2 by the real-time polymerase

chain reaction (PCR) method. Also, in parallel, the development of pre-antral follicles was assessed. **Results:** The maturation parameters of the cell phone-exposed pre-antral follicles were significantly lower compared with the control group (P<0.05). The gelatinolytic activity was significantly decreased in the cell phone-exposed preantral follicles compared with the control group (P<0.05). The relative mRNA expression of the *MMP-2* gene was significantly (P<0.05) increased in the cell phone-exposed pre-antral follicles whereas the expression rate of the MMP-9 gene was considerably (P<0.05) reduced when compared with the control group. Conversely, the relative expression of the *TIMP-1* was markedly (P<0.05) increased in the cell phone-exposed pre-antral follicles while the expression of the *TIMP-2* was (P<0.05) significantly diminished in comparison with the control group. **Conclusion:** Exposure to the cell phone alters the growth and maturation rate of murine ovarian follicle through the changing in the expression of the *MMP-2* and -9 genes, as well as the gelatinolytic activity.

(E) Azimzadeh M, Jelodar G. Alteration of testicular regulatory and functional molecules following long-time exposure to 900 MHz RFW emitted from BTS. Andrologia 51(9):e13372. 2019. (CE, M, MO, VO)

The aim of this investigation was to evaluate changes in testosterone and some of the functional and regulatory molecules of testis such as P450scc, steroidogenic acute regulatory protein (StAR), tumour necrosis factor-α (TNF-α), interleukin-1α (IL-1α), interleukin-1β (IL-1β) and nerve growth factor (NGF) following exposure to 900 MHz radio frequency (RF). Thirty adult male Sprague Dawley rats (190 ± 20 g BW) were randomly classified in three equal groups, control (sham, without any exposure), short-time exposure (2 hr) (STE) and long-time exposure (4 hr) (LTE). The exposure was performed for 30 consecutive days. The testosterone level in both exposed groups was significantly less than control ($p < .05$). Level of TNF-α in both exposed groups was significantly greater than control ($p < .05$). IL-1α and NGF levels in LTE were significantly higher than the STE and control groups ($p < .05$). Level of IL-1β in LTE was significantly higher than control ($p < .05$). Expression of both P450scc and StAR mRNA was significantly down-regulated in both exposed groups compared to control ($p < .05$). Our results showed that RFW can affect testis and reproductive function through changes in factors, which are important during steroidogenesis, and also through changes in inflammatory factors, which regulate Leydig cell functions.

(E) Azimzadeh M, Jelodar G. Prenatal and early postnatal exposure to radiofrequency waves (900 MHz) adversely affects passive avoidance learning and memory. Toxicol Ind Health 36(12):1024-1030, 2020. (BE, CE, IU, ME, PN, VO)

Prenatal and early postnatal are the most sensitive and high-risk periods to expose to electromagnetic fields (EMFs). This study aimed to investigate the effect of prenatal and early postnatal exposure to 900 MHz radiofrequency waves (RFWs) emitted from a base transceiver station antenna on passive avoidance learning and memory (PALM) and hippocampus histomorphology. Female Sprague Dawley rats (190-230 g) were paired with males. The mated rats, confirmed by observing a vaginal plug, were divided into two groups; control and exposed. The control group ($n = 7$) was not exposed to RFW. The exposed group was divided into three subgroups ($n = 8$); exposed I, exposed during the gestational period (fetal life), and exposed II and III (postnatal exposure), exposed to RFW during the first 21 days of life, for 2 h/d and 4 h/d,

respectively. PALM was evaluated by a shuttle box in 45-day-old pups. Learning and memory of animals were demonstrated as the duration of remaining within the light area, which is called the lighting time. Histological sections were prepared from brain tissues and stained with hematoxylin and eosin. An impairment in the PALM performance was noticed in all exposed subgroups (I, II, and III) ($p < 0.05$). Learning (short-term memory) and retention (long-term memory) behaviors were more affected in exposed subgroup I (prenatal exposed) compared to other postnatal exposed subgroups (II and III). Also, a mild decrease in the density of pyramidal cells was observed in the hippocampus of exposed subgroups (I and III). Prenatal and early postnatal exposure to 900 MHz RFW adversely affected PALM performance and hippocampus tissue in rat pups with more impact for prenatal period exposure.

(E)Bahreyni Toossi MH, Sadeghnia HR, Mohammad Mahdizadeh Feyzabadi M, Hosseini M, Hedayati M, Mosallanejad R, Beheshti F, Alizadeh Rahvar Z. Exposure to mobile phone **(900-1800 MHz) during pregnancy: tissue oxidative stress after childbirth. J Matern Fetal Neonatal Med. 31(10):1298-1303, 2018. (CE, IU, OX)**

BACKGROUND: The present study has investigated the effects of **mobile phone** (900-1800 MHz)-induced electromagnetic radiation on redox status in the heart, liver, kidney, cerebellum, and hippocampus of dams and the offspring mice. MATERIALS AND METHODS: Pregnant Balb/C were divided into two groups including the control and the experimental group. The experimental group was exposed to **mobile phone** (900-1800 MHz), during pregnancy (2 h/d for 20 d). The dams and the offspring of both groups were sacrificed and tissues of interest were harvested immediately after delivery. Malondialdehyde (MDA) concentration, total thiol groups (TTG) content, superoxide dismutase (SOD), and catalase (CAT) activities were determined in the tissues. RESULTS: In the experimental groups, MDA levels were significantly increased, while TTG, SOD, and CAT were significantly decreased in the total tissues of dams and their offspring. CONCLUSION: Exposure to **mobile phone** (900-1800 MHz) during pregnancy induced oxidative stress in tissues of dams and their offspring.

(E)Bakacak M, Bostancı MS, Attar R, Yıldırım ÖK, Yıldırım G, Bakacak Z, Sayar H, Han A. The effects of electromagnetic fields on the number of ovarian primordial follicles: An experimental study. Kaohsiung J Med Sci. 31(6):287-292, 2015. (CE, F, ME) (900 MHz, 217 Hz modulation, SAR 0.018 - 4 W/kg in the body)

The aim of this study was to evaluate the effect of an electromagnetic field (EMF), generated close to the ovaries, on primordial follicles. A total of 16 rats were used in this study. The study group consisted of rats exposed to an EMF in the abdominal region for 15 min/d for 15 days. Both the study and control group were composed of eight rats. After the treatment period of 15 days, the ovaries of the rats were extracted, and sections of ovarian tissue were taken for histological evaluation. The independent samples t test was used to compare the two groups. In the study group, the means of the right and left ovarian follicle numbers were 34.00 ± 10.20 and 36.00 ± 10.53, respectively. The average total ovarian follicle number was 70.00 ± 19.03. In the control group, the means of the right and left ovarian follicle numbers were 78.50 ± 25.98 and 71.75 ± 29.66, respectively, and the average total ovarian follicle number was 150.25 ± 49.53. The comparisons of the means of the right and left

ovarian follicle numbers and the means of the total ovarian follicle numbers between the study and control groups indicated that the study group had significantly fewer follicles ($p < 0.001$, $p = 0.011$, and $p = 0.002$, respectively). This study found a significant decrease in the number of ovarian follicles in rats exposed to an EMF. Further clinical studies are needed to reveal the effects of EMFs on ovarian reserve and infertility.

Bakker JF, Paulides MM, Christ A, Kuster N, van Rhoon GC. Assessment of induced SAR in children exposed to electromagnetic plane waves between 10 MHz and 5.6 GHz. Phys Med Biol 55:3115-3130, 2010. (Dosimetry)

To avoid potentially adverse health effects of electromagnetic fields (EMF), the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has defined EMF reference levels from the basic restrictions on the induced whole-body-averaged specific absorption rate (SAR(wb)) and the peak 10 g spatial-averaged SAR (SAR(10g)). The objective of this study is to assess if the SAR in children remains below the basic restrictions upon exposure at the reference levels. Finite difference time domain (FDTD) modeling was used to calculate the SAR in six children and two adults when exposed to all 12 orthogonal plane wave configurations. A sensitivity study showed an expanded uncertainty of 53% (SAR(wb)) and 58% (SAR(10g)) due to variations in simulation settings and tissue properties. In this study, we found that the basic restriction on the SAR(wb) is occasionally exceeded for children, up to a maximum of 45% in small children. The maximum SAR(10g) values, usually found at body protrusions, remain under the limit for all scenarios studied. Our results are in good agreement with the literature, suggesting that the recommended ICNIRP reference levels may need fine tuning.

(E) Balmori A. Mobile Phone Mast Effects on Common Frog (Rana temporaria) Tadpoles: The City Turned into a Laboratory. Electromagn Biol Med. 29(1-2):31-35, 2010. (BE, CE, DE)

An experiment has been made exposing eggs and tadpoles of the common frog (Rana temporaria) to electromagnetic radiation from several mobile (cell) phone antennae located at a distance of 140 meters. The experiment lasted two months, from the egg phase until an advanced phase of tadpole prior to metamorphosis. Measurements of electric field intensity (radiofrequencies and microwaves) in V/m obtained with three different devices were 1.8 to 3.5 V/m. In the exposed group (n = 70), low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) was observed. Regarding the control group (n = 70) under the same conditions but inside a Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained. These results indicate that radiation emitted by phone masts in a real situation may affect the development and may cause an increase in mortality of exposed tadpoles. This research may have huge implications for the natural world, which is now exposed to high microwave radiation levels from a multitude of phone masts.

(NE)Banerjee K, Thind A, Bhatnagar N, Singla B, Agria K, Bajaj P, Jindal A, Arora S, G oyal P, haMittal B, Malhotra K, Pai H, Malhotra J, Goel P, Jindal N. Effect of Reproductive and Lifestyle Factors on Anti-Mullerian Hormone Levels in Women of Indian Origin. J Hum Reprod Sci 15(3):259-271, 2022. (CE, F, HU, MO)

Background: Infertility is a world-wide problem and one third females. Over the years, anti-mullerian hormone (AMH) has emerged as a major marker of ovarian reserve. There is also increasing interest in determining the factors which can impact AMH levels. **Aims:** To correlate the association of reproductive and lifestyle factors on AMH levels in women of Indian origin. **Settings and design:** Multicentric cross sectional study. **Materials and methods:** The study was conducted using data extracted from the patient records of seven private fertility practices located in North India. Women who were attending these clinics for fertility treatment were requested to fill the questionnaire related to reproductive and lifestyle factors. **Statistical analysis used:** Our outcome variable was level of AMH measured in the past 3 months, and was assessed as normal or low. All analyses were conducted using STATA 17. **Results:** We found a direct association of low AMH with increasing age, short cycles, amenorrhea and women with family history of premature menopause. We found a direct correlation of high AMH and women with polycystic ovary syndrome and those whose partners had Oligoasthenoteratozoospermia (OATS) or azoospermia. There was no correlation with smoking, sleep, diet, body mass index, cell phone or laptop use in our study. **Conclusion:** Reproductive and lifestyle factors may affect ovarian reserve and but there was a dearth of human studies in this area. To the best of our knowledge this is the first human study on the effect of AMH on Laptop and Cell phone use. We urgently need more studies to confirm or refute our findings so that we can counsel our patients well.

(E) Bas O, Odaci E, Mollaoglu H, Ucok K, Kaplan S. Chronic prenatal exposure to the 900 megahertz electromagnetic field induces pyramidal cell loss in the hippocampus of newborn rats. Toxicol Ind Health 25(6):377-384, 2009. (CE, IU, ME, NU, VO) (SAR 2 W/kg)

Widespread use of mobile phones which are a major source of electromagnetic fields might affect living organisms. However, there has been no investigation concerning prenatal exposure to electromagnetic fields or their roles in the development of the pyramidal cells of the cornu ammonis in postnatal life. Two groups of pregnant rats, a control group and an experimental group, that were exposed to an electromagnetic field were used. For obtaining electromagnetic field offspring, the pregnant rats were exposed to 900 megahertz electromagnetic fields during the 1-19th gestation days. There were no actions performed on the control group during the same period. The offspring rats were spontaneously delivered--control group (n = 6) and electromagnetic field group (n = 6). Offspring were sacrificed for stereological analyses at the end of the 4th week. Pyramidal cell number in rat cornu ammonis was estimated using the optical fractionator technique. It was found that 900 megahertz of electromagnetic field significantly reduced the total pyramidal cell number in the cornu ammonis of the electromagnetic field group ($P < 0.001$). Therefore, although its exact mechanism is not clear, it is suggested that pyramidal cell loss in the cornu ammonis could be due to the 900 megahertz electromagnetic field exposure in the prenatal period.

(E)Baş O, Sönmez OF, Aslan A, İkinci A, Hancı H, Yıldırım M, Kaya H, Akça M, Odacı E.

Pyramidal Cell Loss in the Cornu Ammonis of 32-day-old Female Rats Following Exposure to a 900 Megahertz Electromagnetic Field During Prenatal Days 13–21. NeuroQuantology 11(4) 591-599, 2013. (CE, IU, ME, NU, VO) (0.0256 mW/cm^2)

The number of studies reporting that the electromagnetic field (EMF) emitted by mobile phones affects human health is increasing by the day. In previous studies we reported that a 900 megahertz (MHz) EMF applied throughout the prenatal period reduced the number of pyramidal cells in the cornu ammonis of rat pups in the postnatal period. In this study we investigated the effect of a 900 MHz EMF applied on days 13-21 of the prenatal period on the number of pyramidal cells in the cornu ammonis of rat pups in the postnatal period. For that purpose, pregnant rats were divided into experimental and control groups. Experimental group pregnant rats were exposed to the effect of a 900 MHz EMF on days 13-21 of pregnancy. No procedure was applied to the control group. Newborn female rat pups were added to the study, and no procedure was performed on these after birth. Five newborn female rats were obtained from the experimental group and six from the control group. All female rat pups were decapitated on the postnatal 32nd day, and histological procedures were performed on the brain tissues. Sections were stained with Cresyl fast violet. The optical dissector technique was used to estimate the total number of pyramidal cells in the cornu ammonis. Sections of cornu ammonis were subjected to histopathological evaluations. Our results showed that exposure to 900 MHz EMF during prenatal days 13-21 led to a significant decrease in the number of pyramidal cells in the cornu ammonis of the experimental group female rat pups ($P<0.05$). Histopathological examination revealed picnotic cells in the cornu ammonis in experimental female rat pups. The pyramidal cell loss in the cornu ammonis may therefore be attributed to exposure to 900 MHz EMF in days 13-21 of the prenatal period.

(E)Bas O, Sengul I, Bas OFM, Hanci H, Degermenci M, Sengul D, Altuntas E, Soztanaci US, Sonmez OF, Soares Junior JM. Impressions of the chronic 900-MHz electromagnetic field in the prenatal period on Purkinje cells in male rat pup cerebella: is it worth mentioning? Rev Assoc Med Bras (1992) 68(10):1383-1388, 2022. (CE, IU, ME, NU, VO)

Objective: The aim of this study was to examine the changes on the Purkinje cells in the cerebella of male rat pups born to pregnant dams that were exposed to an electromagnetic field in the prenatal period. **Methods:** The first stage of the study involved 12 Sprague-Dawley rats, 6 male and 6 female, weighing between 180 and 250 g. The female rats in the experimental group were exposed to a 900-MHz electromagnetic field for 1 h at the same time every day, and no procedure was performed on the control group. Following pregnancy, six male pups from each group were divided into experimental and control groups without any procedure on the pups. After 2 months, they were sacrificed and their cerebella were removed. Histopathologically, following routine processing and fixation procedures, the cerebella were embedded in the tissue blocks. The sections taken from these blocks were stained with cresyl violet. The Purkinje cells in the cerebella were then counted on sections using the optical dissector method on an image analysis system. **Results:** The estimation of number of the Purkinje cells in the groups revealed more cells in rats in the control group than in the experimental group. Histopathologically, Purkinje cells exhibited a normal morphological structure in the control group, while the cells in the experimental group showed damage. **Conclusions:** It might be asserted that the exposure of

mothers to an electromagnetic field in the prenatal period may affect the development of Purkinje cells in the pup cerebella.

(E) Baste V, Riise T, Moen BE. Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. Eur J Epidemiol.23(5):369-377,2008. (CE, FC, HU, M)

Concern is growing about exposure to electromagnetic fields and male reproductive health. The authors performed a cross-sectional study among military men employed in the Royal Norwegian Navy, including information about work close to equipment emitting radiofrequency electromagnetic fields, one-year infertility, children and sex of the offspring. Among 10,497 respondents, 22% had worked close to high-frequency aerials to a "high" or "very high" degree. Infertility increased significantly along with increasing self-reported exposure to radiofrequency electromagnetic fields. In a logistic regression, odds ratio (OR) for infertility among those who had worked closer than 10 m from high-frequency aerials to a "very high" degree relative to those who reported no work near high-frequency aerials was 1.86 (95% confidence interval (CI): 1.46-2.37), adjusted for age, smoking habits, alcohol consumption and exposure to organic solvents, welding and lead. Similar adjusted OR for those exposed to a "high", "some" and "low" degree were 1.93 (95% CI: 1.55-2.40), 1.52 (95% CI: 1.25-1.84), and 1.39 (95% CI: 1.15-1.68), respectively. In all age groups there were significant linear trends with higher prevalence of involuntary childlessness with higher self-reported exposure to radiofrequency fields. However, the degree of exposure to radiofrequency radiation and the number of children were not associated. For self-reported exposure both to high-frequency aerials and communication equipment there were significant linear trends with lower ratio of boys to girls at birth when the father reported a higher degree of radiofrequency electromagnetic exposure.

(E) Baste V, Moen BE, Oftedal G, Strand LA, Bjørge L, Mild KH. Pregnancy Outcomes After Paternal Radiofrequency Field Exposure Aboard Fast Patrol Boats. J Occup Environ Med. 54(4):431-438, 2012. (CE, FC, HU, M)

OBJECTIVES: To investigate adverse reproductive outcomes among male employees in the Royal Norwegian Navy exposed to radiofrequency electromagnetic fields aboard fast patrol boats. METHODS: Cohort study of Royal Norwegian Navy servicemen linked to the Medical Birth Registry of Norway, including singleton offspring born between 1967 and 2008 (n = 37,920). Exposure during the last 3 months before conception (acute) and exposure more than 3 months before conception (nonacute) were analyzed. RESULTS: Perinatal mortality and preeclampsia increased after service aboard fast patrol boats during an acute period and also after increased estimated radiofrequency exposure during an acute period, compared with service aboard other vessels. No associations were found between nonacute exposure and any of the reproductive outcomes. CONCLUSIONS: Paternal work aboard fast patrol boats during an acute period was associated with perinatal mortality and preeclampsia, but the cause is not clear.

(E) Batellier F, Couty I, Picard D, Brillard JP. Effects of exposing chicken eggs to a cell phone in "call" position over the entire incubation period. Theriogenology. 69(6):737-745, 2008. (CE, DE, VO)

The aim of the present study was to assess the effects of exposing fertile chicken eggs to a cell phone repeatedly calling a ten-digit number at 3-min intervals over the entire period of incubation. A pre-experiment was performed first to adjust incubation conditions in an experimental chamber devoid of metallic content and without automatic turning until the overall performance of hatchability was reproducible in the absence of the cell phone. The experimental period consisted of a series of 4 incubations referred to as "replicates". For each replicate, one batch of 60 eggs was exposed to the immediate environment (</=25cm) of a cell phone in the "call" position (exposed group), while another batch of 60 eggs, 1.5m away from the exposed group and also in the incubation chamber, was exposed to a similar cell phone in the "off" position (sham group). For each replicate, 2 other groups each of 60 eggs were also incubated, one in a standard mini-incubator ("Control I" group) and the second in a standard medium size incubator ("Control II" group). Temperature, relative humidity and electromagnetic fields in the experimental chamber were permanently monitored over the entire experiment. A significantly higher percentage of embryo mortality was observed in the "exposed" compared to the "sham" group in 2 of the 4 replicates ($p<.05$). In comparison with control groups, additional embryo mortality in the exposed group occurred mainly between Days 9 and 12 of incubation but a causal relationship between the intensity of the electric field and embryo mortality could not be established.

Bellieni CV, Pinto I, Bogi A, Zoppetti N, Andreuccetti D, Buonocore G. Exposure to electromagnetic fields from laptop use of "laptop" computers. Arch Environ Occup Health. 67(1):31-36, 2012. (Dosimetry)

Portable computers are often used at tight contact with the body and therefore are called "laptop." The authors measured electromagnetic fields (EMFs) laptop computers produce and estimated the induced currents in the body, to assess the safety of laptop computers. The authors evaluated 5 commonly used laptop of different brands. They measured EMF exposure produced and, using validated computerized models, the authors exploited the data of one of the laptop computers (LTCs) to estimate the magnetic flux exposure of the user and of the fetus in the womb, when the laptop is used at close contact with the woman's womb. In the LTCs analyzed, EMF values (range 1.8-6 μT) are within International Commission on Non-Ionizing Radiation (NIR) Protection (ICNIRP) guidelines, but are considerably higher than the values recommended by 2 recent guidelines for computer monitors magnetic field emissions, MPR II (Swedish Board for Technical Accreditation) and TCO (Swedish Confederation of Professional Employees), and those considered risky for tumor development. When close to the body, the laptop induces currents that are within 34.2% to 49.8% ICNIRP recommendations, but not negligible, to the adult's body and to the fetus (in pregnant women). On the contrary, the power supply induces strong intracorporal electric current densities in the fetus and in the adult subject, which are respectively 182-263% and 71-483% higher than ICNIRP 98 basic restriction recommended to prevent adverse health effects. Laptop is paradoxically an improper site for the use of a LTC, which consequently should be renamed to not induce customers towards an improper use.

Benini M, Parazzini M, Bonato M, Gallucci S, Chiaramello E, Fiocchi S, Tognola G. Assessment of Children's Exposure to Intelligent Transport System 5.9 GHz Vehicular Connectivity Using Numerical Dosimetry. Sensors (Basel) 23(11):5170, 2023. (Dosimetry)

This study investigates the radio-frequency electromagnetic field exposure (RF-EMF) levels in pedestrians generated by vehicular communication technology. We specifically investigated exposure levels in children of different ages and both genders. This study also compares the children's exposure levels generated by such technology with those of an adult investigated in our previous study. The exposure scenario consisted of a 3D-CAD model of a vehicle equipped with two vehicular antennas operating at 5.9 GHz, each fed with 1 W power. Four child models were analyzed near the front and back of the car. The RF-EMF exposure levels were expressed as the Specific Absorption Rate (SAR) calculated over the whole body and 10 g mass (SAR10g) of the skin and 1 g mass (SAR1g) of the eyes. The maximum SAR10g value of 9 mW/kg was found in the skin of the head of the tallest child. The maximum whole-body SAR was 0.18 mW/kg and was found in the tallest child. As a general result, it was found that children's exposure levels are lower than those of adults. All the SAR values are well below the limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in the general population.

(E) Besset D, Selmaoui B, Delanaud S, Bessarion L, Chardon K, de Seze R, Leke A, Stéphan-Blanchard E. Influence of radiofrequency electromagnetic fields exposure on sleep patterns in preterm neonates. Int J Radiat Biol 2023 Nov 16:1-6. doi: 10.1080/09553002.2023.2277365. Online ahead of print. (CE, DE, HU, NU) (median field level 0.03 V/m; sources unknow)

Purpose: The study objective was to assess the influence of radiofrequency electromagnetic fields (RF-EMF) exposure on sleep patterns in preterm newborns. We hypothesized that an increase in RF-EMF exposure levels would alter infants' sleep structure parameters. **Materials and methods:** Individual, continuous measurements of RF-EMF levels were performed in 29 hospitalized preterm newborns throughout the first 21 days after birth. The last day, overnight sleep structure was recorded by polysomnography. Relationships between both chronic (three-week period) and acute (polysomnographic period) RF-EMF levels with sleep parameters were computed. **Results:** At median levels, the main chronic effect was an increase in indeterminate sleep with RF-EMF exposure. At the highest exposure levels found in our study, an increase in RF-EMF levels increased sleep fragmentation. No significant relationship was found between acute RF-EMF levels and sleep parameters. **Conclusions:** Despite no consolidated disruption in sleep structure, this study is the first to show that some sleep parameters seem to have a certain sensitivity to chronic - but not acute - RF-EMF exposure in preterm newborns. Further studies are needed to confirm our results and examine possible mid- to long-term, sleep-related cardiorespiratory and neurodevelopmental outcomes.

(E) Bilgici B, Gun S, Avci B, Akar A, Engiz BK. What is adverse effect of wireless local area network, using 2.45 GHz, on the reproductive system? Int J Radiat Biol 94(11):1054-1061, 2018. (CE, M, ME, MO, VO) (Low SAR)

Aim: To investigate the inflammatory effect and testicular damage on rats exposed to low level of electromagnetic fields (EMF) at 2.45 GHz microwave radiation. **Methods:** Twenty two Wistar rats were divided into two groups. Group 1 was the control group and not exposed to EMF. Group 2 was exposed to low level EMF (average E-field 3.68 ± 0.36 V/m, whole body average SAR, 0.0233 W/kg, in 10 g tissue) at 2.45 GHz for 1 hour/day for 30 consecutive days.

At the end of the study, interleukin-6 (IL-6), interleukin-10 (IL-10), interleukin-32 (IL-32), C-reactive protein (CRP) were measured in rat serum and IL-6, IL-10, IL-32 were measured in rat testis tissue. Furthermore, testicular tissues were evaluated histopathologically in terms of spermatogenesis and coagulation necrosis. **Results:** Serum IL-6 and CRP levels were found to be significantly different in the study group compared to the control group ($p < .05$), but no significant difference was found in serum IL-10, IL-32 levels and testis tissue IL-6, IL-10, IL-32 levels compared to the control group ($p > .05$). On the other hand, histopathological evaluation of testicular tissue revealed a significant difference in necrosis and spermatogenesis when compared with the control group ($p < .05$). **Conclusions:** It may be concluded that low level EMF at 2.45 GHz increases inflammation and testicular damage and negative impact on male reproductive system function.

(E) Bin-Meferij MM, El-Kott AF. The radioprotective effects of Moringa oleifera against mobile phone electromagnetic radiation-induced infertility in rats. Int J Clin Exp Med. 8(8):12487-12497, 2015. (CE, M, ME, OX, VO)

The present study has investigated the effects of mobile phone electromagnetic radiation (EMR) on fertility in rats. The purpose of this study was to explore the capability of polyphenolic-rich Moringa oleifera leaf extract in protecting rat testis against EMR-induced impairments based on evaluation of sperm count, viability, motility, sperm cell morphology, anti-oxidants (SOD & CAT), oxidative stress marker, testis tissue histopathology and PCNA immunohistochemistry. The sample consisted of sixty male Wistar rats which were divided into four equal groups. The first group (the control) received only standard diet while the second group was supplemented daily and for eight weeks with 200 mg/kg aqueous extract of Moringa leaves. The third group was exposed to 900 MHz fields for one hour a day and for (7) days a week. As for the fourth group, it was exposed to mobile phone radiation and received the Moringa extract. The results showed that the EMR treated group exhibited a significantly decrease sperm parameters. Furthermore, concurrent exposure to EMR and treated with MOE significantly enhanced the sperm parameters. However, histological results in EMR group showed irregular seminiferous tubules, few spermatogonia, giant multinucleated cells, degenerated spermatozoa and the number of Leydig cells was significantly reduced. PCNA labeling indices were significant in EMR group versus the control group. Also, EMR affects spermatogenesis and causes to apoptosis due to the heat and other stress-related EMR in testis tissue. This study concludes that chronic exposure to EMR marked testicular injury which can be prevented by Moringa oleifera leaf extract.

(E) Birks L, Guxens M, Papadopoulou E, Alexander J, Ballester F, Estarlich M, Gallastegi M, Ha M, Haugen M, Huss A, Kheifets L, Lim H, Olsen J, Santa-Marina L, Sudan M, Vermeulen R, Vrijkotte T, Cardis E, Vrijheid M. Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts. Environ Int. 104:122-131, 2017. (BE, CE, DE, HU)

INTRODUCTION: Previous studies have reported associations between prenatal **cell phone** use and child behavioral problems, but findings have been inconsistent and based on retrospective assessment of **cell phone** use. This study aimed to assess this association in a multi-national analysis, using data from three cohorts with prospective data on prenatal **cell phone** use, together with previously published data from two cohorts with

retrospectively collected **cell phone** use data. METHODS: We used individual participant data from 83,884 mother-child pairs in the five cohorts from Denmark (1996-2002), Korea (2006-2011), the Netherlands (2003-2004), Norway (2004-2008), and Spain (2003-2008). We categorized **cell phone** use into none, low, medium, and high, based on frequency of calls during pregnancy reported by the mothers. Child behavioral problems (reported by mothers using the Strengths and Difficulties Questionnaire or Child Behavior Checklist) were classified in the borderline/clinical and clinical ranges using validated cut-offs in children aged 5-7years. Cohort specific risk estimates were meta-analyzed. RESULTS: Overall, 38.8% of mothers, mostly from the Danish cohort, reported no **cell phone** use during pregnancy and these mothers were less likely to have a child with overall behavioral, hyperactivity/inattention or emotional problems. Evidence for a trend of increasing risk of child behavioral problems through the maternal **cell phone** use categories was observed for hyperactivity/inattention problems (OR for problems in the clinical range: 1.11, 95%CI 1.01, 1.22; 1.28, 95%CI 1.12, 1.48, among children of medium and high users, respectively). This association was fairly consistent across cohorts and between cohorts with retrospectively and prospectively collected **cell phone** use data. CONCLUSIONS: Maternal **cell phone** use during pregnancy may be associated with an increased risk for behavioral problems, particularly hyperactivity/inattention problems, in the offspring. The interpretation of these results is unclear as uncontrolled confounding may influence both maternal **cell phone** use and child behavioral problems.

(E) Bodin R, Seewooruttun C, Corona A, Delanaud S, Pelletier A, Villégier A. Sex-dependent impact of perinatal 5G electromagnetic field exposure in the adolescent rat behavior. Environ Sci Pollut Res Int 30(53):113704-113717, 2023. (BE, CE, DE, IU, ME, PN, VO) (low SAR)

The fifth generation (5G) network is currently being worldwide spread out, raising questions about the potential impact of this new technology, particularly on immature organisms. The current study aimed to investigate the effects of daily 5G electromagnetic field (EMF) perinatal exposure on the neurodevelopment of rats. The exposure level was set to the limit of whole-body public exposure defined by the International Commission on Non-Ionizing Radiation Protection. The mother rat specific absorption rate (SAR) was 0.07 W/kg for 22 h/day at 3500 MHz continuous wave from gestational day (GD) 8 to post-natal day (PND) 21. Clinical observations were performed on weight, length, sex ratio, number of pups per litter, and number of stillborn in sham and EMF-exposed groups (n = 7). The age of pinna ear detachment, incisor eruption, and eye opening were recorded. Behavior was assessed on righting, gripping, and negative geotaxis reflexes at PND 3 or 7 and on stereotyped and horizontal movements in the open field at PND 43. Our results indicated that both male and female pups showed delayed incisor eruption in the EMF-exposed group compared to the sham group (+ 1 day). Regarding activity in the open field, adolescent females showed less stereotyped movements (- 70%), while adolescent males showed more stereotyped movements (+ 50%) compared to the sham-exposed adolescent rats. Thus, the present study suggested that perinatal exposure to 5G at SAR level below reglementary threshold led to perturbations in the descendants seen in juveniles and adolescents.

(E) Boga A, Emre M, Sertdemir Y, Akillioglu K, Binokay S, Demirhan O. The effect of 900 and 1800 MHz GSM-like radiofrequency irradiation and nicotine sulfate administration on the embryonic development of Xenopus laevis. Ecotoxicol Environ Saf. 113:378-390, 2015. (CE, DE, IX, VO)

The aim of this study was to investigate the effects of GSM-like radiofrequency electromagnetic radiation (RF EMR) and nicotine sulfate (NS) exposure on Xenopus embryonic development. The developmental effects of GSM-like RF-EMR (900-1800MHz, at a SAR value of 1 W/kg and NS on Xenopus laevis embryos were investigated). Following the application of radiofrequency radiation and/or NS administration, the embryos were closely examined in order to determine their possible teratogenic effects. Xenopus frogs obtained from the Department of Physiology of the Cukurova University, in accordance described by the Standard Guide of the American Society for Testing and Materials (ASTM). Following the exposure of Xenopus embryos to RF-EMR at 900 and 1800MHz (1.0 W/kg) for 4, 6 and 8 h; the whole body specific energy absorption rate (SAR) of the embryos was calculated. With the exception of irradiation at 1800MHz no dramatic developmental anomalies were observed in the Xenopus embryos in association with RF-EMR applications. Combined RF-EMR and NS applications resulted in dramatic abnormalities and death among the Xenopus embryos.The study results indicated that GSM-like RF-EMR (e.g. radiation from cell phones) was not as harmful to Xenopus embryos as might have been expected. However, the combined effects of GSM-like RF-EMR and NS on Xenopus embryos were more severe than the effect of RF-EMR or NS alone. In conclusion, the study results appear to suggest that the combined use of nicotine and cell phones might result in more pronounced detrimental effects on the health of smokers.

(E) Boga A, Emre M, Sertdemir Y, Uncu İ, Binokay S, Demirhan O. Effects of GSM-like radiofrequency irradiation during the oogenesis and spermiogenesis of Xenopus laevis. Ecotoxicol Environ Saf. 129:137-144, 2016. (BE, CE, DE, F, M, VO)

We aimed to evaluate the effect of GSM-like radiofrequency electromagnetic radiation (RF-EMR) on the oogenesis, and spermiogenesis of Xenopus laevis, and so the development of the embryos obtained from Normal Females + Normal Males (i.e. "N(F)+N(M)"); Normal Females + RF-exposed Males (i.e. "N(F)+RF(M)"); RF-exposed Female + Normal Male (i.e. "RF(F) + N(M)"); and RF-exposed Female + RF-exposed Male (i.e. "RF(F) + RF(M)". Various, assessments were performed to determine potential teratogenic effects and mortality, body growth and behavior on first generation embryos. After exposing adults frogs of both sexes to 900MHz RF-EMR (at 1.0 W/kg) for 8 h a day over a 5-week period, the embryos' specific energy absorption rate (SAR) was calculated. In our present study (control group; 2.2% abnormal, 0.0% dead); with the N(F)+RF(M) combination, the long-term exposure of adult males to GSM-like radiation at 900 MHz (RF: 2W) for 5 week/8h/day resulted in normal, abnormal and dead embryo ratios of 88.3%, 3.3% and 8.3%, respectively ($p<0.001$). In the RF(F) + N(M) combination, long-term exposure (5 week/8h/day) of adult females led to normal, abnormal and dead embryo ratios of 76.7%, 11.7%, and 11.7%, respectively ($p<0.001$). And in the RF(F) + RF(M) combination, long-term exposure (5 week/8h/day) of both adult males and females led to normal, abnormal and dead embryo ratios of 73.3%, 11.7%, and 15%, respectively ($p<0.001$). With the

exception RF(F) + RF(M) group (p<0.001), no significant changes were observed on body growth (lengths) in comparison to the control group. It was also observed that the offspring of female adult Xenopus exposed to RF-EMR during oogenesis exhibited a more aggressive behavior compared to the control group. Cell phones radiation can thus lead to detrimental effects in humans' male and female reproductive cells.

(E) Boileau N, Margueritte F, Gauthier T, Boukeffa N, Preux P-M, Labrunie A, Aubard Y. Mobile phone use during pregnancy: Which association with fetal growth? J Gynecol Obstet Hum Reprod 49(8):101852, 2020. (CE, DE, HU, IU)

Introduction: Few studies have investigated the effect of electromagnetic waves on the human fetus whereas nowadays mobile phone use is ubiquitous. The aim of this study was to evaluate the association between mobile phone use by pregnant women and fetal development during pregnancy in the general population. **Material and methods:** Data came from the NéHaVi cohort ("prospective follow-up, from intrauterine development to the age of 18 years, for children born in Haute-Vienne"), a prospective, longitudinal, multicenter (three maternity units in Haute-Vienne) observational cohort focusing on children born between April 2014 and April 2017. Main objective was to investigate the association of mobile phone use on fetal growth. Univariate and multivariate models were generated adjusted for the socioprofessional category variables of the mother, and other variables likely to influence fetal growth. **Results:** For the analysis 1378 medical charts were considered from which 1368 mothers (99.3 %) used their mobile phones during pregnancy. Mean phone time was 29.8 min (range: 0.0-240.0 min) per day. After adjustment, newborns whose mothers used their mobile phones for more than 30 min/day were significantly more likely to have an AUDIPOG score ≤ 10th percentile than those whose mothers used their mobile phones for less than 5 min/day during pregnancy (aOR = 1.54 [1.03; 2.31], p = 0.0374). For women using their cell phones 5-15 min and 15-30 min, there wasn't a significant association with an AUDIPOG score ≤ 10th, respectively aOR = 0.98 [0.58; 1.65] and aOR = 1.68 [0.99; 2.82]. **Conclusion:** Using a mobile phone for calls for more than 30 min per day during pregnancy may have a negative impact on fetal growth. A prospective study should be performed to further evaluate this potential link

(NE) Bornhausen M, Scheingraber H. Prenatal exposure to 900 MHz, cell-phone electromagnetic fields had no effect on operant-behavior performances of adult rats. Bioelectromagnetics 21(8):566-574, 2000. (BE, CE, IU) (Low SAR)

To clarify potential health risks of radio-frequency electromagnetic fields (EMFs) used in cellular telephone technology to the developing brain, Wistar rats were continuously exposed during pregnancy to a low-level (0.1 mW/cm(2)) 900 MHz, 217 Hz pulse modulated EMF that approximated the highest legal exposure of normal populations to the radiation of base antennas of the GSM digital cell-phone technology. Whole body average specific absorption rate (SAR) values for the freely roaming, pregnant animals were measured in models; they ranged between 17.5 and 75 mW/kg. The offspring of exposed and of sham-exposed dams were coded and tested later as adults in a battery of ten simultaneously operated test chambers (Skinner boxes) during night time. Eight groups of ten coded animals in each group were tested for learning deficits in a sequence of nine, computer-controlled, 15 h sessions of the food-reinforced contingency Differential Reinforcement of Rate with increasing performance requirements. Two different sets

of events were recorded: The food-reinforced lever-pressing activity of the animals and the inter-response intervals (IRIs) between consecutive lever presses. IRI-occurence patterns discriminated consistently between "learners" and "non-learners". Analyses of performance scores and of IRI-patterns both showed that exposure in-utero to the GSM field did not induce any measurable cognitive deficits.

(E) Bozok S, Karaagac E, Sener D, Akakin D, Tumkaya L. The effects of long-term prenatal exposure to 900, 1800, and 2100 MHz electromagnetic field radiation on myocardial tissue of rats. Toxicol Ind Health 39(1):1-9, 2023. (CE, M, IU, ME, OX, VO) (Low SAR 0.087-0.17 W/kg)

It is well-known that wireless communication technologies facilitate human life. However, the harmful effects of electromagnetic field (EMF) radiation on the human body should not be ignored. In the present study, we evaluated the effects of long-term, prenatal exposure to EMF radiation on the myocardium of rats at varying durations. Overall, 18 pregnant Sprague-Dawley rats were assigned into six groups (n = 3 in each group). In all groups other than the control group, three pregnant rats were exposed to EMF radiation (900, 1800 and 2100 MHz) for 6, 12 and 24 h over 20 days. After delivery, the newborn male pups were identified and six newborn male pups from each group were randomly selected**.** Then, histopathological and biochemical analysis of myocardial samples were performed. When 24-h/day prenatal exposures to 900, 1800, 2100 MHz EMF radiation were evaluated, myocardial damage was greater in the 2100 MHz EMF-24h group than the other groups. In addition, when malondialdehyde (MDA) and glutathione (GSH) levels associated with reactive oxidative species (ROS) were evaluated, the MDA level was higher in the 2100 MHz EMF-24h group compared with the other groups. The GSH level was also lower in the 2100 MHz EMF-24h group. When the 6, 12 and 24 h/day prenatal exposures to 1800 MHz EMF radiation were evaluated, myocardial damage was greater in 1800 MHz EMF-24h group than the remaining groups ($p < 0.0001$). Also, MDA level was greater in the 1800 MHz EMF-24h group compared with the other groups while the GSH level was lower in this group. It was shown that myocardial tissue was affected more by long-term exposure to EMF radiation at high frequencies. The data raise concerns that the harmful effects of non-ionizing radiation exposure on cardiac tissue will increase with 5G technology.

(E) Broom KA, Findlay R, Addison DS, Goiceanu C, Sienkiewicz Z. Early-Life Exposure to Pulsed LTE Radiofrequency Fields Causes Persistent Changes in Activity and Behavior in C57BL/6 J Mice. Bioelectromagnetics 40(7):498-511, 2019. (BE, CE, IU, PN, VO) (Effects were SAR dependent.)

Despite much research, gaps remain in knowledge about the potential health effects of exposure to radiofrequency (RF) fields. This study investigated the effects of early-life exposure to pulsed long term evolution (LTE) 1,846 MHz downlink signals on innate mouse behavior. Animals were exposed for 30 min/day, 5 days/week at a whole-body average specific energy absorption rate (SAR) of 0.5 or 1 W/kg from late pregnancy (gestation day 13.5) to weaning (postnatal day 21). A behavioral tracking system measured locomotor, drinking, and feeding behavior in the home cage from 12 to 28 weeks of age. The exposure caused significant effects on both appetitive behaviors and activity of offspring that depended on the SAR. Compared with sham-exposed controls, exposure at 0.5 W/kg significantly decreased drinking frequency ($P \leq 0.000$)

and significantly decreased distance moved ($P \leq 0.001$). In contrast, exposure at 1 W/kg significantly increased drinking frequency ($P \leq 0.001$) and significantly increased moving duration ($P \leq 0.005$). In the absence of other plausible explanations, it is concluded that repeated exposure to low-level RF fields in early life may have a persistent and long-term effect on adult behavior.

(E) Budak GG, Muluk NB, Oztürk GG, Budak B, Apan A, Seyhan N, Sanli C. Effects of GSM-like radiofrequency on distortion product otoacoustic emissions in pregnant adult rabbits. Clin Invest Med. 32(2):E112-116, 2009.(CE, F, NU, VO) (No dosimetry data provided.)

OBJECTIVES: To determine the effects of 1800 MHz GSM-like Radiofrequency (RFR) on the cochlear functions of pregnant adult rabbits by Distortion Product Otoacoustic Emissions (DPOAEs). METHODS: Eighteen 13-month-old pregnant and eighteen 13-month-old non-pregnant New Zealand White rabbits were studied. They were randomly divided into four groups. Nine pregnant rabbits (Group 2) and nine non-pregnant rabbits (Group 4) were exposed to 1800 MHz GSM-like RFR 15 min daily for 7 days. Nine pregnant (Group 1) and nine non-pregnant rabbits (Group 3) were not exposed to GSM like RFR. Cochlear functions were assessed by DPOAEs at 1.0-8.0 kHz. RESULTS: In all pregnant groups except 2.0 kHz, DPOAE amplitudes were not different in Group 2 and Group1. In Group 4, DPOAE amplitudes at 1.0-4.0 kHz (-1.68 dB SPL at 1.0 kHz, 3.05 dB SPL at 1.5 kHz, 2.96 dB SPL at 2.0 kHz, 1.30 dB SPL at 3.0 kHz and 12.22 dB SPL at 4.0 kHz) were lower than Group 3 (8.67 dB SPL at 1.0 kHz, 17.67 dB SPL at 1.5 kHz, 26.10 dB SPL at 2.0 kHz, 18.10 dB SPL at 3.0 kHz and 35.13 dB SPL at 4.0 kHz) ($P < 0.0125$). In the pregnant group, harmful effects of GSM-like RFR were less than in the non-pregnant group. CONCLUSION: GSM-like RFR caused decreases in DPOAE amplitudes mainly in non-pregnant adult rabbits. Prolonged exposure may affect the DPOAE amplitude. Recommendations are given to prevent the potential hazardous effects of RF in humans.

(E) Budak GG, Muluk NB, Budak B, Oztürk GG, Apan A, Seyhan N. Effects of intrauterine and extrauterine exposure to GSM-like radiofrequency on distortion product otoacoustic emissions in infant male rabbits. Int J Pediatr Otorhinolaryngol. 73(3):391-399, 2009. (CE, IU, NU, VO)

OBJECTIVES: The aim of this study was to investigate the potential hazardous effects of intrauterine (IU) and/or extrauterine (EU) exposure to 1800 MHz Global System for Mobile Communications-like (GSM-like) radiofrequency (RF) on the cochlear functions of infant rabbits by measuring distortion product otoacoustic emission (DPOAE) response amplitudes. METHODS: Thirty-six white infant male New Zealand rabbits each 1-month-old were included in the study. The animals were randomly divided into four groups. Nine infant rabbits (Group 1) were not exposed to 1800 MHz GSM-like RF (Control-C). Nine infant rabbits (Group 2) were exposed to 1800 MHz GSM-like RF, 15 min daily for 14 days after they reached 1-month of age (extrauterine-EU). Nine infant rabbits (Group 3) were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days in the intrauterine period (between 15th and 22nd days of the gestational period) (intrauterine-IU). Nine infant rabbits (Group 4) were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days in the intrauterine period (between 15th and 22nd days of the gestational period) and 15 min daily for 14 days after they reached to 1-month of age (IU+EU). The cochlear functions were assessed by

DPOAEs at 1.0-8.0 kHz. RESULTS: At 1.5 kHz, the mean DPOAE amplitude of Group 3 was higher than that of the controls and Group 2; and the mean DPOAE value of Group 4 was higher than that of the controls and Group 2. At 2.0 kHz, the mean DPOAE amplitude of Group 4 was higher than that of Group 2. At 3.0 kHz, the mean DPOAE amplitude of Group 4 was higher than that of the controls and Group 2. At 4.0 kHz, the mean DPOAE amplitude of Group 2 was lower than that of the controls, while the mean value of Group 4 was higher than the mean value of the controls and Group 2. At 6.0 kHz, the mean DPOAE amplitude of Group 2 was lower than that of the control group; however, the mean value of Group 4 was higher than that of Group 2. At 1.0 and 8.0 kHz, no significant differences were found among the four groups. CONCLUSION: Prolonged exposure and hyperthermia related to the power density of applied RF, increasing the temperature in the ear canal, may affect DPOAE amplitudes. Harmful effects of RF are mainly observed as a decrease in DPOAE amplitudes at 4.0-6.0 kHz during extrauterine exposure in infancy. During the intrauterine period, the water content of the middle and inner ear and amnion fluid may play a protective role. Therefore, children must be protected from RF exposure. The use of mobile phones at short distances from the ear of the infants should be avoided because of the lower thickness of the anatomical structure in infancy.

(E) Burlaka A, Tsybulin O, Sidorik E, Lukin S, Polishuk V, Tsehmistrenko S, Yakymenko I. Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation. Exp Oncol. 35(3):219-225, 2013. (CE, GE, IU, OX)

Aim: Long-term exposure of humans to low intensity radiofrequency electromagnetic radiation (RF-EMR) leads to a statistically significant increase in tumor incidence. Mechanisms of such the effects are unclear, but features of oxidative stress in living cells under RF-EMR exposure were previously reported. Our study aims to assess a production of initial free radical species, which lead to oxidative stress in the cell. Materials and Methods: Embryos of Japanese quails were exposed in ovo to extremely low intensity RF-EMR of GSM 900 MHz (0.25 μW/cm2) during 158-360 h discontinuously (48 c - ON, 12 c - OFF) before and in the initial stages of development. The levels of superoxide (O2·-), nitrogen oxide (NO·), thiobarbituric acid reactive substances (TBARS), 8-oxo-2'-deoxyguanosine (8-oxo-dG) and antioxidant enzymes' activities were assessed in cells/tissues of 38-h, 5- and 10-day RF-EMR exposed and unexposed embryos. Results: The exposure resulted in a significant persistent overproduction of superoxide and nitrogen oxide in embryo cells during all period of analyses. As a result, significantly increased levels of TBARS and 8-oxo-dG followed by significantly decreased levels of superoxide dismutase and catalase activities were developed in the exposed embryo cells. Conclusion: Exposure of developing quail embryos to extremely low intensity RF-EMR of GSM 900 MHz during at least one hundred and fifty-eight hours leads to a significant overproduction of free radicals/reactive oxygen species and oxidative damage of DNA in embryo cells. These oxidative changes may lead to pathologies up to oncogenic transformation of cells.

(E) Byun YH, Ha M, Kwon HJ, Hong YC, Leem JH, Sakong J, Kim SY, Lee CG, Kang D, Choi HD, Kim N.Mobile phone use, blood lead levels, and attention deficit

hyperactivity symptoms in children: a longitudinal study. PLoS One. 8(3):e59742, 2013. (BE, CE, DE, HU, IX)

BACKGROUND: Concerns have developed for the possible negative health effects of radiofrequency electromagnetic field (RF-EMF) exposure to children's brains. The purpose of this longitudinal study was to investigate the association between mobile phone use and symptoms of Attention Deficit Hyperactivity Disorder (ADHD) considering the modifying effect of lead exposure. METHODS: A total of 2,422 children at 27 elementary schools in 10 Korean cities were examined and followed up 2 years later. Parents or guardians were administered a questionnaire including the Korean version of the ADHD rating scale and questions about mobile phone use, as well as socio-demographic factors. The ADHD symptom risk for mobile phone use was estimated at two time points using logistic regression and combined over 2 years using the generalized estimating equation model with repeatedly measured variables of mobile phone use, blood lead, and ADHD symptoms, adjusted for covariates. RESULTS: The ADHD symptom risk associated with mobile phone use for voice calls but the association was limited to children exposed to relatively high lead. CONCLUSIONS:The results suggest that simultaneous exposure to lead and RF from mobile phone use was associated with increased ADHD symptom risk, although possible reverse causality could not be ruled out.

Cabot E, Christ A, Bühlmann B, Zefferer M, Chavannes N, Bakker JF, van Rhoon GC, Kuster N. Quantification Of RF-exposure of the Fetus Using Anatomical CAD-Models in Three Different Gestational Stages. Health Phys. 107(5):369-381, 2014. (Dosimetry)

This study analyzes the exposure of pregnant women and their fetuses in three different gestational stages to electromagnetic radiation in the radio frequency range in the near- and the far-field using numerical modeling. For far-field exposure, the power density at which the basic restriction for the whole body SAR is reached is calculated for both the mother and the fetus at whole body resonance and at frequencies between 450 MHz and 2,450 MHz. The near-field exposure is assessed at 450 MHz, 900 MHz, and 2,450 MHz using half wavelength dipoles as generic sources located at different locations around the abdomen of the mother. For the investigated cases, the exposure of the mother is always below or on the order of magnitude of the basic restriction for exposure at the reference level. When applying the reference levels for the general public, the fetus is sufficiently shielded by the mother. However, the basic restrictions for general public exposure can be exceeded in the fetus when the mother is exposed at reference levels for occupational conditions. For plane wave exposure at occupational levels, the whole body SAR in the fetus can exceed the basic restrictions for the general population by at least 1.8 dB, and in the near-field of professional devices, the 10 g SAR can be non-compliant with the product standard for the general public by > 3.5 dB.

(E)Cai JY, Strodl E, Yang WK, Yin XN, Wen GM, Sun DL, Xian DX, Zhao YF, Chen WQ. Critical window for the association between early electronic screen exposure and hyperactive behaviors in preschool children. Psychol Health Med. 28(8):2108-2120, 2023. (BE, CE, DE, HU)

Electronic screens have become an integral part of modern life, accompanied with growing concerns for children's neuropsychological development. This study aimed to evaluate the associations between measures of early life screen exposure and hyperactive behaviors among preschool children. The study also aimed to investigate their cumulative effects and the critical window for these associations. A cross-sectional survey was conducted among 52 625 mother-child dyads at preschools in LongHua District of Shenzhen, China. A self-administered structured questionnaire was used to assess socio-demographic characteristics, duration of children's electronic screen exposure in each of the first 3 years following birth and the presence of current hyperactive behaviors. A series of logistic regression models were used to examine the relationship between previous screen time and current hyperactive behaviors. A crossover analysis was used to explore the critical window for a significant relationship between screen time and hyperactive behaviors. We found that exposure to electronic screens in the first 3 years of life was associated with hyperactive behaviors in preschool children. A cumulative effect was shown in children with an average daily screen time less than 60 min, with adjusted ORs increasing from 1.262 to 1.989 as screen exposure years increased from 1 to 3 years. A critical window was identified in that children in the first 2 years after birth were vulnerable to electronic screen exposure. Exposure to televisions, mobile phones, and computers were all related to elevated risks for hyperactive behaviors. In conclusion, early screen exposure appears to increase the risk for hyperactive behaviors in preschool children with the presence of a cumulative effect, a critical window and different electronic screens having similar effects.

(E)Calis P, Seymen M, Soykan Y, Delen K, SiravAral B, Kaplanoglu GT, Karcaaltincaba DDoes Exposure of Smart Phones during Pregnancy Affect the Offspring's Ovarian Reserve? A Rat Model Study. Fetal Pediatr Pathol 40(2):142-152, 2021. (CE, DE, F, IU, VO) (Low SAR 0.23 W/kg)

We investigated the effect of prenatal exposure to smart phone radiation and the protective effect of omega-3 on ovarian reserve of offspring. **Methods:** 24 pregnant Wistar albino rats were divided into four groups. Group-I received neither radiofrequency (RF) radiation nor omega-3, group-II received RF, group-III received RF radiation and 300 mg omega-3 and group-IV received RF radiation and 600 mg Omega-3 till birth. At 42 days, bilateral oophorectomy was performed on all female offspring for follicle count and immunohistochemical staining (GDF9, FOXO1 and TUNEL). **Results:** Group-II had significantly lower mean number of primordial ($p = 0.006$), secondary follicles($p = 0.003$) and a higher atresia score. Group-III variables were comparable with group-I variables. Group-IV had statistically higher median number of atretic follicles than group-I ($p = 0.023$). **Conclusions:** Ovarian reserve of offspring diminished with RF exposure during pregnancy. Omega-3 supplementation during pregnancy may reduce the potential premature ovarian failure

Calvente I, Fernández MF, Pérez-Lobato R, Dávila-Arias C, Ocón O, Ramos R, Ríos-Arrabal S, Villalba-Moreno J, Olea N, Núñez MI. Outdoor characterization of radio

frequency electromagnetic fields in a Spanish birth cohort. Environ Res. 138:136-143, 2015. (Dosimetry)

There is considerable public concern in many countries about the possible adverse effects of exposure to non-ionizing radiation electromagnetic fields, especially in vulnerable populations such as children. The aim of this study was to characterize environmental exposure profiles within the frequency range 100kHz-6GHz in the immediate surrounds of the dwellings of 123 families from the INMA-Granada birth cohort in Southern Spain, using spot measurements. The arithmetic mean root mean-square electric field (E_{RMS}) and power density (S_{RMS}) values were, respectively, 195.79mV/m (42.3% of data were above this mean) and 799.01μW/m^2 (30% of values were above this mean); median values were 148.80mV/m and 285.94μW/m^2, respectively. Exposure levels below the quantification limit were assigned a value of 0.01V/m. Incident field strength levels varied widely among different areas or towns/villages, demonstrating spatial variability in the distribution of exposure values related to the surface area population size and also among seasons. Although recorded values were well below International Commission for Non-Ionizing Radiation Protection reference levels, there is a particular need to characterize incident field strength levels in vulnerable populations (e.g., children) because of their chronic and ever-increasing exposure. The effects of incident field strength have not been fully elucidated; however, it may be appropriate to apply the precautionary principle in order to reduce exposure in susceptible groups.

(E) Calvente I, Pérez-Lobato R, Núñez MI, Ramos R, Guxens M, Villalba J, Olea N, Fernández MF. Does exposure to environmental radiofrequency electromagnetic fields cause cognitive and behavioral effects in 10-year-old boys? Bioelectromagnetics. 37(1):25-36, 2016. (BE, CE, DE, HU)

The relationship between exposure to electromagnetic fields from non-ionizing radiation and adverse human health effects remains controversial. We aimed to explore the association of environmental radiofrequency-electromagnetic fields (RF-EMFs) exposure with neurobehavioral function of children. A subsample of 123 boys belonging to the Environment and Childhood cohort from Granada (Spain), recruited at birth from 2000 through 2002, were evaluated at the age of 9-11 years. Spot electric field measurements within the 100 kHz to 6 GHz frequency range, expressed as both root mean-square (SRMS) and maximum power density (SMAX) magnitudes, were performed in the immediate surrounds of childreńs dwellings. Neurocognitive and behavioral functions were assessed with a comprehensive battery of tests. Multivariate linear and logistic regression models were used, adjusting for potential confounders. All measurements were lower than reference guideline limits, with median SRMS and SMAX values of 285.94 and 2759.68 μW/m(2) , respectively. Most of the cognitive and behavioral parameters did not show any effect, but children living in higher RF exposure areas (above median SRMS levels) had lower scores for verbal expression/comprehension and higher scores for internalizing and total problems, and obsessive-compulsive and post-traumatic stress disorders, in comparison to those living in areas with lower exposure. These associations were stronger when SMAX values were considered. Although some of our results may suggest that low-level environmental RF-EMF exposure has a negative impact on cognitive and/or behavior development in children;

given limitations in the study design and that the majority of neurobehavioral functioning tasks were not affected, definitive conclusions cannot be drawn.

(E) Capri M, Salvioli S, Altilia S, Sevini F, Remondini D, Mesirca P, Bersani F, Monti D, Franceschi C. Age-Dependent Effects of in Vitro Radiofrequency Exposure (Mobile Phone) on CD95+ T Helper Human Lymphocytes. Ann N Y Acad Sci. 1067:493-499, 2006. (AE, DE, MO, IV)

.Recent studies on "nonthermal" effects of mobile phone radiofrequency (RF) suggest that RF can interact with cellular functions and molecular pathways. To study the possible RF effects on human lymphocyte activation, we analyzed CD25, CD95, CD28 molecules in unstimulated and stimulated CD4+ e CD8+ T cells in vitro. Peripheral blood mononuclear cells (PBMCs) from young and elderly donors were exposed or sham-exposed to RF (1,800 MHz, Specific Absorption Rate 2 W/kg) with or without mitogenic stimulation. No significant changes in the percentage of these cell subsets were found between exposed and sham-exposed lymphocytes in both young and elderly donors. Nevertheless, after RF exposure we observed a slight, but significant, downregulation of CD95 expression in stimulated CD4+ T lymphocytes from elderly, but not from young donors. This age-related result is noteworthy given the importance of such a molecule in regulation of the immune response.

(NE)Celik O, Hascalik S. Effect of electromagnetic field emitted by cellular phones on fetal heart rate patterns. Eur J Obstet Gynecol Reprod Biol. 112(1):55-56, 2004. (AE, FC, IU, HU)

The study was planned to determine the effects of electromagnetic fields produced by cellular phones on baseline fetal heart rate, acceleration and deceleration. Forty pregnant women undergoing non-stress test were admitted to the study. Non-stress test was obtained while the subjects were holding the CP on stand by mode and on dialing mode, each for 5 min. Similar recordings were taken while there were no phones around for 10 min. Electromagnetic fields produced by cellular phones do not cause any demonstrable affect in fetal heart rate, acceleration and deceleration.

(E)Celik S, Aridogan IA, Izol V, Erdoğan S, Polat S, Doran S. An Evaluation of the effects of long-term cell phone use on the testes via light and electron microscope analysis. Urology. 79(2):346-350, 2012. (CE, M, ME, VO)

OBJECTIVE: To investigate whether the low-intensity electromagnetic waves transmitted by cell phones cause histopathological or ultrastructural changes in the testes of rats. MATERIALS AND METHODS: Wistar-Kyoto male rats were placed into either a control group or a group that was exposed to an electromagnetic field (EMF). Two cell phones with Specific Absorbation Rate values of 1.58 were placed and left off in cages that housed 15 rats included in the control group, and four cell phones were placed and left on in cages that housed 30 rats included in the experimental group. After 3 months, weights, seminiferous tubule diameters, and spermatogenic cell conditions of all testes of the rats were evaluated. One half of each testis was examined also under an electron microscope. RESULTS: No significant differences were observed between the testis weights, seminiferous tubule diameters, and histopathological evaluations between rats that had and had not been exposed to EMF. Electron microscope analysis revealed that the membrana propria thickness and the collagen fiber contents were increased and the capillary veins extended in the experimental group. Common vacuolization in the cytoplasm of the Sertoli cells, growth of electron-dense structures, and existence of large lipid droplets were noted as the remarkable findings of this study.

(E) Cetin H, Nazıroğlu M, Celik O, Yüksel M, Pastacı N, Ozkaya MO. Liver antioxidant stores protect the brain from electromagnetic radiation (900 and 1800 MHz)-induced oxidative stress in rats during pregnancy and the development of offspring. J Matern Fetal Neonatal Med. 27(18):1915-1921, 2014. (CE, IU, MO, OX, PN, VO) (decreased oxidative stress) (Low SAR 0.15 W/kg)

Objectives: The present study determined the effects of mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (EMR) exposure on oxidative stress in the brain and liver as well as the element levels in growing rats from pregnancy to 6 weeks of age. Methods: Thirty-two rats and their offspring were equally divided into 3 different groups: the control, 900 MHz, and 1800 MHz groups. The 900 MHz and 1800 MHz groups were exposed to EMR for 60 min/day during pregnancy and neonatal development. At the 4th, 5th, and 6th weeks of the experiment, brain samples were obtained. Results: Brain and liver glutathione peroxidase (GSH-Px) activities, as well as liver vitamin A and β-carotene concentrations decreased in the EMR groups, although brain iron, vitamin A, and β-carotene concentrations increased in the EMR groups. In the 6th week, selenium concentrations in the brain decreased in the EMR groups. There were no statistically significant differences in glutathione, vitamin E, chromium, copper, magnesium, manganese, and zinc concentrations between the 3 groups. Conclusion: EMR-induced oxidative stress in the brain and liver was reduced during the development of offspring. Mobile phone-induced EMR could be considered as a cause of oxidative brain and liver injury in growing rats.

(E) Chen C, Ma Q, Liu C, Deng P, Zhu G, Zhang L, He M, Lu Y, Duan W, Pei L, Li M, Yu Z, Zhou Z. Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells. Sci Rep. 4:5103, 2014. (CE, DE, GE, ME, IV)

A radiofrequency electromagnetic field (RF-EMF) of 1800 MHz is widely used in mobile communications. However, the effects of RF-EMFs on cell biology are unclear. Embryonic neural stem cells (eNSCs) play a critical role in brain development. Thus, detecting the effects of RF-EMF on eNSCs is important for exploring the effects of RF-EMF on brain development. Here, we exposed eNSCs to 1800 MHz RF-EMF at specific absorption rate (SAR) values of 1, 2, and 4 W/kg for 1, 2, and 3 days. We found that 1800 MHz RF-EMF

exposure did not influence eNSC apoptosis, proliferation, cell cycle or the mRNA expressions of related genes. RF-EMF exposure also did not alter the ratio of eNSC differentiated neurons and astrocytes. However, neurite outgrowth of eNSC differentiated neurons was inhibited after 4 W/kg RF-EMF exposure for 3 days. Additionally, the mRNA and protein expression of the proneural genes Ngn1 and NeuroD, which are crucial for neurite outgrowth, were decreased after RF-EMF exposure. The expression of their inhibitor Hes1 was upregulated by RF-EMF exposure. These results together suggested that 1800 MHz RF-EMF exposure impairs neurite outgrowth of eNSCs. More attention should be given to the potential adverse effects of RF-EMF exposure on brain development.

(E) Chen, H, Qu Z, Liu W. Effects of Simulated Mobile Phone Electromagnetic Radiation on Fertilization and Embryo Development. Fetal Pediatr Pathol 36(2):123-129, 2017. (CE, DE, F) (150, 570. and 1400 μW/cm^2)

This study investigated the effects of 935-MHz electromagnetic radiation (ER) on fertilization and subsequent embryonic development in mice. Ovulating mice were irradiated at three ER intensities for 4 h/day (d) or 2 h/d for three consecutive days; the ova were then harvested for in vitro fertilization to observe the 6-h fertilization rate (6-FR), 72-h morula rate (72-MR), and 110-h blastula rate (110-BR). Compared with the control group, the 6-FR, 72-MR, and 110-BR were decreased in the low ER intensity group, but the differences were not significant; in the mid- and high-intensity ER groups, 72-MR and 110-BR in the 4 h/d and 2 h/d subgroups were decreased, showing significant differences compared with the control group. Moreover, the comparison between 4 h/d and 2 h/d subgroups showed significant differences. Mid- and high-intensity ER at 935 MHz can reduce the fertilization rate in mice, and reduce the blastulation rate, thus reducing the possibility of embryo implantation.

(E) Chen H-G, Wu P, Sun B, Chen J-X, Xiong C-L, Meng T-Q, Huang X-Y, Su Q-L, Huiliang Zhou H, Wang Y-X, Ye W, Pan A. Association between electronic device usage and sperm quality parameters in healthy men screened as potential sperm donors. Environ Pollut 312:120089, 2022. (CE, HU, M, ME)

Cell phone use and radio-frequency electromagnetic radiation (RF-EMF) are rapidly increasing and may be associated with lower semen quality, yet results from epidemiological studies are inconclusive. Information on electronic devices use was collected through standard questionnaires from 1454 men aged 22-45 years old. Semen volume, sperm concentration, total sperm count, total motility, progressive motility, and normal morphology in repeated specimens were determined by trained clinical technicians. Percent changes [95% confidence intervals (CIs)] were estimated as (10β-1) × 100 for electronic devices use associated with repeated sperm quality parameters in the linear mixed-effect models. After adjusting for multiple confounders, we found significant inverse associations of total duration of electronic devices use with sperm progressive motility and total motility, duration of cell phone and computer use with sperm concentration, progressive motility, and total motility (all $P < 0.05$). No significant association was found between cell phone/computer use alone and sperm quality parameters. Moreover, per hour increase of time spent on cell phone talking was associated with decreased sperm concentration and total count by an average of -8.0% (95% CI: -15.2%, -0.2%) and -12.7% (95% CI: -21.3%, -3.1%), respectively. Besides, daily calling time was associated with lower sperm

progressive motility and total motility among those who used headsets during a call (P for interaction <0.05). In conclusion, our study suggested that more time spent on electronic devices use had a modest reduction effect on semen quality. Daily calling time was significantly associated with lower sperm concentration and total count, and using headsets during a call appeared to aggravate the negative association between daily calling time and sperm motility. Additional studies are needed to confirm these findings.

(E) Chen L, Qin F, Chen Y, Sun J, Tong J.[Chronotoxicity of 1800 MHz microwave radiation on sex hormones and spermatogenesis in male mice]. Wei Sheng Yan Jiu. 43(1):110-115, 2014.[Article in Chinese] (AE, M, ME, MO, VO) (Low SAR)

OBJECTIVE: To study the chronotoxicity of 1800 MHz microwave radiation on the male reproductive system. METHODS: Sixty healthy male C57 mice with circadian rhythm in a 12:12 h light-dark photoperiod were divided into false radiation group (Sham) and microwave radiation (MR) group exposed to 1800 MHz RF at 208 microW/cm2 power (SAR: 0 .2221 W/kg) density at different zeitgeber times of a day (ZT01:00, ZT05:00, ZT09 : 00, ZT13: 00, ZT17 : 00, ZT21 : 00) for continuous 32 days with 2 h/d. The testicular sperm head was counted with a microscope, and serum testosterone (T) and estradiol (E2) levels were measured by ELISA method. RESULTS: Compared with the sham group,microwave radiation induced reduced level in testicular sperm head count and serum testosterone, while the level of serum estradiol increased. Also, the circadian rhythms of testicular sperm head count and estradiol disappeared after the microwave radiation. CONCLUSION: 1800 MH2 microwave radiation may disturb the level as well as circadian rhythmicity of the reproductive functions in male mice.

(E) Chiu CT, Chang YH, Chen CC, Ko MC, Li CY. Mobile phone use and health symptoms in children. J Formos Med Assoc. 114(7):598-604, 2015. (CE, DE, FC, HU)

BACKGROUND/PURPOSE: To investigate the mobile phone (MP) use for talking in relation to health symptoms among 2042 children aged 11-15 years in Taiwan. METHODS: A nationwide, cross-sectional study, using the computer assisted telephone interview (CATI) technique, was conducted in 2009 to collect information on children's utilization of MPs and the perceived health symptoms reported by their parents. RESULTS: The overall prevalence of MP use in the past month was estimated at 63.2% [95% confidence interval (CI) = 61.1-65.3%]. MP use was associated with a significantly increased adjusted odds ratio (AOR) for headaches and migraine (1.42, 95% CI = 1.12-1.81) and skin itches (1.84, 95% CI = 1.47-2.29). Children who regularly used MPs were also considered to have a health status worse than it was 1 year ago (β = 0.27, 95% CI = 0.17-0.37). CONCLUSION: Although the cross-sectional design precludes the causal inference for the observed association, our study tended to suggest a need for more cautious use of MPs in children, because children are expected to experience a longer lifetime exposure to radiofrequency electromagnetic fields (RF-EMF) from MPs.

(NE) Choi KH, Ha M, Ha EH, Park H, Kim Y, Hong YC, Lee AK, Hwa Kwon J, Choi HD, Kim N, Kim S, Park C. Neurodevelopment for the first three years following prenatal mobile phone use, radio frequency radiation and lead exposure. Environ Res. 156:810-817, 2017. (DE, HU, IU, NU)

BACKGROUND: Studies examining prenatal exposure to **mobile phone** use and its effect on child neurodevelopment show different results, according to child's developmental stages. OBJECTIVES: To examine neurodevelopment in children up to 36 months of age, following prenatal **mobile phone** use and radiofrequency radiation (RFR) exposure, in relation to prenatal lead exposure. METHODS: We analyzed 1198 mother-child pairs from a prospective cohort study (the Mothers and Children's Environmental Health Study). Questionnaires were provided to pregnant women at ≤20 weeks of gestation to assess **mobile phone** call frequency and duration. A personal exposure meter (PEM) was used to measure RFR exposure for 24h in 210 pregnant women. Maternal blood lead level (BLL) was measured during pregnancy. Child neurodevelopment was assessed using the Korean version of the Bayley Scales of Infant Development-Revised at 6, 12, 24, and 36 months of age. Logistic regression analysis applied to groups classified by trajectory analysis showing neurodevelopmental patterns over time. RESULTS: The psychomotor development index (PDI) and the mental development index (MDI) at 6, 12, 24, and 36 months of age were not significantly associated with maternal **mobile phone** use during pregnancy. However, among children exposed to high maternal BLL in utero, there was a significantly increased risk of having a low PDI up to 36 months of age, in relation to an increasing average calling time (p-trend=0.008). There was also a risk of having decreasing MDI up to 36 months of age, in relation to an increasing average calling time or frequency during pregnancy (p-trend=0.05 and 0.007 for time and frequency, respectively). There was no significant association between child neurodevelopment and prenatal RFR exposure measured by PEM in all subjects or in groups stratified by maternal BLL during pregnancy. CONCLUSIONS: We found no association between prenatal exposure to RFR and child neurodevelopment during the first three years of life; however, a potential combined effect of prenatal exposure to lead and **mobile phone** use was suggested.

Christ A, Kuster N. Differences in RF energy absorption in the heads of adults and children. Bioelectromagnetics. Suppl 7:S31-44. 2005. (Dosimetry)

There has been a long and controversial debate on possible differences in electromagnetic (EM) energy absorption between adults and children during cell phone usage. Some published studies report higher specific absorption rate (SAR) in children and explain this based on smaller head size. More recently, age dependent changes of the dielectric tissue parameters have again ignited the discussion. This study intends to give a comprehensive review of the current state of knowledge about the parameters and mechanisms affecting the exposure of the mobile phone user with special focus on the exposure of children. Discussed are the absorption mechanism, tissue parameters, the effect of the pinna, and the uncertainties associated with head models based on spheroids, scaled adult heads, and magnetic resonance imaging (MRI) data of children. The conclusions of the review do not support the assumption that the energy exposure increases due to smaller heads, but identifies open issues regarding the dielectric tissue parameters and the thickness of the pinna.

Christ A, Gosselin MC, Christopoulou M, Kühn S, Kuster N. Age-dependent tissue-specific exposure of cell phone users. Phys Med Biol. 55(7):1767-1783, 2010. (Dosimetry)

The peak spatial specific absorption rate (SAR) assessed with the standardized specific

anthropometric mannequin head phantom has been shown to yield a conservative exposure estimate for both adults and children using mobile phones. There are, however, questions remaining concerning the impact of age-dependent dielectric tissue properties and age-dependent proportions of the skull, face and ear on the global and local absorption, in particular in the brain tissues. In this study, we compare the absorption in various parts of the cortex for different magnetic resonance imaging-based head phantoms of adults and children exposed to different models of mobile phones. The results show that the locally induced fields in children can be significantly higher (>3 dB) in subregions of the brain (cortex, hippocampus and hypothalamus) and the eye due to the closer proximity of the phone to these tissues. The increase is even larger for bone marrow (>10 dB) as a result of its significantly high conductivity. Tissues such as the pineal gland show no increase since their distances to the phone are not a function of age. This study, however, confirms previous findings saying that there are no age-dependent changes of the peak spatial SAR when averaged over the entire head.

(E) Chu KY, Khodamoradi K, Blachman-Braun R, Dullea A, Bidhan J, Campbell K, Zizzo J, Israeli J, Kim M, Petrella F, Ibrahim E, Ramasamy R. Effect of Radiofrequency Electromagnetic Radiation Emitted by Modern Cellphones on Sperm Motility and Viability: An In Vitro Study. Eur Urol Focus. 9(1):69-74, 2023. (AE, FC, HU, M, ME)

Background: Cellphones emit radiofrequency electromagnetic radiation (RF-EMR) for transmission of data for social media communication, web browsing, and music/podcast streaming. Use of Bluetooth ear buds has probably prolonged the time during which cellphones reside in the trouser pockets of men. It has been postulated that RF-EMR increases oxidative stress and induces free radical formation. **Objective:** To investigate the effect of wireless-spectrum (4G, 5G, and WiFi) RF-EMR emitted by modern smartphones on sperm motility and viability and explore whether these effects can be mitigated using a physical barrier or distance. **Design, setting, and participants:** Semen samples were obtained from fertile normozoospermic men aged 25-35 yr. A current-generation smartphone in talk mode was used as the RF-EMR source. A WhatsApp voice call was made using either 4G, 5G, or WiFi wireless connectivity. We determined if exposure effects were mitigated by either a cellphone case or greater distance from the semen sample. **Outcome measurements and statistical analysis:** The semen samples were analyzed according to 2010 World Health Organization laboratory guidelines. Statistical analysis was performed using SPSS v.28. **Results and limitations:** We observed decreases in sperm motility and viability with WiFi exposure but not with exposure to 4G or 5G RF-EMR. With large variability among smartphones, continued research on exposure effects is needed. **Conclusions:** Our exploratory study revealed that sperm motility and viability are negatively impacted by smartphones that use the WiFi spectrum for data transmission. **Patient summary:** We looked at the effect of cellphone use on sperm motility and viability. We found that cellphones using WiFi connectivity for data usage have harmful effects on semen quality in men.

(E) Clark ML, Burch JB, Yost MG, Zhai Y, Bachand AM, Fitzpatrick CT, Ramaprasad J, Cragin LA, Reif JS. Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters. J Occup

Environ Med. 49(10):1149-1156, 2007. (CE, F, HU. MO)

OBJECTIVES: Metabolites of estrogen (estrone-3-glucuronide [E1G]) and melatonin (6-hydroxymelatonin sulfate [6-OHMS]) were characterized among women living in a community with increased radiofrequency (RF) exposure from radio and television transmitters. **METHODS:** RF spot measurements, and personal 60-Hz magnetic field and residential parameters were collected. Overnight urine samples were assayed for E1G and 6-OHMS excretion. **RESULTS:** Among premenopausal women, there were no associations between RF or 60-Hz nonionizing radiation and E1G or 6-OHMS excretion. Among postmenopausal women, increased residential RF exposures, transmitter proximity and visibility, and temporally stable 60-Hz exposures were significantly associated with increased E1G excretion. This association was strongest among postmenopausal women with low overnight 6-OHMS levels. **CONCLUSIONS:** RF and temporally stable 60-Hz exposures were associated with increased E1G excretion among postmenopausal women. Women with reduced nocturnal 6-OHMS excretion may represent a sensitive subgroup.

(E) Col-Araz N. Evaluation of factors affecting birth weight and preterm birth in southern Turkey. J Pak Med Assoc. 63(4):459-462, 2013. (CE, DE, F, HU, IU)

OBJECTIVE: To identify factors affecting birth weight and pre-term birth, and to find associations with electromagnetic devices such as television, computer and mobile phones. METHODS: The study was conducted in Turkey at Gazintep University, Faculty of Medicine's Outpatient Clinic at the Paediatric Ward. It comprised 500 patients who presented at the clinic from May to December 2009. All participants were administered a questionnaire regarding their pregnancy history. SPSS 13 was used for statistical analysis. RESULTS: In the study, 90 (19%) patients had pre-term birth, and 64 (12.9%) had low birth weight rate Birth weight was positively correlated with maternal age and baseline maternal weight ($r = 0.115$, $p < 0.010$; $r = 0.168$, $p < 0.000$, respectively). Pre-term birth and birth weight less than 2500g were more common in mothers with a history of disease during pregnancy ($p < 0.046$ and $p < 0.008$, respectively). The habit of watching television and using mobile phones and computer by mothers did not demonstrate any relationship with birth weight. Mothers who used mobile phones or computers during pregnancy had more deliveries before 37 weeks ($p < 0.018$, $p < 0.034$; respectively). Similarly, pregnancy duration was shorter in mothers who used either mobile phone or computers during pregnancy ($p < 0.005$, $p < 0.048$, respectively). CONCLUSION: Mobile phones and computers may have an effect on pre-term birth.

Cordelli E, Ardoino L, Benassi B, Consales C, Eleuteri P, Marino C, Sciortino M, Villani P, Brinkworth MH, Chen G, McNamee JP, Wood AW, Belackova L, Verbeek J, Paccierotti F. Effects of Radiofrequency Electromagnetic Field (RF-EMF) exposure on pregnancy and birth outcomes: A systematic review of experimental studies on non-human mammals. Environ Int 180:108178, 2023. (Review)

Background: The World Health Organization is coordinating an international project aimed at systematically reviewing the evidence regarding the association between radiofrequency

electromagnetic field (RF-EMF) exposure and adverse health effects. Within the project, 6 topics have been prioritized by an expert group, which include reproductive health outcomes. Objectives: According to the protocol published in 2021, a systematic review and meta-analyses on the adverse effects of RF-EMF exposure during pregnancy in offspring of experimental animals were conducted. Methods: Three electronic databases (PubMed, Scopus and EMF Portal) were last searched on September 8 or 17, 2022. Based on predefined selection criteria, the obtained references were screened by two independent reviewers. Studies were included if they met the following criteria: 1) original, sham controlled experimental study on non-human mammals exposed in utero, published in peer-reviewed journals, 2) the experimental RF-EMF exposure was within the frequency range 100 kHz-300 GHz, 3) the effects of RF-EMF exposure on fecundity (litter size, embryonic/fetal losses), on the offspring health at birth (decrease of weight or length, congenital malformations, changes of sex ratio) or on delayed effects (neurocognitive alterations, female infertility or early-onset cancer) were studied. Study characteristics and outcome data were extracted by two reviewers. Risk of bias (RoB) was assessed using the Office of Health Assessment and Translation (OHAT) guidelines. Study results were pooled in a random effects meta-analysis comparing average exposure to no-exposure and in a dose-response meta-analysis using all exposure doses, after exclusion of studies that were rated at "high concern" for RoB. Subgroup analyses were conducted for species, Specific Absorption Rate (SAR) and temperature increase. The certainty of the evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach. Results: Eighty-eight papers could be included in this review. Effects on fecundity. The meta-analysis of studies on litter size, conducted at a whole-body average SAR of 4.92 W/kg, did not show an effect of RF-EMF exposure (MD 0.05; 95% CI -0.21 to 0.30). The meta-analysis of studies on resorbed and dead fetuses, conducted at a whole-body average SAR of 20.26 W/kg, showed a significant increase of the incidence in RF-EMF exposed animals (OR 1.84; 95% CI 1.27 to 2.66). The results were similar in the dose-response analysis. Effects on the offspring health at birth. The meta-analysis of studies on fetal weight, conducted at a whole-body average SAR of 9.83 W/kg, showed a small decrease in RF-EMF exposed animals (SMD 0.31; 95% CI 0.15 to 0.48). The meta-analysis of studies on fetal length, conducted at a whole-body average SAR of 4.55 W/kg, showed a moderate decrease in length at birth (SMD 0.45; 95% CI 0.07 to 0.83). The meta-analysis of studies on the percentage of fetuses with malformations, conducted at a whole-body average SAR of 6.75 W/kg, showed a moderate increase in RF-EMF exposed animals (SMD -0.45; 95% CI -0.68 to -0.23). The meta-analysis of studies on the incidence of litters with malformed fetuses, conducted at a whole-body average SAR of 16.63 W/kg, showed a statistically significant detrimental RF-EMF effect (OR 3.22; 95% CI 1.9 to 5.46). The results were similar in the dose-response analyses. Delayed effects on the offspring health. RF-EMF exposure was not associated with detrimental effects on brain weight (SMD 0.10; 95% CI -0.09 to 0.29) and on learning and memory functions (SMD -0.54; 95% CI -1.24 to 0.17). RF-EMF exposure was associated with a large detrimental effect on motor activity functions (SMD 0.79; 95% CI 0.21 to 1.38) and a moderate detrimental effect on motor and sensory functions (SMD -0.66; 95% CI -1.18 to -0.14). RF-EMF exposure was not associated with a decrease of the size of litters conceived by F2 female offspring (SMD 0.08; 95% CI -0.39 to 0.55). Notably, meta-analyses of neurobehavioural effects were based on few studies, which suffered of lack of independent replication deriving from only few laboratories. Discussion: There was high certainty in the evidence for a lack of association of RF-EMF exposure with litter size. We attributed a moderate certainty to the evidence of a small

detrimental effect on fetal weight. We also attributed a moderate certainty to the evidence of a lack of delayed effects on the offspring brain weight. For most of the other endpoints assessed by the meta-analyses, detrimental RF-EMF effects were shown, however the evidence was attributed a low or very low certainty. The body of evidence had limitations that did not allow an assessment of whether RF-EMF may affect pregnancy outcomes at exposure levels below those eliciting a well-known adverse heating impact. In conclusion, in utero RF-EMF exposure does not have a detrimental effect on fecundity and likely affects offspring health at birth, based on the meta-analysis of studies in experimental mammals on litter size and fetal weight, respectively. Regarding possible delayed effects of in utero exposure, RF-EMF probably does not affect offspring brain weight and may not decrease female offspring fertility; on the other hand, RF-EMF may have a detrimental impact on neurobehavioural functions, varying in magnitude for different endpoints, but these last findings are very uncertain. Further research is needed on the effects at birth and delayed effects with sample sizes adequate for detecting a small effect. Future studies should use standardized endpoints for testing prenatal developmental toxicity and developmental neurotoxicity (OECD TG 414 and 426), improve the description of the exposure system design and exposure conditions, conduct appropriate dosimetry characterization, blind endpoint analysis and include several exposure levels to better enable the assessment of a dose-response relationship.

Costantino C, Mazzucco W, BonaccorsoN, Sciortino M, Cimino L, Pizzo S, Conforto A, Calò I, Gilimberti D, Gambino CR, Segreto D, Maiorana A, Vitale F, Casuccio A. A cross-sectional study on smartphone uses among pregnant women attending childbirth classes in the Metropolitan Area of Palermo, Italy: The Stop-Phone study. Ann Ig 35(3):319-330, 2023. (Survey)

Background: Prevalence of mobile device addiction has increased over the years; both women and men have assimilated the mobile phone as a central component of their personal existence: integrating it into their lifestyle or becoming so dependent on it that life without it has become unimaginable. Smartphones generate radio-frequency electromagnetic fields. While short-term exposure in adults was considered quite safe, effects of long-term exposure or exposure during pregnancy on fetuses or during breastfeeding on newborns are not well studied yet. The objective of the present study was to investigate the prevalence and usage characteristics of smartphones among a sample of pregnant women, and promote the correct and conscious use of the smartphone. **Methods:** A cross-sectional study was conducted, with a questionnaire administered during childbirth classes and - after the questionnaire administration - an educational intervention focused on promoting the correct and conscious use of smartphones was carried out by psychologists and psychotherapists. **Results:** The findings of our study suggest that a significant number of the participants suffered addiction to mobile phone usage, but were not aware of it. More than two third of the sample (67.2%) have not changed their smartphone use habits since the beginning of their pregnancy and even more significant data shows that almost all future moms (98.3%) never speak with their doctor about smartphone use during pregnancy. **Conclusions:** Data collected suggest a lack of attention to the proposed topic, especially in relation to pregnancy. It seems necessary to sensitize future mothers on this topic. The promotion of a more conscious and controlled use of electronic devices can help reduce the radiation to

which the unborn child may be exposed, but has a fundamental role even after birth, to ensure an adequate psychomotor and relational development of the child and do not affect, due to uncontrolled use of smartphones, the mother-child relationship.

(E) Dasdag, S, Ketani, MA, Akdag, Z, Ersay, AR, Sari, I, Demirtas, OC, Celik, MS. Whole-body microwave exposure emitted by cellular phones and testicular function of rats. Urol Res 27(3):219-223, 1999. (CE, M, ME, VO)

This study investigated whether there are adverse effects due to microwave exposure emitted by cellular phones in male rats. Eighteen Wistar Albino rats were separated into three groups, a sham group and two experimental groups. The rats were confined in Plexiglas cages and cellular phones were placed 0.5 cm under the cages. In the first experimental group, cellular phones were in standby position for 2 h. In the second experimental group, phones were turned to the speech position three times each for 1 min duration over 2 h. Rats in the first and second experimental groups were exposed to microwaves emitted by phones for 2 h/day for a duration of 1 month. After the last exposure the rats were killed. Brain, eyes, ears, liver, heart, lungs, stomach, kidneys, testes, small and large intestines and skin of the rats were observed histologically. The decrease of epididymal sperm counts in the speech groups were not found to be significant ($P > 0.05$). Differences in terms of normal and abnormal sperm forms were not observed ($P > 0.05$). Histological changes were especially observed in the testes of rats of the speech groups. Seminiferous tubular diameter of rat testes in the standby and speech groups was found to be lower than the sham group ($P < 0.05$). Rectal temperatures of rats in the speech group were found to be higher than the sham and standby groups ($P < 0.05$). The rectal temperatures of rats before and after exposure were also found to be significantly higher in the speech group ($P < 0.05$). Specific absorption rate (SAR) was determined as 0.141 W/kg.

(NE) Dasdag S, Akdag MZ, Aksen F, Yilmaz F, Bashan M, Dasdag M, Celik MS. Whole body exposure of rats to microwaves emitted from a cell phone does not affect the testes. Bioelectromagnetics 24(3):182-188, 2003. (CE, M, FC, ME, VO)

The objective of this study was to investigate the effects of radiofrequency radiation emitted from cellular phones on the lipid composition, malondialdehyde concentration, p53 immune reactivity, sperm count, morphology, histological structure of testes, and on rectal temperature of rats exposed to microwave radiation emitted from cellular phones. Sixteen Spraque-Dawley rats were separated into two groups of eight, sham exposed (control) and experimental. The rats were confined in plexiglas cages specially designed for this study, and cellular phones were placed 0.5 cm under the cages. For the experimental group, cellular phones were activated 20 min per day (7 days a week) for 1 month. For the control group, the cellular phones were placed beneath the cages for 20 min a day, but the phones were turned off. Rectal temperatures were measured weekly. For 250 mW radiated power, the whole body average SAR (rms) is 0.52 W/kg and 1 g averaged peak SAR (rms) is 3.13 W/kg. The Mann-Whitney U-test was used for statistical comparisons of groups. No statistically significant alteration in any of the endpoints was noted. This study found no evidence suggesting an adverse effect of cell phone exposure on measures of testicular function or structure.

(E) Dasdag S; Akdag MZ; Ayyildiz O, Demirtas OC, Yayla M, Sert C. Do cellular

phones alter blood parameters and birth weight of rats? Electromag Biol Med. 19:107-113, 2000. (CE, DE, IU, VO)

The present study aimed to investigate the effects of microwaves (MW) emitted by cellular phones (CPs) on peripheral blood parameters and birth weights of rats. Thirty-six albino rats were divided into four groups, male (n = 6) and female sham-exposed groups (n = 12) and male (n = 6) and female experimental groups (n = 12). No blood parameters differed following exposure ($p > 0.05$). The birth weight of offspring in the experimental group was significantly lower than in the sham-exposed group ($p < 0.001$). No significant differences were observed between rectal temperatures of rats in the sham and experimental groups ($p > 0.05$). The specific absorption rate (SAR) was found to be 0.155 W/kg for the experimental groups. All parameters investigated were normal in the next generation of rats ($p > 0.05$).

(NE) Dasdag S, Akdag MZ, Ulukaya E, Uzunlar AK, Yegin D. Mobile phone exposure does not induce apoptosis on spermatogenesis in rats. Arch Med Res. 39(1):40-44, 2008. (CE, M, MO, VO) (SAR 0.07-0.57 W/kg)

BACKGROUND: Some studies have reported that microwave radiation can have adverse effects on reproduction. Therefore, the purpose of this study was to investigate the apoptosis-inducing effect of mobile phone exposure on spermatogonia in seminiferous tubules. METHODS: The study was carried out on 31 Wistar albino adult male rats. The rats were separated into three groups in this study (cage control: 10, sham group: 7, and exposed group: 14). For the study group, rats were exposed to radiation 2 h/day (7 days/week) for 10 months. For the sham group, rats were placed into the carousel and the same procedure was applied except that the generator was turned off. For the cage control, nothing was applied to the rats in this group and they completed their life cycle in the cage during the study period. In this study, rats were sacrificed after 10 months of exposure and their testes were taken. Testes tissue was immunohistochemically stained for the active (cleaved) caspase-3. Positively stained cells were counted in up to ten different areas, and the frequency of positive cells was determined in percentage. Scoring was done by taking into account both the intensity of staining and the distribution of positively stained cells. Therefore, protein expression was evaluated by a semiquantitative scoring system. RESULTS: The final score for apoptosis of testes in the exposed group was not statistically significant according to the sham and the cage control groups ($p > 0.05$). CONCLUSIONS: The results of this study showed that 2 h/day (7 days/week) exposure of 900 MHz radiation over a period of 10 months does not affect the active (cleaved) caspase-3 levels in testes, a well-known feature of typical apoptosis.

(E) Dasdag S, Taş M, Akdag MZ, Yegin K. Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions. Electromagn Biol Med. 34(1):37-42, 2015. (CE, M, ME, VO) (Low SAR)

The aim of this study was to investigate long-term effects of radiofrequency radiation (RFR) emitted from a Wireless Fidelity (Wi-Fi) system on testes. The study was carried out on 16 Wistar Albino adult male rats by dividing them into two groups such as sham (n: 8) and exposure (n: 8). Rats in the exposure group were exposed to 2.4 GHz RFR radiation for 24 h/d during 12 months (1 year). The

same procedure was applied to the rats in the sham control group except the Wi-Fi system was turned off. Immediately after the last exposure, rats were sacrificed and reproductive organs were removed. Motility (%), concentration ($\times 10^6$/mL), tail defects (%), head defects (%) and total morphologic defects (%) of sperms and weight of testes (g), left epididymis (g), prostate (g), seminal vesicles (g) were determined. Seminiferous tubules diameter (μm) and tunica albuginea thickness (μm) were also measured. However, the results were evaluated by using Johnsen's score. Head defects increased in the exposure group ($p < 0.05$) while weight of the epididymis and seminal vesicles, seminiferous tubules diameter and tunica albuginea thickness were decreased in the exposure group ($p < 0.01$, $p < 0.001$, $p < 0.0001$). However, other alterations of other parameters were not found significant ($p > 0.05$). In conclusion, we observed that long-term exposure of 2.4 GHz RF emitted from Wi-Fi (2420 μW/kg, 1 g average) affects some of the reproductive parameters of male rats. We suggest Wi-Fi users to avoid long-term exposure of RF emissions from Wi-Fi equipment.

(NE)Dasgupta S, Wang G, Simonich MT, Zhang T, Truong L1, H Liu H, Tanguay RL Impacts of high dose 3.5 GHz cellphone radiofrequency on zebrafish embryonic development. PLoS One 15(7):e0235869 2020. (BE, CE, DE, IU)

The rapid deployment of 5G spectrum by the telecommunication industry is intended to promote better connectivity and data integration among various industries. However, since exposures to radio frequency radiations (RFR) >2.4 GHz are still uncommon, concerns about their potential health impacts are ongoing. In this study, we used the embryonic zebrafish model to assess the impacts of a 3.5 GHz RFR on biology- a frequency typically used by 5G-enabled cell phones and lies within the 4G and 5G bandwidth. We established a plate-based exposure setup for RFRs, exposed developing zebrafish to 3.5 GHz RFR, specific absorption rate (SAR) ≈ 8.27 W/Kg from 6 h post fertilization (hpf) to 48 hpf, and measured a battery of morphological and behavioral endpoints at 120 hpf. Our results revealed no significant impacts on mortality, morphology or photomotor response and a modest inhibition of startle response suggesting some levels of sensorimotor disruptions. This suggests that the cell phone radiations at low GHz-level frequencies are likely benign, with subtle sensorimotor effects. Through this assessment, we have established a robust setup for zebrafish RFR exposures readily amenable to testing various powers and frequencies. Future developmental exposure studies in zebrafish will evaluate a wider portion of the radio frequency spectrum to discover the bioactive regions, the potential molecular targets of RFR and the potential long-term effects on adult behavior.

(E) DastAmooz S, Broujeni ST, Sarahian N. A primary study on rat fetal development and brain-derived neurotrophic factor levels under the control of electromagnetic fields Background: In previous researches, electromagnetic fields have been shown to adversely affect the behavior and biology of humans and animals; however, body growth and brain-derived neurotrophic factor levels were not evaluated. J Public Health Afr 14(6):2347, 2023. (CE, DE, IU, ME, MO, VO)

Objective: The original investigation aimed to examine whether Electromagnetic Fields (EMF) exposure had adverse effects on spatial learning and motor function in rats and if physical activity could diminish the damaging effects of EMF exposure. In this study, we measured anthropometric measurements and brain-derived neurotrophic factor (BDNF) levels in pregnant rats' offspring to determine if Wi-Fi EMF also affected their growth. These data we report for the

first time in this publication. **Methods:** Twenty Albino-Wistar pregnant rats were divided randomly into EMF and control (CON) groups, and after delivery, 12 male fetuses were randomly selected. For assessing the body growth change of offspring beginning at delivery, then at 21 postnatal days, and finally at 56 post-natal days, the crown-rump length of the body was assessed using a digital caliper. Examining BDNF factor levels, an Enzyme-linked immunosorbent assay ELISA kit was taken. Body weight was recorded by digital scale. **Results:** Outcomes of the anthropometric measurements demonstrated that EMF blocked body growth in rats exposed to EMF. The results of the BDNF test illustrated that the BDNF in the EMF liter group was remarkably decreased compared to the CON group. The results indicate that EMF exposure could affect BDNF levels and harm body growth in pregnant rats' offspring. **Conclusions:** The results suggest that EMF exposure could affect BDNF levels and impair body growth in pregnant rats' offspring.

Davis D, Birnbaum L, Ben-Ishai P, Taylor H, Sears M, Butler T, Scarato T. Wireless technologies, non-ionizing electromagnetic fields and children: Identifying and reducing health risks. Curr Probl Pediatr Adolesc Health Care. 57(2):101374, 2023. (Review)

Children today are conceived and live in a sea of wireless radiation that did not exist when their parents were born. The launch of the digital age continues to transform the capacity to respond to emergencies and extend global communications. At the same time that this increasingly ubiquitous technology continues to alter the nature of commerce, medicine, transport and modern life overall, its varied and changing forms have not been evaluated for their biological or environmental impacts. Standards for evaluating radiation from numerous wireless devices were first set in 1996 to avoid heating tissue and remain unchanged since then in the U.S. and many other nations. A wide range of evidence indicates that there are numerous non-thermal effects from wireless radiation on reproduction, development, and chronic illness. Many widely used devices such as phones and tablets function as two-way microwave radios, sending and receiving various frequencies of information-carrying microwave radiation on multiple simultaneously operating antennas. Expert groups advising governments on this matter do not agree on the best approaches to be taken. The American Academy of Pediatrics recommends limited screen time for children under the age of two, but more than half of all toddlers regularly have contact with screens, often without parental engagement. Young children of parents who frequently use devices as a form of childcare can experience delays in speech acquisition and bonding, while older children report feelings of disappointment due to 'technoference'—parental distraction due to technology. Children who begin using devices early in life can become socially, psychologically and physically addicted to the technology and experience withdrawal upon cessation. We review relevant experimental, epidemiological and clinical evidence on biological and other impacts of currently used wireless technology, including advice to include key questions at pediatric wellness checkups from infancy to young adulthood. We conclude that consistent with advice in pediatric radiology, an approach that recommends that microwave radiation exposures be As Low As Reasonably

Achievable (ALARA) seems sensible and prudent, and that an independently-funded training, research and monitoring program should be carried out on the long term physical and psychological impacts of rapidly changing technological milieu, including ways to mitigate impacts through modifications in hardware and software. Current knowledge of electrohypersensitivity indicates the importance of reducing wireless exposures especially in schools and health care settings.

(NE) de Gannes FP, Taxile M, Duleu S, Hurtier A, Haro E, Geffard M, Ruffié G, Billaudel B, Lévêque P, Dufour P, Lagroye I, Veyret B. A confirmation study of Russian and Ukrainian data on effects of 2450 MHz microwave exposure on immunological processes and teratology in rats. Radiat Res. 172(5):617-624, 2009. (CE, DE, VO)

In a series of Russian and Ukrainian papers published from 1974-1986, it was reported that 30-day whole-body exposures to continuous-wave (CW) radiofrequency (RF) radiation at 2375 MHz and 5 W/m(2) disrupted the antigenic structure of rat brain tissue. The authors suggested that this action caused an autoimmune response in exposed animals. Moreover, these studies reported that blood serum from exposed rats injected into intact nonexposed female rats on the 10th day of pregnancy led to increased postimplantation embryo mortality and decreased fetus size and body weight. Because the results of these studies served in part as the basis for setting exposure limits in the former USSR, it was deemed necessary to perform confirmation studies, using modern dosimetric and biological methods. In our study, a new system was constructed to expose free-moving rats under far-field conditions. Whole-body and brain-averaged specific absorption rates (SARs) were calculated. All results, using ELISA and classic teratology end points, were negative in our laboratory. On the basis of this investigation, we conclude that, under these exposure conditions (2450 MHz, CW, 7 h/day, 30 days, 0.16 W/kg whole-body SAR), RF-radiation exposure had no influence on several immune and degenerative parameters or on prenatal development.

(E) Delavarifar S, Razi Z, Tamadon A, Rahmanifar F, Mehrabani D, Owjfard M, Koohi-Hoseinabadi O, Zaker Abasali S. Low-power Density Radiations Emitted from Common Wi-Fi Routers Influence Sperm Concentration and Sperm Histomorphometric Parameters: A New Horizon on Male Infertility Treatment. J Biomed Phys Eng 10(2):167-176, 2020. (CE, M, increased sperm concentration) (Low SAR 0.03-0.092 W/kg)

Background: Male infertility is defined as an inability to impregnate a fertile female; it is a widespread problem which is usually caused by some male factors such as low quantity and quality of sperm, specifically oligospermia and azoospermia. **Objective:** This study aimed to evaluate the bio-positive effects of low power density Wi-Fi radiation on the reproductive system of infertile and healthy mice. **Materials and methods:** In this experimental study, thirty adult male Balb/c mice were randomly divided into 5 groups. Groups oligospermic-sham (OS), oligospermic-exposure 1 (OE1) and oligospermic-exposure 2 (OE2) received Busulfan, 10 mg/kg, intraperitoneally, but the control-sham (CS) and control-exposure (CE) groups left without Busulfan therapy. Groups CE, OE1 and OE2 were exposed to 2.4 GHz Wi-Fi radiation while, the CS and OS were sham exposed to Wi-Fi radiation without energizing the Wi-Fi router.

The right and left testes and right epididymis were dissected out and histopathological, histomorphologic changes and the quality of the sperms were analyzed. **Results:** Low power density Wi-Fi radiation significantly increased sperm concentration in the CE group compared to that in CS, while enhancement of spermatid cells was not significant. Sperm concentration in OE2 was more than that in OE1 as the spermatid cells enhanced. **Conclusion:** Findings revealed that radiation hormesis induced by low power density Wi-Fi radiation have biological beneficial effects on mouse sperm concentration and sperm histomorphometric parameters.

(E) De Iuliis GN, Newey RJ, King BV, Aitken RJ. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PLoS One. 4(7):e6446, 2009. (AE, FC, GE, IV, M, OX)

BACKGROUND: In recent times there has been some controversy over the impact of electromagnetic radiation on human health. The significance of mobile phone radiation on male reproduction is a key element of this debate since several studies have suggested a relationship between mobile phone use and semen quality. The potential mechanisms involved have not been established, however, human spermatozoa are known to be particularly vulnerable to oxidative stress by virtue of the abundant availability of substrates for free radical attack and the lack of cytoplasmic space to accommodate antioxidant enzymes. Moreover, the induction of oxidative stress in these cells not only perturbs their capacity for fertilization but also contributes to sperm DNA damage. The latter has, in turn, been linked with poor fertility, an increased incidence of miscarriage and morbidity in the offspring, including childhood cancer. In light of these associations, we have analyzed the influence of RF-EMR on the cell biology of human spermatozoa in vitro. PRINCIPAL FINDINGS: Purified human spermatozoa were exposed to radio-frequency electromagnetic radiation (RF-EMR) tuned to 1.8 GHz and covering a range of specific absorption rates (SAR) from 0.4 W/kg to 27.5 W/kg. In step with increasing SAR, motility and vitality were significantly reduced after RF-EMR exposure, while the mitochondrial generation of reactive oxygen species and DNA fragmentation were significantly elevated ($P<0.001$). Furthermore, we also observed highly significant relationships between SAR, the oxidative DNA damage bio-marker, 8-OH-dG, and DNA fragmentation after RF-EMR exposure. CONCLUSIONS: RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells while stimulating DNA base adduct formation and, ultimately DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring.

(E) Demirbağ B, Aktaş S, Çömelekoğlu Ü, Kara I, Yildirim M, Derici Yildirim DD. Protective effect of paricalcitol in rat testicular damage induced by subchronic 1800 MHz radiofrequency radiation. Biochem Biophys Res Commun 680:42-50, 2023. (CE, IX, M, ME, OX, VO) (Low SAR: Max in body 0.0029 W/kg; at testis: 0.001 W/kg)

In the present study, the possible protective effects of paricalcitol (P) were investigated in testicular damage because of 1800 MHz radiofrequency radiation (RFR) exposure. Male Sprague Dawley rats 8-10 weeks old (n = 28) were randomly divided into four groups as control (C) (n = 7), RFR (n = 7, 1800 MHz RFR 1 h/day for 30 days), P (n = 7, 0.2 μg/kg paricalcitol, 3 times a

week for 30 days), and RFR + P (n = 7, 1800 MHz RFR 1 h/day for 30 days +0.2 µg/kg paricalcitol, 3 times a week for 30 days). Testicular tissue was evaluated with histological and biochemical methods. No statistically significant differences were detected between the groups in seminiferous tubule diameters and germinal epithelial thicknesses. While ultrastructural changes were observed in the seminiferous tubule and Leydig cells in the RFR group, these changes were decreased in the RFR + P group. It was found that the Johnsen Score, Ki67, and p63 immunoreactivity scores (IRS), superoxide dismutase (SOD), and catalase (CAT) activities in the RFR + P group were statistically increased as compared to the RFR group and the malondialdehyde (MDA) levels were decreased statistically and significantly. These results show that paricalcitol administration may have an ameliorative effect on testicular damage occurring because of 1800 MHz RFR exposure.

(E) Deniz OG, Kaplan S. The effects of different herbals on the rat hippocampus exposed to electromagnetic field for one hour during the prenatal period. J Chem Neuroanat 119:102043, 2022. (CE, IU, IX, ME, NU, OX, VO)

The purpose of this study was to highlight the possible effects on the hippocampus of the electromagnetic field (EMF) emitted by mobile phones, and to investigate whether these potential effects can be reduced using various antioxidant substances. Twenty-seven female Wistar albino rats were divided into nine equal groups, each containing three pregnant rats aged 8-10 weeks and weighing 200-250 gr. The EMF groups were exposed to 900 Megahertz (MHz) EMF for 1 h (hr) a day for 21 days. No EMF exposure was applied to the Cont and also the groups given only Garcinia kola (GK), Momordica charantia (MC), and thymoquinone (TQ). The Sham group was kept in the polycarbonate EMF exposure system, but was not exposed to EMF. Four weeks after birth, rat pups were subjected to behavioural tests. Brain tissue samples were evaluated using histological, stereological, functional, and immunohistochemical methods. The numbers of pyramidal neurons in the rat cornu ammonis (CA) were determined using the optical fractionator method. Superoxide dismutase (SOD) and catalase (CAT) enzyme activities in the blood samples were also evaluated. The analysis data indicated that total pyramidal neuron numbers were decreased significantly in the CA of the EMF (1 hr) group ($p < 0.01$). Our results also showed that the protective effect of MC was more potent than that of the other antioxidant substances ($p < 0.01$). A 900 MHz EMF can cause deleterious changes in the brain. It can also be suggested that GK, MC and TQ are capable of reducing these adverse effects.

(E) de Pomerai DI, Dawe A, DjerbibL, Allan, Brunt G, Daniells C. Growth and maturation of the nematode Caenorhabditis elegans following exposure to weak microwave fields. Enzyme Microbial Tech 30:73-79, 2002. (CE, DE, VO)

Prolonged exposure to weak microwave fields (750–1000 MHz, 0.5 W) at 25°C induces a heat-shock response in transgenic C. elegans strains carrying hsp16 reporter genes [1]. A comparable response to heat alone requires a substantially higher temperature of 28°C, suggesting that microwave heating of worms or of the system as a whole might provide a sufficient explanation, although this can be ruled out by indirect arguments [1]. Here we investigate two further biological consequences of prolonged microwave exposure at 25°C in synchronised cultures of wild-type worm larvae, namely alterations in (i) growth rate (GR) and (ii) the proportion of worms later maturing into egg-bearing adults (MP). Both of these parameters are significantly increased following microwave

exposure (GR by 8–11%, and MP by 28–40%), whereas both are significantly decreased (GR by 10% and MP almost abolished) after mild heat treatment at 28°C for the same period. It follows that the biological consequences of microwave exposure are opposite to, and therefore incompatible with, those attributable to mild heating. This evidence does not in itself necessitate a non-thermal mechanism, but does eliminate explanations that invoke the bulk heating of tissues by microwaves. This latter, however, remains the sole basis for current regulations governing microwave exposure.

(E) De Roos AJ, Teschke K, Savitz DA, Poole C, Grufferman S, Pollock BH, Olshan AF. Parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring. Epidemiology 12(5):508-517, 2001. (HU, Maternal RFR exposure increased neuroblastoma in offspring)

We examined parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring. Cases were 538 children diagnosed with neuroblastoma between 1992 and 1994 in the United States or Canada. Age-matched controls were selected by random-digit dialing. Occupational exposures to electrical equipment and radiation sources were classified by an industrial hygienist, and average exposures to extremely low frequency magnetic fields were estimated using a job exposure matrix. Maternal exposure to a broad grouping of sources that produce radiofrequency radiation was associated with an increased incidence of neuroblastoma (odds ratio = 2.8; 95% confidence interval = 0.9-8.7). Paternal exposure to battery-powered forklifts was positively associated with neuroblastoma (odds ratio = 1.6; 95% confidence interval = 0.8-3.2), as were some types of equipment that emit radiofrequency radiation (odds ratios congruent with2.0); however, the broad groupings of sources that produce ELF fields, radiofrequency radiation, or ionizing radiation were not associated with neuroblastoma. Paternal average extremely low frequency magnetic field exposure >0.4 microTesla was weakly associated with neuroblastoma (odds ratio = 1.6; 95% confidence interval = 0.9-2.8), whereas maternal exposure was not. Overall, there was scant supportive evidence of strong associations between parental exposures in electromagnetic spectrum and neuroblastoma in offspring.

de Salles AA, Bulla G, Rodriguez CE. Electromagnetic absorption in the head of adults and children due to mobile phone operation close to the head. Electromagn Biol Med. 2006;25(4):349-360, 2006. (Dosimetry)

The Specific Absorption Rate (SAR) produced by mobile phones in the head of adults and children is simulated using an algorithm based on the Finite Difference Time Domain (FDTD) method. Realistic models of the child and adult head are used. The electromagnetic parameters are fitted to these models. Comparison also are made with the SAR calculated in the children model when using adult human electromagnetic parameters values. Microstrip (or patch) antennas and quarter wavelength monopole antennas are used in the simulations. The frequencies used to feed the antennas are 1850 MHz and 850 MHz. The SAR results are compared with the available international recommendations. It is shown that under similar conditions, the 1g-SAR calculated for children is higher than that for the adults. When using the 10-year old child model, SAR values higher than 60% than those for adults are obtained.

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(NE) Devrim E, Ergüder IB, Kılıçoğlu B, Yaykaşlı E, Cetin R, Durak I. Effects of electromagnetic radiation use on oxidant/antioxidant status and DNA turn-over enzyme activities in erythrocytes and heart, kidney, liver, and ovary tissues from rats: possible protective role of Vitamin C. Toxicol Mech Methods.18(9):679-683, 2008. (CE, F, OX, VO) (There was a significant decrease in xanthine oxidase in the ovary.) (SAR 1.2 W/kg)

ABSTRACT In this study, the aim was to investigate possible effects of Electromagnetic Radiation (EMR) use on oxidant and antioxidant status in erythrocytes and kidney, heart, liver, and ovary tissues from rats, and possible protective role of vitamin C. For this aim, 40 Wistar albino female rats were used throughout the study. The treatment group was exposed to EMR in a frequency of 900 MHz, the EMR plus vitamin C group was exposed to the same EMR frequency and given vitamin C (250 mg/kg/day) orally for 4 weeks. There were 10 animals in each group including control and vitamin C groups. At the end of the study period, blood samples were obtained from the animals to get erythrocyte sediments. Then the animals were sacrificed and heart, kidney, liver, and **ovary tissues** were removed. Malondialdehyde (MDA) levels and superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px), xanthine oxidase (XO), and adenosine deaminase (ADA) enzyme activities were measured in the tissues and erythrocytes. It was observed that MDA level, XO, and GSH-Px activities significantly increased in the EMR group as compared with those of the control group in the erythrocytes. In the kidney tissues, it was found that MDA level and CAT activity significantly increased, whereas XO and ADA activities decreased in the cellular phone group as compared with those of the control group. However, in the heart tissues it was observed that MDA level, ADA, and XO activities significantly decreased in the cellular phone group as compared with those of the control group. The results suggest that EMR at the frequency generated by a cell phone causes oxidative stress and peroxidation in the erythrocytes and kidney tissues from rats. In the erythrocytes, vitamin C seems to make partial protection against the oxidant stress.

Dimbylow P. SAR in the mother and foetus for RF plane wave irradiation. Phys Med Biol. 52(13):3791-3802, 2007. (Dosimetry)

This paper describes the finite-difference time-domain calculation of SAR from 20 MHz to 3 GHz in hybrid voxel-mathematical models of the pregnant female. Mathematical models of the developing foetus at 8-, 13-, 26- and 38-week gestation were converted into voxels and combined with the reference adult female model, NAOMI at a resolution of 2 mm. Whole-body averaged SAR in the mother is presented as well as the average over the foetus, over the foetal brain and in 10 g of the foetus. The electric field values required to produce the ICNIRP public exposure restriction of 2 W kg(-1) when averaged over 10 g of the foetus were calculated. Comparison suggests that the ICNIRP public reference level is a conservative predictor of local SAR in the foetus.

Dimbylow PJ, Nagaoka T, Xu XG. A comparison of foetal SAR in three sets of pregnant female models. Phys Med Biol. 54(9):2755-2767, 2009. (Dosimetry)

This paper compares the foetal SAR in the HPA hybrid mathematical phantoms with the 26-week foetal model developed at the National Institute of Information and Communications Technology, Tokyo, and the set of 13-, 26- and 38-week boundary representation models produced at Rensselaer Polytechnic Institute. FDTD calculations are performed at a resolution of 2 mm for a plane wave with a vertically aligned electric field incident upon the body from the front, back and two sides from 20 MHz to 3 GHz under isolated conditions. The external electric field values required to produce the ICNIRP public exposure localized restriction of 2 W kg(-1) when averaged over 10 g of the foetus are compared with the ICNIRP reference levels.

(E) Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology 19(4):523-529, 2008. (BE, CE, HU, IU, PN)

Background: The World Health Organization has emphasized the need for research into the possible effects of radiofrequency fields in children. We examined the association between prenatal and postnatal exposure to cell phones and behavioral problems in young children. **Methods:** Mothers were recruited to the Danish National Birth Cohort early in pregnancy. When the children of those pregnancies reached 7 years of age in 2005 and 2006, mothers were asked to complete a questionnaire regarding the current health and behavioral status of children, as well as past exposure to cell phone use. Mothers evaluated the child's behavior problems using the Strength and Difficulties Questionnaire. **Results:** Mothers of 13,159 children completed the follow-up questionnaire reporting their use of cell phones during pregnancy as well as current cell phone use by the child. Greater odds ratios for behavioral problems were observed for children who had possible prenatal or postnatal exposure to cell phone use. After adjustment for potential confounders, the odds ratio for a higher overall behavioral problems score was 1.80 (95% confidence interval = 1.45-2.23) in children with both prenatal and postnatal exposure to cell phones. **Conclusions:** Exposure to cell phones prenatally-and, to a lesser degree, postnatally-was associated with behavioral difficulties such as emotional and hyperactivity problems around the age of school entry. These associations may be noncausal and may be due to unmeasured confounding. If real, they would be of public health concern given the widespread use of this technology.

(E) Divan HA, Kheifets L, Obel C, Olsen J. Cell phone use and behavioural problems in young children. J Epidemiol Community Health 66(6):524-529, 2012. (BE, CE, HU)

Background: Potential health effects of cell phone use in children have not been adequately examined. As children are using cell phones at earlier ages, research among this group has been identified as the highest priority by both national and international organisations. The authors previously reported results from the Danish National Birth Cohort (DNBC), which looked at prenatal and postnatal exposure to cell phone use and behavioural problems at age 7 years. Exposure to cell phones prenatally, and to a lesser degree postnatally, was associated with more behavioural difficulties. The original analysis included nearly 13 000 children who reached age 7 years by November 2006. **Methods:** To see if a larger, separate group of DNBC children would produce similar results after considering additional confounders, children of mothers who might better represent current users of cell phones were analysed. This 'new' dataset consisted of 28

745 children with completed Age-7 Questionnaires to December 2008. **Results:** The highest OR for behavioural problems were for children who had both prenatal and postnatal exposure to cell phones compared with children not exposed during either time period. The adjusted effect estimate was 1.5 (95% CI 1.4 to 1.7). **Conclusions:** The findings of the previous publication were replicated in this separate group of participants demonstrating that cell phone use was associated with behavioural problems at age 7 years in children, and this association was not limited to early users of the technology. Although weaker in the new dataset, even with further control for an extended set of potential confounders, the associations remained.

(NE)Dong VNK, Tantisuwat L, Setthawong P, Tharasanit T, Sutayatram S, Kijtawornrat The Preliminary Chronic Effects of Electromagnetic Radiation from Mobile Phones on Heart Rate Variability, Cardiac Function, Blood Profiles, and Semen Quality in Healthy Dogs. Vet Sci 9(5):201, 2022. (DE, FC, M, VO)

The present study aims to determine the effects of long-term exposure to electromagnetic radiation from mobile phones (MPs) on heart rate variability (HRV), cardiac function, blood profiles, body surface temperature, and semen quality in healthy dogs. Eight male dogs were exposed to MPs (1962-1966 MHz; specific absorption rate 0.96 W/kg) for 2 h/day, 5 days/week, for 10 weeks. Holter monitoring for HRV analysis was performed at baseline (BL) and every 2 weeks, until the end of the study. Electrocardiograms (ECG), blood pressure (BP), echocardiography, cardiac troponin I (cTnI), hematology and biochemistry profiles, body surface temperature, and semen quality were evaluated at BL, week 5, and week 10 during exposure. The results showed that most of the HRV parameters did not significantly differ among timepoints, except for the mean of an interval between continuous normal R waves in week 6 that was higher than that at BL ($p = 0.022$). The RR and QT intervals from ECG in week 5 were prolonged, compared to the BL values ($p = 0.001$ and $p = 0.003$, respectively), but those parameters were within the normal limits. The echocardiography, BP, cTnI concentrations, body surface temperature, and semen quality results were not different from BL values. In conclusion, this study found no evidence suggesting an adverse effect of cell phone exposure on HRV, cardiac function, blood profiles, body surface temperature, or semen quality in healthy dogs, when exposed for 10 weeks.

(E) D'Silva MH, Swer RT, Anbalagan J, Rajesh B. Effect of Radiofrequency Radiation Emitted from 2G and 3G Cell Phone on Developing Liver of Chick Embryo - A Comparative Study. J Clin Diagn Res. 11(7):AC05-AC09, 2017. (CE, GE, IU, ME)

INTRODUCTION: The increasing scientific evidence of various health hazards on exposure of Radiofrequency Radiation (RFR) emitted from both the **cell phones** and base stations have caused significant media attention and public discussion in recent years. The mechanism of interaction of RF fields with developing tissues of children and fetuses may be different from that of adults due to their smaller physical size and variation in tissue electromagnetic properties. The present study may provide an insight into the basic mechanisms by which RF fields interact with developing tissues in an embryo. AIM: To evaluate the possible tissue and DNA damage in developing liver of chick embryo following chronic exposure to Ultra-High Frequency/Radiofrequency Radiation (UHF/RFR) emitted from 2G and 3G **cell phone**. MATERIALS AND METHODS: Fertilized chick embryos were

incubated in four groups. Group A-experimental group exposed to 2G radiation (60 eggs), Group B- experimental group exposed to 3G radiation (60 eggs), Group C- sham exposed control group (60 eggs) and Group D- control group (48 eggs). On completion of scheduled duration, the embryos were collected and processed for routine histological studies to check structural changes in liver. The nuclear diameter and karyorrhexis changes of hepatocytes were analysed using oculometer and square reticule respectively. The liver procured from one batch of eggs from all the four groups was subjected to alkaline comet assay technique to assess DNA damage. The results were compared using one-way ANOVA test. RESULTS: In our study, the exposure of developing chick embryos to 2G and 3G **cell phone** radiations caused structural changes in liver in the form of dilated sinusoidal spaces with haemorrhage, increased vacuolations in cytoplasm, increased nuclear diameter and karyorrhexis and significantly increased DNA damage. CONCLUSION: The chronic exposure of chick embryo liver to RFR emitted from 2G and 3G **cell phone** resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Based on these findings it is necessary to create awareness among public about the possible ill effects of RFR exposure from **cell phone**

(E) Eghlidospour M, Ghanbari A, Mortazavi SMJ, Azari H. Effects of radiofrequency exposure emitted from a GSM mobile phone on proliferation, differentiation, and apoptosis of neural stem cells. Anat Cell Biol. 50(2):115-123, 2017. (AE, IV, ME) (SAR 2.287 W/kg)

Due to the importance of neural stem cells (NSCs) in plasticity of the nervous system and treating neurodegenerative diseases, the main goal of this study was to evaluate the effects of radiofrequency radiation emitted from a GSM 900-MHz mobile phone with different exposure duration on proliferation, differentiation and apoptosis of adult murine NSCs *in vitro*. We used neurosphere assay to evaluate NSCs proliferation, and immunofluorescence assay of neural cell markers to examine NSCs differentiation. We also employed alamarBlue and caspase 3 apoptosis assays to assess harmful effects of mobile phone on NSCs. Our results showed that the number and size of resulting neurospheres and also the percentage of cells differentiated into neurons decreased significantly with increasing exposure duration to GSM 900-MHz radiofrequency (RF)-electromagnetic field (EMF). In contrast, exposure to GSM 900-MHz RF-EMF at different durations did not influence cell viability and apoptosis of NSCs and also their astrocytic differentiation. It is concluded that accumulating dose of GSM 900-MHz RF-EMF might have devastating effects on NSCs proliferation and neurogenesis requiring more causations in terms of using mobile devices.

(NE) Elliott P, Toledano MB, Bennett J, Beale L, de Hoogh K, Best N, Briggs DJ. Mobile phone base stations and early childhood cancers: case-control study. BMJ. 340:c3077, 2010. (CE, HU, IU) Cancer

OBJECTIVE: To investigate the risk of early childhood cancers associated with the mother's exposure to radiofrequency from and proximity to macrocell mobile phone base stations(masts) during pregnancy. **DESIGN:** Case-control study. **SETTING:** Cancer registry and national birth register data in Great Britain. **PARTICIPANTS:** 1397 cases of cancer in children aged 0-4 from national cancer registry 1999-2001 and 5588 birth controls from

national birth register, individually matched by sex and date of birth (four controls per case). **MAIN OUTCOME MEASURES:** Incidence of cancers of the brain and central nervous system, leukaemia, and non-Hodgkin's lymphomas, and all cancers combined, adjusted for small area measures of education level, socioeconomic deprivation, population density, and population mixing. **RESULTS:** Mean distance of registered address at birth from a macrocell base station, based on a national database of 76,890 base station antennas in 1996-2001, was similar for cases and controls (1107 (SD 1131) m v 1073 (SD 1130) m, P=0.31), as was total power output of base stations within 700 m of the address (2.89 (SD 5.9) kW v 3.00 (SD 6.0) kW, P=0.54) and modelled power density (-30.3 (SD 21.7) dBm v -29.7 (SD 21.5) dBm, P=0.41). For modelled power density at the address at birth, compared with the lowest exposure category the adjusted odds ratios were 1.01 (95% confidence interval 0.87 to 1.18) in the intermediate and 1.02 (0.88 to 1.20) in the highest exposure category for all cancers (P=0.79 for trend), 0.97 (0.69 to 1.37) and 0.76 (0.51 to 1.12), respectively, for brain and central nervous system cancers (P=0.33 for trend), and 1.16 (0.90 to 1.48) and 1.03 (0.79 to 1.34) for leukaemia and non-Hodgkin's lymphoma (P=0.51 for trend). **CONCLUSIONS:** There is no association between risk of early childhood cancers and estimates of the mother's exposure to mobile phone base stations during pregnancy.

(E) Er H, Tas GG, Soygur B, Ozen S, Sati L. Acute and Chronic Exposure to 900 MHz Radio Frequency Radiation Activates p38/JNK-mediated MAPK Pathway in Rat Testis. Reprod Sci 29(5):1471-1485, 2022. (CE, M, MO, VO) (Whole body SAR 1.157 W/kg, testis SAR 0.107 W/kg)

The use of electronic devices such as mobile phones has had a long stretch of rapid growth all over the world. Therefore, exposure to radio frequency radiation (RFR) has increased enormously. Here, we aimed to assess the balance between cell death and proliferation and also investigate the involvement of the JNK/p38 MAPK signaling pathway in the testis of rats exposed to 900 MHz RFR in acute and chronic periods (2 h/day, 5 days/week) for 1 or 10 weeks, respectively. The expression of proliferating cell nuclear antigen (PCNA), Bcl-xL, cleaved caspase-3, phosphorylated-JNK (p-JNK), and phosphorylated-p38 (p-p38) was analyzed in line with histopathology and TUNEL analysis in rat testis. There were no histopathological differences between sham and RFR groups in the acute and chronic groups. PCNA expression was not altered between groups in both periods. However, alterations for cleaved caspase-3 and Bcl-xL were observed depending on the exposure period. TUNEL analysis showed a significant increase in the RFR group in the acute period, whereas no difference in the chronic groups for the apoptotic index was reported. In addition, both p-p38 and p-JNK protein expressions increased significantly in RFR groups in both periods. Our study indicated that 900 MHz RFR might result in alterations during acute period exposure for several parameters, but this can be ameliorated in the chronic period in rat testis. Here, we also report the involvement of the p38/JNK-mediated MAPK pathway after exposure to 900 MHz RFR. Hence, this information might shed light in future studies toward detailed molecular mechanisms in male reproduction and infertility.

(E)ErdenKoç GE, Kaplan S, Altun G, Gümüş H, Deniz ÖG, Aydin I, Onger ME, Altunk aynak. Neuroprotective effects of melatonin and omega-3 on hippocampal cells prenatally

exposed to 900 MHz electromagnetic fields. Int J Radiat Biol 92(10):590-595, 2016. (CE, IU, ME, NU, VO) (SAR 2 W/kg)

Purpose: Adverse effects on human health caused by electromagnetic fields (EMF) associated with the use of mobile phones, particularly among young people, are increasing all the time. The potential deleterious effects of EMF exposure resulting from mobile phones being used in close proximity to the brain require particular evaluation. However, only a limited number of studies have investigated the effects of prenatal exposure to EMF in the development of the pyramidal cells using melatonin (MEL) and omega-3 (ω-3). **Materials and methods:** We established seven groups of pregnant rats consisting of three animals each; control (CONT), SHAM, EMF, EMF + MEL, MEL, EMF + ω-3 and ω-3 alone. The rats in the EMF, EMF + MEL, EMF + ω-3 groups were exposed to 900 MHz EMF for 60 min/day in an exposure tube during the gestation period. The CONT, MEL and ω-3 group rats were not placed inside the exposure tube or exposed to EMF during the study period. After delivery, only spontaneously delivered male rat pups were selected for the establishment of further groups. Each group of offspring consisted of six animals. The optical fractionator technique was used to determine total pyramidal neuron numbers in the rat hippocampal region. **Results:** The total number of pyramidal cells in the cornu ammonis (CA) in the EMF group was significantly lower than in the CONT, SHAM, EMF + MEL, and EMF + ω-3 groups. No significant difference was observed between the EMF, MEL and ω-3 groups. No difference was also observed between any groups in terms of rats' body or brain weights. **Conclusion:** MEL and ω-3 can protect the cell against neuronal damage in the hippocampus induced by 900 MHz EMF. However, further studies are now needed to evaluate the chronic effects of 900 MHz EMF on the brain in the prenatal period.

(E) Erkut A, Tumkaya L, Balik MS, Kalkan Y, Guvercin Y, Yilmaz A, Yuce S, Cure E, Sehitoglu I. The effect of prenatal exposure to 1800 MHz electromagnetic field on calcineurin and bone development in rats. Acta Cir Bras. 31(2):74-83, 2016. (CE, DE, IU, ME, VO) (No dosimetry data available.)

PURPOSE: To investigate the effects of exposure to an 1800 MHz electromagnetic field (EMF) on bone development during the prenatal period in rats. METHODS: Pregnant rats in the experimental group were exposed to radiation for six, 12, and 24 hours daily for 20 days. No radiation was given to the pregnant rats in the control group. We distributed the newborn rats into four groups according to prenatal EMF exposure as follows: Group 1 was not exposed to EMF; groups 2, 3, and 4 were exposed to EMF for six, 12, and 24 hours a day, respectively. The rats were evaluated at the end of the 60th day following birth. RESULTS: Increasing the duration of EMF exposure during the prenatal period resulted in a significant reduction of resting cartilage levels and a significant increase in the number of apoptotic chondrocytes and myocytes. There was also a reduction in calcineurin activities in both bone and muscle tissues. We observed that the development of the femur, tibia, and ulna were negatively affected, especially with a daily EMF exposure of 24 hours. CONCLUSION: Bone and muscle tissue development was negatively affected due to prenatal exposure to 1800 MHz radiofrequency electromagnetic field.

(E) Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, Irkilata HC, Irmak MK, Peker AF. Effects of electromagnetic radiation from a cellular phone on human sperm

motility: an in vitro study. Arch Med Res. 37(7):840-843, 2006. (AE, FC, HU, IV, M)

BACKGROUND: There has been growing public concern on the effects of electromagnetic radiation (EMR) emitted by cellular phones on human health. Many studies have recently been published on this topic. However, possible consequences of the cellular phone usage on human sperm parameters have not been investigated adequately. METHODS: A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. The concentration and motility of the specimens were compared to analyze the effects of EMR. Assessment of sperm movement in all specimens was performed using four criteria: (A) rapid progressive, (B) slow progressive, (C) nonprogressive, (D) no motility. RESULTS: Statistically significant changes were observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR exposure caused a subtle decrease in the rapid progressive and slow progressive sperm movement. It also caused an increase in the no-motility category of sperm movement. There was no statistically significant difference in the sperm concentration between two groups. CONCLUSIONS: These data suggest that EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.

(E) Eskander EF, Estefan SF, Abd-Rabou AA. How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin Biochem. 45(1-2):157-161, 2012. (CE, HU, M, MO)

OBJECTIVES: This study is concerned with assessing the role of exposure to radio frequency radiation (RFR) emitted either from mobiles or base stations and its relations with human's hormone profiles. **DESIGN AND METHODS:** All volunteers' samples were collected for hormonal analysis. **RESULTS:** This study showed significant decrease in volunteers' ACTH, cortisol, thyroid hormones, prolactin for young females, and testosterone levels. **CONCLUSION:** The present study revealed that high RFR effects on pituitary-adrenal axis.

(E) Esmekaya MA, Ozer C, Seyhan N. 900 MHz pulse-modulated radiofrequency radiation induces oxidative stress on heart, lung, testis and liver tissues. Gen Physiol Biophys. 30(1):84-89, 2011. (CE, M, MO, OX, VO)

Oxidative stress may affect many cellular and physiological processes including gene expression, cell growth, and cell death. In the recent study, we aimed to investigate whether 900 MHz pulse-modulated radiofrequency (RF) fields induce oxidative damage on lung, heart and liver tissues. We assessed oxidative damage by investigating lipid peroxidation (malondialdehyde, MDA), nitric oxide (NOx) and glutathione (GSH) levels which are the indicators of tissue toxicity. A total of 30 male Wistar albino rats were used in this study. Rats were divided randomly into three groups; control group (n = 10), sham group (device off, n = 10) and 900 MHz pulsed-modulated RF radiation group (n = 10). The RF rats were exposed to 900 MHz pulsed modulated RF radiation at a specific absorption rate (SAR) level of 1.20

W/kg 20 min/day for three weeks. MDA and NOx levels were increased significantly in liver, lung, testis and heart tissues of the exposed group compared to sham and control groups ($p < 0.05$). Conversely GSH levels were significantly lower in exposed rat tissues ($p < 0.05$). No significantly difference was observed between sham and control groups. Results of our study showed that pulse-modulated RF radiation causes oxidative injury in liver, lung, testis and heart tissues mediated by lipid peroxidation, increased level of NOx and suppression of antioxidant defense mechanism.

(E)Fadiloglu E, Tapisiz OL, Unsal M, Fadiloglu S, Celik B, Mollamahmutoglu L. Non-Ionizing Radiation Created by Mobile Phone Progresses Endometrial Hyperplasia: An Experimental Rat Study. Arch Med Res 50(2):36-43, 2019. (CE, F, ME, MO, VO) (No dosimetry data)

Background: Non-ionizing radiation is related with many pathologies. **Aim:** Determine association between non-ionizing radiation and endometrial hyperplasia. **Methods:** Fifty oopherectomized Wistar albino rats were administered Estradiol hemihydrate (4 mg/kg) to induce hyperplasia, and were exposed to 1800 MHz radiation created by a mobile phone and a signal generator working as base station. This study was carried out with 5 groups in two phases. The study groups were. Control group without any exposure; group receiving estrogen in first phase of the study; group receiving estrogen in both phases; group receiving estrogen in the first phase and exposed to non-ionizing radiation during second phase and group taking estrogen in both phases and exposed to non-ionizing radiation during the second phase. Following both phases, uterine horns were excised and evaluated based on glandular density (GD), epithelial cell height (ECH), and luminal epithelial cell height (LECH). **Results:** Estrogen increased all parameters during both phases (LECH, GD, and ECH values were 12,2 vs. 16,5 ($p = 0.001$), 34 vs. 47 ($p <0.001$), and 201 vs. 376.6 ($p = 0.001$), respectively during the first phase; LECH, GD and ECH values were 13,2 vs. 20,3 ($p <0.001$), 35.5 vs. 65,5 ($p <0.001$), 219.9 vs. 419.6 ($p <0.001$), respectively, during the second phase).Non-ionizing radiation increased all values without estrogen exposure (LECH, GD and ECH values were 13,2 vs. 17,2 ($p = 0,074$), 35,5 vs. 59 ($p = 0.074$), and 219 vs. 318.3 ($p <0.001$), respectively) or with estrogen exposure (LECH, GD, and ECH, values were 20,3 vs. 22,8 ($p = 0,168$), 65,5 vs. 77 ($p = 0,058$), and 419,6 vs. 541,6 ($p = 0.004$), respectively). **Conclusion:** Non-ionizing radiation progressed endometrial hyperplasia in an experimental rat model with/without estrogen exposure.

(E) Falzone N, Huyser C, Fourie F, Toivo T, Leszczynski D, Franken D. In vitro effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential and motility of human spermatozoa. Bioelectromagnetics.29(4):268-276, 2008. (AE, FC, HU. IV, M)

Ejaculated, density purified, human spermatozoa were exposed to pulsed 900 MHz GSM mobile phone radiation at two specific absorption rate levels (SAR 2.0 and 5.7 W/kg) and compared with controls over time. Change in sperm mitochondrial membrane potential was analysed using flow cytometry. Sperm motility was determined by computer assisted sperm analysis (CASA). There was no effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential. This was also the case for all kinematic parameters assessed at a SAR of 2.0 W/kg. However, over time, the two kinematic parameters straight line velocity (VSL) and beat-cross frequency (BCF) were

significantly impaired (P < 0.05) after the exposure at SAR 5.7 W/kg and no exposure by time interaction was present. This result should not be ascribed to thermal effects, due to the cooling methods employed in the RF chamber and temperature control within the incubator.

(E) Falzone N, Huyser C, Becker P, Leszczynski D, Franken DR. The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. Int J Androl. 34(1):20-26, 2011. (AE, HU, ME, IV, M)

Several recent studies have indicated that radiofrequency electromagnetic fields (RF-EMF) have an adverse effect on human sperm quality, which could translate into an effect on fertilization potential. This study evaluated the effect of RF-EMF on sperm-specific characteristics to assess the fertilizing competence of sperm. Highly motile human spermatozoa were exposed for 1 h to 900-MHz mobile phone radiation at a specific absorption rate of 2.0 W/kg and examined at various times after exposure. The acrosome reaction was evaluated using flow cytometry. The radiation did not affect sperm propensity for the acrosome reaction. Morphometric parameters were assessed using computer-assisted sperm analysis. Significant reduction in sperm head area (9.2 +/- 0.7 mum(2) vs. 18.8 +/- 1.4 mum(2)) and acrosome percentage of the head area (21.5 +/- 4% vs. 35.5 +/- 11.4%) was reported among exposed sperm compared with unexposed controls. Sperm-zona binding was assessed directly after exposure using the hemizona assay. The mean number of zona-bound sperm of the test hemizona and controls was 22.8 +/- 12.4 and 31.8 +/- 12.8 (p < 0.05), respectively. This study concludes that although RF-EMF exposure did not adversely affect the acrosome reaction, it had a significant effect on sperm morphometry. In addition, a significant decrease in sperm binding to the hemizona was observed. These results could indicate a significant effect of RF-EMF on sperm fertilization potential.

(NE) Falzone N, Huyser C, Franken DR, Leszczynski D. Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa. Radiat Res. 174(2):169-176, 2010. (AE, GE, HU, IV, M, OX)

Recent reports suggest that mobile phone radiation may diminish male fertility. However, the effects of this radiation on human spermatozoa are largely unknown. The present study examined effects of the radiation on induction of apoptosis-related properties in human spermatozoa. Ejaculated, density-purified, highly motile human spermatozoa were exposed to mobile phone radiation at specific absorption rates (SARs) of 2.0 and 5.7 W/kg. At various times after exposure, flow cytometry was used to examine caspase 3 activity, externalization of phosphatidylserine (PS), induction of DNA strand breaks, and generation of reactive oxygen species. Mobile phone radiation had no statistically significant effect on any of the parameters studied. This suggests that the impairment of fertility reported in some studies was not caused by the induction of apoptosis in spermatozoa.

(E) Fejes I, Za Vaczki Z, Szollosi J, Kolosza R S, Daru J, Kova Cs L, Pa LA. Is there a relationship between cell phone use and semen quality? Arch Androl. 51(5):385-393, 2005. (CE, FC, HU, M)

This study was conducted to determine a possible relationship between regular cell phone use and different human semen attributes. The history-taking of men in our university clinic was supplemented with questions concerning cell phone use habits, including possession, daily standby position and daily transmission times. Semen analyses were performed by conventional methods. Statistics were calculated with SPSS statistical software. A total of 371 were included in the study. The duration of possession and the daily transmission time correlated negatively with the proportion of rapid progressive motile sperm (r = - 0.12 and r = - 0.19, respectively), and positively with the proportion of slow progressive motile sperm (r = 0.12 and r = 0.28, respectively). The low and high transmitter groups also differed in the proportion of rapid progressive motile sperm (48.7% vs. 40.6%). The prolonged use of cell phones may have negative effects on the sperm motility characteristics.

(E) Ferreira AR, Knakievicz T, de Bittencourt Pasquali MA, Gelain DP, Dal-Pizzol F, Fernandez CE, de Almeida de Salles AA, Ferreira HB, Moreira JC. Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronucle i incidence in rat offspring. Life Sci. 80(1):43-50, 2006. (CE, GE, IU, VO) (SAR 0.55-1.23 W/kg)

Mobile telephones and their base stations are an important ultra high frequency-electromagnetic field (UHF-EMF) source and their utilization is increasing all over the world. Epidemiological studies suggested that low energy UHF-EMF emitted from a cellular telephone may cause biological effects, such as DNA damage and changes on oxidative metabolism. An in vivo mammalian cytogenetic test, the micronucleus (MN) assay, was used to investigate the occurrence of chromosomal damage in erythrocytes from rat offspring exposed to a non-thermal UHF-EMF from a cellular phone during their embryogenesis; the irradiated group showed a significant increase in MN occurrence. In order to investigate if UHF-EMF could also alter oxidative parameters in the peripheral blood and in the liver - an important hematopoietic tissue in rat embryos and newborns - we also measured the activity of antioxidant enzymes, quantified total sulfhydryl content, protein carbonyl groups, thiobarbituric acid-reactive species and total non-enzymatic antioxidant defense. No significant differences were found in any oxidative parameter of offspring blood and liver. The average number of pups in each litter has also not been significantly altered. Our results suggest that, under our experimental conditions, UHF-EMF is able to induce a genotoxic response in hematopoietic tissue during the embryogenesis through an unknown mechanism.

Findlay RP, Dimbylow PJ. SAR in a child voxel phantom from exposure to wireless computer networks (Wi-Fi). Phys Med Biol. 55(15):N405-411, 2010. (Dosimetry)

Specific energy absorption rate (SAR) values have been calculated in a 10 year old sitting voxel model from exposure to electromagnetic fields at 2.4 and 5 GHz, frequencies commonly used by Wi-Fi devices. Both plane-wave exposure of the model and irradiation from antennas in the near field were investigated for a variety of exposure conditions. In all situations studied, the SAR values calculated were considerably below basic restrictions. For a typical Wi-Fi exposure scenario using an inverted F antenna operating at 100 mW, a duty factor of 0.1 and an antenna-body separation of 34 cm, the maximum peak localized SAR was found to be 3.99 mW kg(-1)

in the torso region. At 2.4 GHz, using a power of 100 mW and a duty factor of 1, the highest localized SAR value in the head was calculated as 5.7 mW kg(-1). This represents less than 1% of the SAR previously calculated in the head for a typical mobile phone exposure condition.

(NE) Finnie JW, Blumbergs PC, Cai Z, Manavis J, Kuchel TR. Effect of mobile telephony on blood-brain barrier permeability in the fetal mouse brain. Pathology 38(1):63-65, 2006. (CE, IU, NU, VO) (SAR 4 W/kg)

Aims: To study the effect of mobile telephone exposure on blood-brain barrier (BBB) permeability in the immature brain. **Methods:** Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint and a positive control group with cadmium-induced BBB damage was also included. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in Bouin's fixative and paraffin embedded. Disruption of BBB integrity was detected immunohistochemically using endogenous albumin as a vascular tracer in cerebral cortex, thalamus, basal ganglia, hippocampus, cerebellum, midbrain and medulla. **Results:** No albumin extravasation was found in exposed or control brains. **Conclusion:** In this animal model, whole of gestation exposure to global system for mobile communication-like radiofrequency fields did not produce any increase in vascular permeability in the fetal brain regions studied using endogenous albumin as a light microscopic immunohistochemical marker.

(NE) Finnie JW, Cai Z, Blumbergs PC, Manavis J, Kuchel TR. Expression of the immediate early gene, c-fos, in fetal brain after whole of gestation exposure of pregnant mice to global system for mobile communication microwaves. Pathology. 38(4):333-335, 2006. (CE, GE, IU, NU, VO)

AIMS: To study immediate early gene, c-fos, expression as a marker of neural stress after whole of gestation exposure of the fetal mouse brain to mobile telephone-type radiofrequency fields. METHODS: Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in 4% paraformaldehyde and paraffin embedded. Any stress response in the brain was detected by c-fos immunohistochemistry in the cerebral cortex, basal ganglia, thalamus, hippocampus, midbrain, cerebellum and medulla. RESULTS: c-fos expression was of limited, but consistent, neuroanatomical distribution and there was no difference in immunoreactivity between exposed and control brains. CONCLUSION: In this animal model, no stress response was detected in the fetal brain using c-fos immunohistochemistry after whole of gestation exposure to mobile telephony.

(NE) Finnie JW, Chidlow G, Blumbergs PC, Manavis J, Cai Z.. Heat shock protein induction in fetal mouse brain as a measure of stress after whole of gestation exposure to mobile telephony radiofrequency fields. Pathology. 41(3):276-279, 2009. (CE, IU, MO, VO)

Aim: To determine whether whole of gestation exposure of fetal mouse brain to mobile telephone radiofrequency fields produces a stress response detectable by induction of heat shock proteins (HSPs). Methods: Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. Immediately prior to parturition on day 19, fetal brains were collected, fixed in 4% paraformaldehyde and paraffin-embedded. Three coronal sections encompassing a wide range of anatomical regions were cut from each brain and any stress response detected by immunostaining for HSP25, 32 and 70. Results: There was no induction of HSP32 or 70 in any brains, while HSP25 expression was limited to two brainstem nuclei and occurred consistently in exposed and non-exposed brains. Conclusion: Whole of gestation exposure of fetal mouse brains to mobile phone radiofrequency fields did not produce any stress response using HSPs as an immunohistochemical marker.

(E) Forgacs Z, Somosy Z, Kubinyi G, Bakos J, Hudak A, Surjan A, Thuroczy G. Effect of whole-body 1800MHz GSM-like microwave exposure on testicular steroidogenesis and histology in mice. Reprod Toxicol.22(1):111-117, 2006. (CE, M, ME, MO, VO) (Low SAR)

The aim of our study was to evaluate the possible effects of whole-body 1800MHz GSM-like microwave exposure on male reproduction. After repeated exposure of mice to microwaves at 0.018-0.023 W/kg whole-body specific energy absorption rate (SAR) an elevated serum testosterone level was measured, but no microwave exposure related histopathological alteration could be detected in the reproductive organs. The in vitro steroidogenic response of 48h Leydig cell cultures obtained from exposed animals did not differ from the controls, suggesting that Leydig cells were not the primary targets of the applied microwave exposure or direct action of microwaves on Leydig cells was temporary only. In exposed animals the red blood cell count and volume of packed red cells were also increased. Further investigations are required to clarify the mechanism of action of the applied microwave exposure on male mice, as well as to establish the biological significance of the observed phenomena.

(E) Fragopoulou AF, Koussoulakos SL, Margaritis LH. Cranial and postcranial skeletal variations induced in mouse embryos by mobile phone radiation. Pathophysiology. 17(3):169-177, 2010. (CE, IU, ME, VO)

This study focuses on foetal development following mild daily exposure of pregnant mice to near field electromagnetic radiation emitted by a mobile phone. The investigation was motivated by the fact that the potentially hazardous electromagnetic radiation emitted by mobile phones is currently of tremendous public interest. Physically comparable pregnant mice were exposed to radiofrequency radiation GSM 900 MHz emitted by a mobile phone. Within 5h after birth most cubs were fixed followed by double staining in toto, and conventional paraffin histology. Other cubs remained with their mothers until teeth eruption. Structural development was assessed by examining newborns for the presence of anomalies and/or variations in soft tissues and skeletal anatomy. Electromagnetic radiofrequency exposed newborns, externally examined, displayed a normal phenotype. Histochemical and histological studies, however, revealed variations in the exposed

foetuses with respect to control ones concerning the ossification of cranial bones and thoracic cage ribs, as well as displacement of Meckelian cartilage. Littermates examined after teeth eruption displayed normal phenotypes. It is concluded that mild exposure to mobile phone radiation may affect, although transiently, mouse foetal development at the ossification level. The developmental variations observed could be explained by considering the different embryonic origin and mode of ossification of the affected skeletal elements.

(E) Galat VV, Mezhevikina LM, Zubin MN, Lepikhov KA, Khramov RN, Chailakhian LM, [Effect of millimeter waves on the early development of the mouse and sea urchin embryo]. Biofizika 44(1):137-140, 1999. [Article in Russian] (AE, DE, ME, VO)

The action of nonthermal electromagnetic radiation (EMR) of the millimeter range on the early development of murine and sea urchin embryos was investigated. An MRTA-01E-03 generator with a frequency of 54-78 GHz and radiation intensity of 0.06 mWt/cm^2 was used. The embryos were irradiated during 30 min at the stage of two blastomeres. The number of murine embryos that reached the blastocyst stage increased (up to 97.3% in comparison with 87.5% in control). The total time of cultivation up to the blastocyst stage was also shorter (72 h) than in control (96 h). The irradiation had effect on the development of sea urchin embryos only if embryos with a weakened viability were tested. The results indicate that millimeter electromagnetic radiation has a stimulating effect on the early development of embryos, increasing the resistance of embryos to unfavorable environmental conditions.

(E) Gao X, Luo R, Ma B, Wang H, Liu T, Zhang J, Lian Z, Cui X. [Interference of vitamin E on the brain tissue damage by electromagnetic radiation of cell phone in pregnant and fetal rats]. Wei Sheng Yan Jiu. 42(4):642-646, 2013. [Article in Chinese] (CE, IU, ME, NU, OX, VO)

OBJECTIVE: To investigate the interlerence ot vitamin E on brain tissue damage by electromagnetic radiation of cell phone in pregnant and fetal rats. METHODS: 40 pregnant rats were randomly divided into five groups (positive control, negative control, low, middle and high dosage of vitamin E groups). The low, middle and high dosage of vitamin E groups were supplemented with 5, 15 and 30 mg/ml vitamin E respectively since the first day of pregnancy. And the negative control group and the positive control group were given peanut oil without vitamin E. All groups except for the negative control group were exposed to 900MHz intensity of cell phone radiation for one hour each time, three times per day for 21 days. After accouchement, the right hippocampus tissue of fetal rats in each group was taken and observed under electron microscope. The vitality of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), and the content of malondialdehyde (MDA) in pregnant and fetal rats' brain tissue were tested. RESULTS: Compared with the negative control group, the chondriosomes in neuron and neuroglia of brain tissues was swelling, mild edema was found around the capillary, chromatin was concentrated and collected, and bubbles were formed in vascular endothelial cells (VEC) in the positive fetal rat control group, whereas the above phenomenon was un-conspicuous in the middle and high dosage of vitamin E groups. We can see uniform chromatin, abundant mitochondrion, rough endoplasmic reticulum and free ribosomes in the high dosage group. The apoptosis has not found in all groups'sections. In the antioxidase activity analysis, compared with the negative control group, the vitality of SOD and GSH-Px significantly decreased and the content of MDA

significantly increased both in the pregnant and fetal rats positive control group ($P < 0.05$). In fetal rats, the vitality of SOD and GSH-Px significantly increased in the brain tissues of all three different vitamin E dosages groups when compared with the positive control group, and the content of MDA was found significantly decreased in both middle and high dosage of vitamin E groups($P < 0.05$). The same results have also been found in high dosage pregnant rat group, but in middle dosage group only SOD activity was found increased with significance ($P < 0.05$). With the dosage increase of vitamin E, the vitality of SOD and GSH-Px was increasing and the content of MDA was decreasing. CONCLUSION: Under the experimental dosage, vitamin E has certain interference on damage of antioxidant capacity and energy metabolization induced by electromagnetic radiation of cell phone in pregnant rats and fetal rats.

(E) Gautam R, Priyadarshini E, Nirala JP, Meena R, Rajamani R. Modulatory effects of Punica granatum L juice against 2115 MHz (3G) radiation-induced reproductive toxicity in male Wistar rat. Environ Sci Pollut Res Int 28(39):54756-54765, 2021. (CE, M, ME, OX, VO)

Advancements in telecommunication sector result in increasing exposure to electromagnetic (EM) radiation, which has been correlated with incidence of male infertility. Therefore, the present study focused on analyzing the consequence of EM radiation (2115 MHz) exposure on the reproductive system of male Wistar rats. Besides, the antioxidant protective effect of Punica granatum juice was also evaluated. For experimental analysis, rats were divided into five groups (control, sham exposed, exposed, herbal plus exposed, and herbal only). Individual group consisted of 6 rats which were exposed to radiation for 45 days (2 h/day). The herbal-treated groups were given 1 ml of Punica granatum extract orally. Various parameters such as organ to body ratio, sperm count, motility, viability, and testis histopathology were studied. Furthermore, oxidative stress parameters and free radical generation were analyzed. The exposed group showed changes in sperm parameters along with decrease in seminiferous tubule diameter. On the contrary, herbal-exposed group showed enhanced sperm count, increased motility, and viability in comparison to exposed group. Histopathology studies also revealed the protective role of herbal juice. Significant alteration in oxidative parameters along with an enhanced free radical generation in exposed group and reduction in herbal groups was observed. The results thus indicate that continuous exposure to EM radiation can lead to oxidative stress which induces biochemical changes in rat sperms. However, Punica granatum extract has a protective role against oxidative damage induced by EM radiation.

Gautam R, Priyadarshini E, Nirala JP, Rajamani P. Impact of nonionizing electromagnetic radiation on male infertility: an assessment of the mechanism and consequences. Int J Radiat Biol 98(6):1063-1073, 2022.(Review)

Purpose: Environment and lifestyle factors are being attributed toward increased instances of male infertility. Rapid technological advancement, results in emission of electromagnetic radiations of different frequency which impacts human both biologically as well as genetically. Devices like cell phone, power line and monitors emit electromagnetic radiation and are a major source of the exposure. Numerous studies describe the detrimental consequence of radiation on physiological parameters of male reproductive system including sperm parameters (morphology,

motility, and viability), metabolism and genomic instability. While the thermal and nonthermal interaction of nonionizing radiations with biological tissues can't be ruled out, most studies emphasize the generation of reactive oxygen species. Oxidative stress alters redox equilibrium and disrupts morphology and normal functioning of sperms along with declination of total anti-oxidant capacity. **Conclusion:** In this paper, we describe a detailed literature review with the intent of analyzing the impact of electromagnetic radiation and understand the consequence on male reproductive system. The underlying mechanism suggesting ROS generation and pathway of action has also been discussed. Additionally, the safety measures while using electronic gadgets and mobile phones has also been presented.

(E) Gautam R, Pardhiya S, Nirala JP, Sarsaiya P, Rajamani P. Effects of 4G mobile phone radiation exposure on reproductive, hepatic, renal, and hematological parameters of male Wistar rat. Environ Sci Pollut Res Int 31(3):4384-4399, 2024. (CE, M, ME, MO, OX, VO) (SAR= 0.0625 W/kg)

Background and objective: Mobile phones have become a vital part of human life. Due to drastic increase in the number of mobile phone subscribers, exposure to radiofrequency radiation (RFR) emitted from these phones has increased dramatically. Hence, the effect of RFR on humans is an area of concern. This study was performed to determine the impact of 4G mobile phone radiation on the male reproductive system, liver, kidney, and hematological parameters. **Methods:** Seventy-day-old Wistar rats were exposed to 4G radiation (2350 MHz for 2 h/day for 56 days). Sperm parameters such as sperm count, viability, sperm head morphology, mitochondrial activity, total antioxidant activity, and lipid peroxidation of sperm were evaluated. Histopathology of the testis, prostate, epididymis, seminal vesicle, liver, and kidney was carried out. Complete blood count, liver and kidney function tests, and testosterone hormone analysis were done. **Results:** At the end of the experiment, results showed a significant ($p < 0.05$) decrease in sperm viability with alterations in the histology of the liver, kidney, testis, and other reproductive organs in the exposed group of rats. A reduced level of testosterone, total antioxidant capacity, and decreased sperm mitochondrial function were also observed in the exposed rats. Moreover, the exposed rats showed an increase in sperm lipid peroxidation and sperm abnormality. Hematological parameters like hemoglobin, red blood cells (RBC), and packed cell volume (PCV) showed a significant ($p < 0.05$) increase in the exposed rats. **Conclusion:** The results indicate that chronic exposure to 4G radiation may affect the male reproductive system, hematological system, liver, and kidney of rats.

(E) Geronikolou SA, Chamakou A, Mantzou A, Chrousos G, KanakaGantenbein C. Frequent cellular phone use modifies hypothalamic-pituitary-adrenal axis response to a cellular phone call after mental stress in healthy children and adolescents: A pilot study. Sci Total Environ. 536:182-188, 2015. (AE, BE, HU, MO, NU)

OBJECTIVE: The hypothalamic-pituitary-adrenal (HPA) axis is the main "gate-keeper" of the organism's response to every somatic or mental stress. This prospective study aims to investigate the HPA-axis response to a cellular phone call exposure after mental stress in healthy children and adolescents and to assess the possible predictive role of baseline endocrine markers to this response. SUBJECTS AND METHODS: Two groups of healthy school-age children aged 11-14 (12.5±1.5) years were included in the study, the one

comprising those who are occasional users of a cellular phone (Group A; n=16)) while the second those who do regularly use one (Group B; n=12). Blood samples were obtained from all participants at 8.00am after a 12-hour overnight fasting for thyroid hormone, glucose, insulin, and cortisol levels determination. The participants performed the Trier Social Stress Test for Children (TSST-C) (5 min oral task followed by 5min arithmetic task). Salivary cortisol samples were obtained at baseline, 10 and 20 min after the TSST-C and 10 and 20 min after a 5-minute cellular phone call. RESULTS: Significant changes in the salivary cortisol levels were noted between 10 and 20 mins after the cellular phone call with different responses between the two groups. Baseline thyroid hormone levels seem to predict the cortisol response to mental stress mainly in group A, while HOMA (homostasis model assessment) had no impact on salivary cortisol response at any phase of the test, in either group. CONCLUSIONS: HPA axis response to cellular phone after mental stress in children and adolescents follow a different pattern in frequent users than in occasional users that seems to be influenced by the baseline thyroid hormone levels.

(E) Ghanbari M, Mortazavi SB, Khavanin A, Khazaei M. The Effects of Cell Phone Waves (900 MHz-GSM Band) on Sperm Parameters and Total Antioxidant Capacity in Rats. Int J Fertil Steril. 7(1):21-28, 2013. (CE, FC, M, ME, OX, VO) (No dosimetry data)

BACKGROUND: There is tremendous concern regarding the possible adverse effects of cell phone microwaves. Contradictory results, however, have been reported for the effects of these waves on the body. In the present study, the effect of cell phone microwaves on sperm parameters and total antioxidant capacity was investigated with regard to the duration of exposure and the frequency of these waves. MATERIALS AND METHODS: This experimental study was performed on 28 adult male Wistar rats (200-250 g). The animals were randomly assigned to four groups (n=7): i. control; ii. two-week exposure to cell phone-simulated waves; iii. three-week exposure to cell phone simulated waves; and iv. two-week exposure to cell phone antenna waves. In all groups, sperm analysis was performed based on standard methods and we determined the mean sperm total antioxidant capacity according to the ferric reducing ability of plasma (FRAP) method. Data were analyzed by one-way ANOVA followed by Tukey's test using SPSS version 16 software. RESULTS: The results indicated that sperm viability, motility, and total antioxidant capacity in all exposure groups decreased significantly compared to the control group ($p<0.05$). Increasing the duration of exposure from 2 to 3 weeks caused a statistically significant decrease in sperm viability and motility ($p<0.05$). CONCLUSION: Exposure to cell phone waves can decrease sperm viability and motility in rats. These waves can also decrease sperm total antioxidant capacity in rats and result in oxidative stress.

(E) Ghatei N, Nabavi AS, Toosi MHB, Azimian H, Homayoun M, Targhi RG, Haghir H. Evaluation of bax, bcl-2, p21 and p53 genes expression variations on cerebellum of BALB/c mice before and after birth under mobile phone radiation exposure. Iran J Basic Med Sci. 20(9):1037-1043, 2017. (CE, GE, IU, PN, VO) (No dosimetry data)

OBJECTIVES: The increasing rate of over using cell phones has been considerable in youths and pregnant women. We examined the effect of mobile phones radiation on genes expression variation on cerebellum of BALB/c mice before and after of the birth. MATERIALS AND METHODS: In this study, a mobile phone jammer, which is an instrument to prevent receiving signals between cellular phones and base transceiver stations (two frequencies 900 and 1800 MHz) for exposure was used and twelve pregnant mice (BALB/c) divided into two groups (n=6), first group irradiated in pregnancy period (19th day), the second group did not irradiate in pregnancy period. After childbirth, offspring were classified into four groups (n=4): Group1: control, Group 2: B1 (Irradiated after birth), Group 3: B2 (Irradiated in pregnancy period and after birth), Group 4: B3 (Irradiated in pregnancy period). When maturity was completed (8-10 weeks old), mice were dissected and cerebellum was isolated. The expression level of *bax*, bcl-2, p21 and *p53* genes examined by real-time reverse transcription polymerase chain reaction (Real-Time RT- PCR). RESULTS: The data showed that mobile phone radio waves were ineffective on the expression level of bcl-2 and p53 genes) $P>0.05$(. Also gene expression level of *bax* decreased and gene expression level of *p21* increased comparing to the control group ($P<0.05$). CONCLUSION: From the obtained data it could be concluded that the mobile phone radiations did not induce apoptosis in cells of the cerebellum and the injured cells can be repaired by cell cycle arrest.

(E) Gorpinchenko I, Nikitin O, Banyra O, Shulyak A. The influence of direct mobile phone radiation on sperm quality. Cent European J Urol. 67(1):65-71, 2014. (AE, FC, GE, HU, IV, M)

INTRODUCTION: It is impossible to imagine a modern socially-active man who does not use mobile devices and/or computers with Wi-Fi function. The effect of mobile phone radiation on male fertility is the subject of recent interest and investigations. The aim of this study was to investigate the direct in vitro influence of mobile phone radiation on sperm DNA fragmentation and motility parameters in healthy subjects with normozoospermia. **MATERIAL AND METHODS:** 32 healthy men with normal semen parameters were selected for the study. Each sperm sample was divided into two equal portions (A and B). Portions A of all involved men were placed for 5 hours in a thermostat, and portions B were placed into a second thermostat for the same period of time, where a mobile phone in standby/talk mode was placed. After 5 hours of incubation the sperm samples from both thermostats were re-evaluated regarding basic motility parameters. The presence of DNA fragmentation in both A and B portions of each sample was determined each hour using a standard sperm chromatin dispersion test. **RESULTS:** The number of spermatozoa with progressive movement in the group, influenced by electromagnetic radiation, is statistically lower than the number of spermatozoa with progressive movement in the group under no effect of the mobile phone. The number of non-progressive movement spermatozoa was significantly higher in the group, which was influenced by cell phone radiation. The DNA fragmentation was also significantly higher in this group. **CONCLUSIONS:** A correlation exists between mobile phone radiation exposure, DNA-fragmentation level and decreased sperm motility.

(E) Grajewski B, Cox C, Schrader SM, Murray WE, Edwards RM, Turner TW, Smith JM, Shekar SS, Evenson DP, Simon SD, Conover DL, Semen quality and hormone levels among radiofrequency heater operators. J Occup Environ Med 42(10):993-1005, 2000. (CE, HU, M, ME, MO)

Approximately 9,000,000 US workers are occupationally exposed to radiogrequency (RF) radiation; over 250,000 operate RF dielectric heaters. Our purpose was to determine whether male RF heater operators experience increased adverse reproductive effects reflected in reduced semen quality or altered hormone levels. We measured incident RF heater radiation exposures and RF-induced foot currents at four companies. For 12 male heater operators and a comparison group of 34 RF-unexposed men, we measured 33 parameters of semen quality and four serum hormones. Despite wide variation in individual exposure levels, near field strengths and induced foot currents did not exceed current standard levels and guidelines. We observed minor semen quality and hormonal differences between the groups, including a slightly higher mean follicle-stimulating hormone level for exposed operators (7.6 vs 5.8 mIU/mL). Further occupational studies of RF-exposed men may be warranted.

(E) Grigor'ev IuG. [Biological effects of mobile phone electromagnetic field on chick embryo (risk assessment using the mortality rate)] Radiats Biol Radioecol. 43(5):541-543, 2003. [Article in Russian] (CE, DE, IU)

Chicken embryos were exposed to EMF from GSM mobile phone during the embryonic development (21 days). As a result the embryo mortality rate in the incubation period increased to 75% (versus 16% in control group).

(E) Gul A, Celebi H, Uğraş S. The effects of microwave emitted by cellular phones on ovarian follicles in rats. Arch Gynecol Obstet. 280(5):729-733, 2009. (CE, F, IU, ME, VO)

OBJECTIVE: The aim of this study was to investigate whether there were any toxic effects of microwaves of cellular phones on ovaries in rats. METHODS: In this study, 82 female pups of rats, aged 21 days (43 in the study group and 39 in the control group) were used. Pregnant rats in the study group were exposed to mobile phones that were placed beneath the polypropylene cages during the whole period of pregnancy. The cage was free from all kinds of materials, which could affect electromagnetic fields. A mobile phone in a standby position for 11 h and 45 min was turned on to speech position for 15 min every 12 h and the battery was charged continuously. On the 21st day after the delivery, the female rat pups were killed and the right ovaries were removed. The volumes of the ovaries were measured and the number of follicles in every tenth section was counted. RESULTS: The analysis revealed that in the study group, the number of follicles was lower than that in the control group. The decreased number of follicles in pups exposed to mobile phone microwaves suggest that intrauterine exposure has toxic effects on ovaries. CONCLUSION: We suggest that the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms.

(NE) Guler G, Tomruk A, Ozgur E, Seyhan N. The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen Physiol Biophys. 29(1):59-66, 2010. (CE, GE, IU, OX, VO)

The concerns of people on possible adverse health effects of radiofrequency radiation (RFR) generated from mobile phones as well as their supporting transmitters (base stations)

have increased markedly. RFR effect on oversensitive people, such as pregnant women and their developing fetuses, and older people is another source of concern that should be considered. In this study, oxidative DNA damage and lipid peroxidation levels in the brain tissue of pregnant and non-pregnant New Zealand White rabbits and their newborns exposed to RFR were investigated. Thirteen-month-old rabbits were studied in four groups as non-pregnant-control, non-pregnant-RFR exposed, pregnant-control and pregnant-RFR exposed. They were exposed to RFR (1800 MHz GSM; 14 V/m as reference level) for 15 min/day during 7 days. Malondialdehyde (MDA) and 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels were analyzed. MDA and 8-OHdG levels of non-pregnant and pregnant-RFR exposed animals significantly increased with respect to controls ($p < 0.001$, Mann-Whitney test). No difference was found in the newborns ($p > 0.05$, Mann-Whitney). There exist very few experimental studies on the effects of RFR during pregnancy. It would be beneficial to increase the number of these studies in order to establish international standards for the protection of pregnant women from RFR.

(E) Güler G, Ozgur E, Keles H, Tomruk A, Vural SA, Seyhan N. Neurodegenerative changes and apoptosis induced by intrauterine and extrauterine exposure of radiofrequency radiation. J Chem Neuroanat 75(Pt B):128-133, 2016. (CE, GE, IU, ME, OX, PN) Effects depended on sex of the rabbit and when exposure (intrauterine or extrauterine) occurred.)

Adverse health effects of radiofrequency radiation (RFR) on the ongoing developmental stages of children from conception to childhood are scientifically anticipated subject. This study was performed to identify the effects of global system for mobile communications (GSM) modulated mobile phone like RFR in 1800 MHz frequency on oxidative DNA damage and lipid peroxidation beside the apoptotic cell formation, using histopathological and immunohistochemical methods in the brain tissue of 1-month-old male and female New Zealand White rabbits that were exposed to these fields at their mother's womb and after the birth. Oxidative DNA damage and lipid peroxidation levels were investigated by measuring the 8-hydroxy-2'-deoxyguanosine (8-OHdG) and malondialdehyde (MDA) levels, respectively. Histopathological changes were observed using by hematoxylin and eosin (HE) staining. Apoptotic cells were detected in the examined organs by terminal deoxynucleotidyl transferase-mediated dUTP nick end-labeling (TUNEL) staining. For both male and female infants; 8-OHdG levels increased in the group exposed to RFR in both intrauterine and extrauterine periods compared to the infants that were never exposed to RFR and the ones were exposed when they reached one month of age ($p<0.05$). MDA results were different for male and female rabbits. There was no difference between all female infant groups ($p>0.05$), while only intrauterine exposure significantly causes MDA level increase for the male infants. HE staining revealed mild lessions in neuronal necrobiosis in brain tissues of female rabbits that had only intaruterine exposure and male rabbits had only extrauterine exposure. Gliosis were mildly positive in brain tissues of rabbits that are exposed only intrauterine period, also the group exposed both intrauterine and extrauterine periods. However, there was no apoptotic change detected by TUNEL staining in the brain tissues of all.

(E) Gupta V, Srivastava R. 2.45 GHz microwave radiation induced oxidative stress: Role of inflammatory cytokines in regulating male fertility through estrogen receptor alpha in

Gallus gallus domesticus. Biochem Biophys Res Commun 629:61-70, 2022. (CE, M, ME, MO, VO)

Due to the growing number of gadgets emitting electromagnetic radiation (EMR), particularly microwave (MW) radiation, in our daily lives, it is believed that EMR have both long-term and short-term biological impacts that are quite concerning for avian as well as human health. Due to the negative impact of MW emitting equipment on the biological system this study looks into the mechanistic approach by which low-level of 2.45 GHz MW radiation causes an oxidative stress and inflammatory response in the testes micro-environment which further gets regulated by estrogen receptor alpha (ERα) expression in immature Gallus gallus domesticus leading to male infertility. Two weeks old immature male chickens were exposed to non-thermal low-level 2.45-GHz MW radiation for 2 h/day for 30 days (power density = 0.1264 mw/cm2 and SAR = 0.9978 W/kg). In the exposed group, morphometric examination of the testes revealed decreased testicular weight, volume and gonado-somatic index. Further, histological staining demonstrated a substantial reduction in the diameter of seminiferous tubules in the exposed group as compared to the control. The degree of oxidative stress was also determined showing an increase in oxidative stress parameters after exposure. The radiation exposed testes showed a significant increase in IL-1β immunoreactivity and decline in IL-10 immunoreactivity, indicating a sense of MW radiation-induced oxidative stress-regulated inflammatory response. A substantial reduction in ERα expression was also observed in exposed testes by Western blotting. Our investigations conclude that testes being vulnerable to free radical damage become an easy target organ for MW exposure induced oxidative and inflammatory stress. Therefore it becomes evident that it may cause male infertility in chicks via downregulation of ER-α in testis.

(E) Gutschi T, Mohamad Al-Ali B, Shamloul R, Pummer K, Trummer H. Impact of cell phone use on men's semen parameters. Andrologia. 43(5):312-316, 2011. (CE, HU, M, ME, MO, VO)

The objective of the present retrospective study was to report our experience concerning the effects of cell phone usage on semen parameters. We examined 2110 men attending our infertility clinic from 1993 to October 2007. Semen analysis was performed in all patients. Serum free testosterone (T), follicle stimulating hormone (FSH), luteinising hormone (LH) and prolactin (PRL) were collected from all patients. The information on cell phone use of the patients was recorded and the subjects were divided into two groups according to their cell phone use: group A: cell phone use (n = 991); group B: no use (n = 1119). Significant difference was observed in sperm morphology between the two groups. In the patients of group A, 68.0% of the spermatozoa featured a pathological morphology compared to only 58.1% in the subjects of group B. Patients with cell phone usage showed significantly higher T and lower LH levels than those who did not use cell phone. No significant difference between the two groups was observed regarding FSH and PRL values. Our results showed that cell phone use negatively affects sperm quality in men. Further studies with a careful design are needed to determine the effect of cell phone use on male fertility.

(NE) Guxens M, van Eijsden M, Vermeulen R, Loomans E, Vrijkotte TG, Komhout H, van Strien RT, Huss A. Maternal cell phone and cordless phone use during pregnancy and behaviour problems in 5-year-old children. J Epidemiol Community Health. 67(5):432-438, 2013. (CE, DE, HU, IU, NU, VO)

BACKGROUND: A previous study found an association between maternal cell phone use during pregnancy and maternal-reported child behaviour problems at age 7. Together with cell phones, cordless phones represent the main exposure source of radiofrequency-electromagnetic fields to the head. Therefore, we assessed the association between maternal cell phone and cordless phone use during pregnancy and teacher-reported and maternal-reported child behaviour problems at age 5. **METHODS:** The study was embedded in the Amsterdam Born Children and their Development study, a population-based birth cohort study in Amsterdam, the Netherlands (2003-2004). Teachers and mothers reported child behaviour problems using the Strength and Difficulties Questionnaire at age 5. Maternal cell phone and cordless phone use during pregnancy was asked when children were 7 years old. **RESULTS:** A total of 2618 children were included. As compared to non-users, those exposed to prenatal cell phone use showed an increased but non-significant association of having teacher-reported overall behaviour problems, although without dose-response relationship with the number of calls (OR=2.12 (95% CI 0.95 to 4.74) for <1 call/day, OR=1.58 (95% CI 0.69 to 3.60) for 1-4 calls/day and OR=2.04 (95% CI 0.86 to 4.80) for ≥5 calls/day). ORs for having teacher-reported overall behaviour problems across categories of cordless phone use were below 1 or close to unity. Associations of maternal cell phone and cordless phone use with maternal-reported overall behaviour problems remained non-significant. Non-significant associations were found for the specific behaviour problem subscales. **CONCLUSION:** Our results do not suggest that maternal cell phone or cordless phone use during pregnancy increases the odds of behaviour problems in their children.

(NE) Haarala C, Bergman M, Laine M, Revonsuo A, Koivisto M, Hamalainen H. Electromagnetic field emitted by 902 MHz mobile phones shows no effects on children's cognitive function. Bioelectromagnetics. Suppl 7:S144-150,2005. (AE, FC, HU)

The present study investigated the potential effects of a standard 902 MHz global system for mobile communication (GSM) mobile phone on 10-14 years old children's cognitive function. A total of 32 children (16 boys, 16 girls) participated with their own and parental consent. The subjects were 10-14 years old (mean 12.1 years, SD 1.1). They performed a battery of cognitive tests twice in a counter-balanced order: once while exposed to an active mobile phone and once during exposure to an inactive phone. The tests were selected from those we used earlier with adults. The statistical analyses showed no significant differences between the mobile phone off and on conditions in reaction times and accuracy over all tests or in any single test. It was concluded that a standard mobile phone has no effect on children's cognitive function as measured by response speed and accuracy. The present results challenge some earlier findings suggesting that the electromagnetic field (EMF) created by an active mobile phone would facilitate cognitive functioning.

(E) Haghani M, Shabani M, Moazzami K. Maternal mobile phone exposure adversely affects the electrophysiological properties of Purkinje neurons in rat offspring. Neuroscience. 250:588-596, 2013. (CE, BE, IU, NU, VO) (SAR 0.5-0.9 W/kg)

Electromagnetic field (EMF) radiations emitted from mobile phones may cause structural damage to neurons. With the increased usage of mobile phones worldwide, concerns about their possible effects on the nervous system are rising. In the present study, we aimed to elucidate the possible effects of prenatal EMF exposure on the cerebellum of offspring Wistar rats. Rats in EMF group were exposed to 900 MHz Pulse-EMF irradiation for six hours per day during all gestation period. Ten offspring's per each group were evaluated for behavioral and electrophysiological evaluations. Cerebellum - related behavioral dysfunctions were analyzed using motor learning and cerebellum-dependent functional tasks (Accelerated Rotarod, Hanging and Open field tests). Whole cell- patch clamp recordings were used for electrophysiological evaluations. The results of the present study failed to show any behavioral abnormalities in rats exposed to chronic EMF radiation. However, whole cell patch clamp recordings revealed decreased neuronal excitability of Purkinje cells in rats exposed to EMF. The most prominent changes included after hyperpolarization amplitude, spike frequency, half width and first spike latency. In conclusion, the results of the present study show that prenatal EMF exposure results in altered electrophysiological properties of Purkinje neurons. However, these changes may not be severe enough to alter the cerebellum-dependent functional tasks.

(E) Haghani M, Pouladvand V, Mortazavi S M J, Razavinasab M, Bayat M, Shabani M. Exposure to Electromagnetic Field during Gestation Adversely Affects the Electrophysiological Properties of Purkinje Cells in Rat Offspring. J Biomed Phys Eng 10(4):433-440, 2020. (CE, IU, NU, VO) (No dosimetry data)

Background: Prenatal adverse effects of radiofrequency electromagnetic fields (RF-EMF) exposure on nervous system are an issue of major concern. **Objective:** Thus, in this study we evaluated the membrane current flow properties of Purkinje neurons after maternal exposure to 900 MHz pulsed RF-EMF. **Material and methods:** In this experimental study, during all days of pregnancy, rats in the EMF-exposed group were exposed to 900 MHz pulsed-EMF radiation for 6 h per day. The effects of RF-EMF exposure on the electrophysiological properties of the Purkinje cerebellum neurons from male pups were evaluated by whole-cell patch clamp recordings in current and voltage clamp modes. In voltage-clamp experiments, the holding potential was -60mV, and a depolarizing voltage step (1000 ms duration) was applied from -60 to +50 mV in 10 mV increments at 2s intervals. **Results:** The exposure group demonstrated reduced spontaneous firing associated with upward and rightward shift in I/V curve compared to the control rats. Moreover, the peak amplitude of the current for the exposure pups also revealed a significant decrement. The reversal potential was +40 mV and +20 mV for the control and RF-EMF groups, respectively and showed significant differences between the two groups. **Conclusion:** The decrease in ion's conductance could be attributed to the observed decrease in the voltage onset of the inward current, peak amplitude and voltage shift.

(E) Hancı H, Odacı E, Kaya H, Aliyazıcıoğlu Y, Turan I, Demir S, Colakoğlu S. The effect of prenatal exposure to 900-MHz electromagnetic field on the 21-old-day rat testicle. Reprod Toxicol. 42:203-209, 2013. (CE, GE, IU, M, ME, OX, VO) (0.0265 mW/cm²)

The aim of this study was to investigate the effect of exposure to a 900-MHz electromagnetic field (EMF) in the prenatal term on the 21-old-day rat testicle. Pregnant rats were divided into control (CG) and EMF (EMFG) groups. EMFG was exposed to 900-MHz EMF during days 13-21 of pregnancy. Newborn CG rats were obtained from the CG and newborn EMFG (NEMFG) rats from the EMFG. Testicles were extracted at postnatal day 21. Lipid peroxidation and DNA oxidation levels, apoptotic index and histopathological damage scores were compared. NEMFG rats exhibited irregularities in seminiferous tubule basal membrane and epithelium, immature germ cells in the lumen, and a decreased diameter in seminiferous tubules and thickness of epithelium. Apoptotic index, lipid peroxidation and DNA oxidation were higher in NEMFG rats than in NCG. 21-day-old rat testicles exposed to 900-MHz EMF in the prenatal term may be adversely affected, and this effect persists after birth

(E) Hancı H, Türedi S, Topal Z, Mercantepe T, Bozkurt I, Kaya H, Ersöz Ş, Ünal B, Odacı E. Can prenatal exposure to a 900 MHz electromagnetic field affect the morphology of the spleen and thymus, and alter biomarkers of oxidative damage in 21-day-old male rats? Biotech Histochem. 90(7):535-543, 2015. (CE, IU, ME, OX, VO) (Low SAR 0.025 W/kg)

We investigated the effects of a 900 Megahertz (MHz) electromagnetic field (EMF), applied during the prenatal period, on the spleen and thymus of 21-day-old male rat pups. Pregnant Sprague-Dawley rats were divided into control and EMF groups. We applied 900 MHz EMF for 1 h/day to the EMF group of pregnant rats. Newborn male rat pups were removed from their mothers and sacrificed on postnatal day 21. Spleen and thymus tissues were excised and examined. Compared to the control group, thymus tissue malondialdehyde levels were significantly higher in the group exposed to EMF, while glutathione levels were significantly decreased. Increased malondialdehyde and glutathione levels were observed in splenic tissue of rats exposed to EMF, while a significant decrease occurred in superoxide dismutase values compared to controls. Transmission electron microscopy showed pathological changes in cell morphology in the thymic and splenic tissues of newborn rats exposed to EMF. Exposure to 900 MHz EMF during the prenatal period can cause pathological and biochemical changes that may compromise the development of the male rat thymus and spleen.

(E) Hancı H, Kerimoğlu G, Mercantepe T, Odacı E. Changes in testicular morphology and oxidative stress biomarkers in 60-day-old Sprague Dawley rats following exposure to continuous 900-MHz electromagnetic field for 1 h a day throughout adolescence. Reprod Toxicol 81:71-78, 2018. (CE, M, ME. OX, VO) (Low SAR 0.0067 W/kg)

The purpose of this study was to investigate the 60-day-old male rat testis following exposure to continuous 900-megahertz (MHz) electromagnetic field (EMF) throughout the adolescent period using histopathological and biochemical analysis methods. Twenty-four Sprague Dawley rats aged 21

days were randomly and equally (n = 8) divided into three groups. No procedure was performed on the control group rats. The sham group rats were held in an EMF-cage without exposure to EMF. The EMF group rats were exposed to continuous 900-MHz EMF for 1 h each day inside the EMF-cage during adolescence. On postnatal day 60 the testes were extracted and divided into right and left halves. The right half was used for histopathological evaluation and the left half for biochemical analyses. Our results show that changes may occur in morphology and oxidative stress biomarkers in the rat testis following exposure to continuous 900-MHz EMF throughout the adolescent period.

(E)HassanzadehTaheri M, Khalili MA, Mohebati AH, Zardast M, Hosseini M, Palmerini MG, Doostabadi MR. The detrimental effect of cell phone radiation on sperm biological characteristics in normozoospermic. Andrologia 54(1):e14257, 2022. (AE, IV, M, ME) (No dosimetry data)

Radiofrequency electromagnetic radiation emitted from cell phone has harmful effects on some organs of the body, such as the brain, heart, and testes. This study aimed to assess the effects of cell phones on sperm parameters, DNA fragmentation, and apoptosis in normozoospermic. Normal sperm samples were divided into two groups of control and case. The samples from the case were placed for 60 min at a distance of approximately 2.5 cm from the cell phone set in the active antenna position. Control samples were exposed to cell phones without active antennas. All specimens were analysed by World Health Organization criteria. Sperm viability, sperm with chromatin abnormality and maturity, DNA fragmentation, and apoptosis were examined. Viability and motility in the case were significantly lower than the control ($p < .001$, $p = .004$ respectively). The percentage of apoptotic sperms and DNA fragmentation were significantly higher in the case when compared with the control ($p = .031$, $p < .001$ respectively). The other parameters studied such as morphology, chromatin abnormality, and maturity showed no significant difference between the case and control groups. Cell phone waves had a detrimental effect on human sperm's biological features. Therefore, it is recommended to keep the cell phone away from the pelvis as much as possible.

(NE)Hatch EE, Willis SK, Wesselink AK, Mikkelsen EM, Eisenberg ML, Sommer GJ, Sorensen HT, Rothman KJ, Wise LA. Male cellular telephone exposure, fecundability, and semen quality: results from two preconception cohort studies. Hum Reprod 36(5):1395-1404, 2021. (CE, FC, HU, M, ME) (No dosimetry data)

Study question: To what extent is exposure to cellular telephones associated with male fertility? **Summary answer:** Overall, we found little association between carrying a cell phone in the front pants pocket and male fertility, although among leaner men (BMI <25 kg/m2), carrying a cell phone in the front pants pocket was associated with lower fecundability. **What is known already:** Some studies have indicated that cell phone use is associated with poor semen quality, but the results are conflicting. **Study design, size, duration:** Two prospective preconception cohort studies were conducted with men in Denmark (n = 751) and in North America (n = 2349), enrolled and followed via the internet from 2012 to 2020. **Participants/materials, setting, methods:** On the baseline questionnaire, males reported their hours/day of carrying a cell phone in different body locations. We ascertained time to pregnancy via bi-monthly follow-up questionnaires completed by the female partner for up to 12 months or until reported conception.

We used proportional probabilities regression models to estimate fecundability ratios (FRs) and 95% confidence intervals (CIs) for the association between male cell phone habits and fecundability, focusing on front pants pocket exposure, within each cohort separately and pooling across the cohorts using a fixed-effect meta-analysis. In a subset of participants, we examined selected semen parameters (semen volume, sperm concentration and sperm motility) using a home-based semen testing kit. **Main results and the role of chance:** There was little overall association between carrying a cell phone in a front pants pocket and fecundability: the FR for any front pants pocket exposure versus none was 0.94 (95% CI: 0.0.83-1.05). We observed an inverse association between any front pants pocket exposure and fecundability among men whose BMI was <25 kg/m2 (FR = 0.72, 95% CI: 0.59-0.88) but little association among men whose BMI was ≥25 kg/m2 (FR = 1.05, 95% CI: 0.90-1.22). There were few consistent associations between cell phone exposure and semen volume, sperm concentration, or sperm motility. **Limitations, reasons for caution:** Exposure to radiofrequency radiation from cell phones is subject to considerable non-differential misclassification, which would tend to attenuate the estimates for dichotomous comparisons and extreme exposure categories (e.g. exposure 8 vs. 0 h/day). Residual confounding by occupation or other unknown or poorly measured factors may also have affected the results. **Wider implications of the findings:** Overall, there was little association between carrying one's phone in the front pants pocket and fecundability. There was a moderate inverse association between front pants pocket cell phone exposure and fecundability among men with BMI <25 kg/m2, but not among men with BMI ≥25 kg/m2. Although several previous studies have indicated associations between cell phone exposure and lower sperm motility, we found few consistent associations with any semen quality parameters.

(NE) Heinrich S, Thomas S, Heumann C, von Kries R, Radon K. Association between exposure to radiofrequency electromagnetic fields assessed by dosimetry and acute symptoms in children and adolescents: a population based cross-sectional study. Environ Health. 9:75, 2010. (CE, FC, HU)

BACKGROUND: The increase in numbers of mobile phone users was accompanied by some concern that exposure to radiofrequency electromagnetic fields (RF EMF) might adversely affect acute health especially in children and adolescents. The authors investigated this potential association using personal dosimeters. METHODS: A 24-hour exposure profile of 1484 children and 1508 adolescents was generated in a population-based cross-sectional study in Germany between 2006 and 2008 (participation 52%). Personal interview data on socio-demographic characteristics, self-reported exposure and potential confounders were collected. Acute symptoms were assessed twice during the study day using a symptom diary. RESULTS: Only few of the large number of investigated associations were found to be statistically significant. At noon, adolescents with a measured exposure in the highest quartile during morning hours reported a statistically significant higher intensity of headache (Odd Ratio: 1.50; 95% confidence interval: 1.03, 2.19). At bedtime, adolescents with a measured exposure in the highest quartile during afternoon hours reported a statistically significant higher intensity of irritation in the evening (4th quartile 1.79; 1.23, 2.61), while children reported a statistically significant higher intensity of concentration problems (4th quartile 1.55; 1.02, 2.33). *CONCLUSIONS: We observed few statistically significant results which are not consistent over the two time points.* Furthermore,

when the 10% of the participants with the highest exposure are taken into consideration the significant results of the main analysis could not be confirmed. Based on the pattern of these results, we assume that the few observed significant associations are not causal but rather occurred by chance.

(NE) Heinrich S, Thomas S, Heumann C, von Kries R, Radon K. The impact of exposure to radio frequency electromagnetic fields on chronic well-being in young people - A cross-sectional study based on personal dosimetry. Environ Int. 37(1):26-30, 2011. (CE, FC, HU)

A possible influence of radio frequency electromagnetic field (RF EMF) exposure on health outcomes was investigated in various studies. The main problem of previous studies was exposure assessment. The aim of our study was the investigation of a possible association between RF EMF and chronic well-being in young persons using personal dosimetry. 3022 children and adolescents were randomly selected from the population registries of four Bavarian cities in Germany (participation 52%). Personal interview data on chronic symptoms, socio-demographic characteristics and potential confounders were collected. A 24-h radio frequency exposure profile was generated using a personal dosimeter. Exposure levels over waking hours were expressed as mean percentage of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference level. Half of the children and nearly every adolescent owned a mobile phone which was used only for short durations per day. Measured exposure was far below the current ICNIRP reference levels. The most reported chronic symptom in children and adolescents was fatigue. No statistically significant association between measured exposure and chronic symptoms was observed. Our results do not indicate an association between measured exposure to RF EMF and chronic well-being in children and adolescents. Prospective studies investigating potential long-term effects of RF EMF are necessary to confirm our results.

Herbert MR, Sage C. Autism and EMF? Plausibility of a pathophysiological link - Part I. Pathophysiology 20(3):191-209, 2013. (Review)

Although autism spectrum conditions (ASCs) are defined behaviorally, they also involve multileveled disturbances of underlying biology that find striking parallels in the physiological impacts of electromagnetic frequency and radiofrequency exposures (EMF/RFR). Part I of this paper will review the critical contributions pathophysiology may make to the etiology, pathogenesis and ongoing generation of core features of ASCs. We will review pathophysiological damage to core cellular processes that are associated both with ASCs and with biological effects of EMF/RFR exposures that contribute to chronically disrupted homeostasis. Many studies of people with ASCs have identified oxidative stress and evidence of free radical damage, cellular stress proteins, and deficiencies of antioxidants such as glutathione. Elevated intracellular calcium in ASCs may be due to genetics or may be downstream of inflammation or environmental exposures. Cell membrane lipids may be peroxidized, mitochondria may be dysfunctional, and various kinds of immune system disturbances are common. Brain oxidative stress and inflammation as well as measures consistent with blood-brain barrier and brain perfusion compromise have been documented. Part II of this paper will review how behaviors in ASCs may emerge from alterations of electrophysiological oscillatory synchronization, how EMF/RFR could contribute to these by de-tuning the organism, and policy implications of these vulnerabilities. Changes in brain and autonomic nervous system

electrophysiological function and sensory processing predominate, seizures are common, and sleep disruption is close to universal. All of these phenomena also occur with EMF/RFR exposure that can add to system overload ('allostatic load') in ASCs by increasing risk, and worsening challenging biological problems and symptoms; conversely, reducing exposure might ameliorate symptoms of ASCs by reducing obstruction of physiological repair. Various vital but vulnerable mechanisms such as calcium channels may be disrupted by environmental agents, various genes associated with autism or the interaction of both. With dramatic increases in reported ASCs that are coincident in time with the deployment of wireless technologies, we need aggressive investigation of potential ASC - EMF/RFR links. The evidence is sufficient to warrant new public exposure standards benchmarked to low-intensity (non-thermal) exposure levels now known to be biologically disruptive, and strong, interim precautionary practices are advocated.

Herbert MR, Sage C. Autism and EMF? Plausibility of a pathophysiological link part II. Pathophysiology 20(3):211-234, 2013. (Review)

Autism spectrum conditions (ASCs) are defined behaviorally, but they also involve multileveled disturbances of underlying biology that find striking parallels in the physiological impacts of electromagnetic frequency and radiofrequency radiation exposures (EMF/RFR). Part I (Vol 776) of this paper reviewed the critical contributions pathophysiology may make to the etiology, pathogenesis and ongoing generation of behaviors currently defined as being core features of ASCs. We reviewed pathophysiological damage to core cellular processes that are associated both with ASCs and with biological effects of EMF/RFR exposures that contribute to chronically disrupted homeostasis. Many studies of people with ASCs have identified oxidative stress and evidence of free radical damage, cellular stress proteins, and deficiencies of antioxidants such as glutathione. Elevated intracellular calcium in ASCs may be due to genetics or may be downstream of inflammation or environmental exposures. Cell membrane lipids may be peroxidized, mitochondria may be dysfunctional, and various kinds of immune system disturbances are common. Brain oxidative stress and inflammation as well as measures consistent with blood-brain barrier and brain perfusion compromise have been documented. Part II of this paper documents how behaviors in ASCs may emerge from alterations of electrophysiological oscillatory synchronization, how EMF/RFR could contribute to these by de-tuning the organism, and policy implications of these vulnerabilities. It details evidence for mitochondrial dysfunction, immune system dysregulation, neuroinflammation and brain blood flow alterations, altered electrophysiology, disruption of electromagnetic signaling, synchrony, and sensory processing, de-tuning of the brain and organism, with autistic behaviors as emergent properties emanating from this pathophysiology. Changes in brain and autonomic nervous system electrophysiological function and sensory processing predominate, seizures are common, and sleep disruption is close to universal. All of these phenomena also occur with EMF/RFR exposure that can add to system overload ('allostatic load') in ASCs by increasing risk, and can worsen challenging biological problems and symptoms; conversely, reducing exposure might ameliorate symptoms of ASCs by reducing obstruction of physiological repair. Various vital but vulnerable mechanisms such as calcium channels may be disrupted by environmental agents, various genes associated with autism or the interaction of both. With dramatic increases in reported ASCs that are coincident in time with the deployment of wireless technologies, we need

aggressive investigation of potential ASC-EMF/RFR links. The evidence is sufficient to warrant new public exposure standards benchmarked to low-intensity (non-thermal) exposure levels now known to be biologically disruptive, and strong, interim precautionary practices are advocated.

(E) Hjollund NH, Bonde JP, Skotte J, Semen analysis of personnel operating military radar equipment. Reprod Toxicol 11(6):897, 1997. (CE, HU, M)

This is a preliminary survey of semen quality among Danish military personnel operating mobile ground-to-air missile units that use several microwave emitting radar systems. The maximal mean exposure was estimated to be 0.01 mW/cm^2. The median sperm density of the military personnel was significantly low compared to the references. The difference is either due to chance, uncontrolled bias, or nonthermal effects of transitory microwaves.

(E) Houston BJ, Nixon B, King BV, Aitken RJ, De Iuliis GN. Probing the Origins of 1,800 MHz Radio Frequency Electromagnetic Radiation Induced Damage in Mouse Immortalized Germ Cells and Spermatozoa *in vitro.* Front Public Health 6:270, 2018. (AE, GE, IV, M, OX)

As the use of mobile phone devices is now highly prevalent, many studies have sought to evaluate the effects of the radiofrequency-electromagnetic radiation (RF-EMR) on both human health and biology. While several such studies have shown RF-EMR is capable of inducing cellular stress, the physicobiological origin of this stress remains largely unresolved. To explore the effect of RF-EMR on the male reproductive system, we exposed cultured mouse spermatogonial GC1 and spermatocyte GC2 cell lines, as well as cauda epididymal spermatozoa to a waveguide generating continuous wave RF-EMR (1.8 GHz, 0.15 and 1.5 W/kg). This study demonstrated that a 4 h exposure is capable of inducing the generation of mitochondrial reactive oxygen species (ROS) in populations of GC1 (7 vs. 18%; $p < 0.001$) and GC2 cells (11.5 vs. 16 %; $p < 0.01$), identifying Complex III of the electron transport chain (ETC) as the potential source of electrons producing ROS. Assessing the generation of ROS in the presence of an antioxidant, penicillamine, as well as measuring lipid peroxidation via 4-hydroxynonenal levels, indicated that the elevated incidence of ROS generation observed under our exposure conditions did not necessarily induce an overt cellular oxidative stress response. However, exposure to RF-EMR at 0.15 W/kg for 3 h did induce significant DNA fragmentation in spermatozoa (that was no longer significant after 4 h), assessed by the alkaline comet assay ($p < 0.05$). Furthermore, this fragmentation was accompanied by an induction of oxidative DNA damage in the form of 8-hydroxy-2'-deoxyguanosine, which was significant ($p < 0.05$) after spermatozoa were exposed to RF-EMR for 4 h. At this exposure time point, a decline in sperm motility ($p < 0.05$) was also observed. This study contributes new evidence toward elucidating a mechanism to account for the effects of RF-EMR on biological systems, proposing Complex III of the mitochondrial ETC as the key target of this radiation.

(E) Houston BJ, Nixon B, McEwan KE, Martin JH, King BV, Aitken RJ, De Iuliis GN.Whole-body exposures to radiofrequency-electromagnetic energy can cause DNA damage in mouse spermatozoa via an oxidative mechanism. Sci Rep 9(1):17478, 2019. (CE, M, ME, OX, VO)

Artificially generated radiofrequency-electromagnetic energy (RF-EME) is now ubiquitous in our environment owing to the utilization of mobile phone and Wi-Fi based communication devices. While several studies have revealed that RF-EME is capable of eliciting biological stress, particularly in the context of the male reproductive system, the mechanistic basis of this biophysical interaction remains largely unresolved. To extend these studies, here we exposed unrestrained male mice to RF-EME generated via a dedicated waveguide (905 MHz, 2.2 W/kg) for 12 h per day for a period of 1, 3 or 5 weeks. The testes of exposed mice exhibited no evidence of gross histological change or elevated stress, irrespective of the RF-EME exposure regimen. By contrast, 5 weeks of RF-EME exposure adversely impacted the vitality and motility profiles of mature epididymal spermatozoa. These spermatozoa also experienced increased mitochondrial generation of reactive oxygen species after 1 week of exposure, with elevated DNA oxidation and fragmentation across all exposure periods. Notwithstanding these lesions, RF-EME exposure did not impair the fertilization competence of spermatozoa nor their ability to support early embryonic development. This study supports the utility of male germ cells as sensitive tools with which to assess the biological impacts of whole-body RF-EME exposure.

(E) İkinci A, Odacı E, Yıldırım M, Kaya H, Akça M, Hancı H, Aslan A, Sönmez OF, Baş O. The Effects of Prenatal Exposure to a 900 Megahertz Electromagnetic Field on Hippocampus Morphology and Learning Behavior in Rat Pups. NeuroQuantology. 11(4):582-590, 2013. (BE, CE, IU, ME, NU, VO) (No dosimetry data)

The purpose of this study was to examine the effect on hippocampus morphology and learning behavior in rat pups following prenatal exposure to a 900 megahertz (MHz) electromagnetic field (EMF). Female Sprague Dawley rats weighing 180-250 g were left to mate with males. The following day, pregnant rats identified as such by the vaginal smear test were divided into two groups, control (n=3) and EMF (n=3). No procedures were performed on the control group. The rats in the EMF group were exposed to 900 MHz EMF on days 13 to 21 of pregnancy, for 1 h a day. Female rat pups were removed from their mothers at 22 days old. We then established two newborn rat groups, a 13 member control group and a 10 member EMF group. Radial arm maze and passive avoidance tests were used to measure rat pups' learning and memory performance. All rats were decapitated on the postnatal 32nd day. Routine histological procedures were performed on the brain tissues, and sections were stained with Cresyl fast violet. The radial arm maze (p=0.007) and passive avoidance (p=0.032) tests were administered to both groups under identical conditions, and compromised learning behavior was determined in the EMF group rats. Morphological compromise was also determined in the EMF group sections. Our results show that the application of a 900 MHz EMF in the prenatal period adversely affected female pups' learning behavior and also resulted in histopathological changes appearing in the hippocampus.

(NE) Imai N, Kawabe M, Hikage T, Nojima T, Takahashi S, Shirai T. Effects on rat testis of 1.95-GHz W-CDMA for IMT-2000 cellular phones. Syst Biol Reprod Med. 57(4):204-209, 2011. (CE, M, ME, VO) (low SAR)

In recent years concern has arisen whether carrying a cellular phone near the reproductive organs such as the testes may cause dysfunction and particularly decrease in sperm development and production, and thus fertility in men. The present study was performed to investigate the effects of a 1.95GHz electromagnetic field on testicular function in male Sprague-Dawley rats. Five week old animals were divided into 3 groups of 24 each and a 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is used for the freedom of mobile multimedia access (FOMA), was employed for whole body exposure for 5 hours per day, 7 days a week for 5 weeks (the period from the age of 5 to 10 weeks, corresponding to reproductive maturation in the rat). Whole-body average specific absorption rates (SAR) for individuals were designed to be 0.4 and 0.08 W/kg respectively. The control group received sham exposure. There were no differences in body weight gain or weights of the testis, epididymis, seminal vesicles, and prostate among the groups. The number of sperm in the testis and epididymis were not decreased in the electromagnetic field (EMF) exposed groups, and, in fact, the testicular sperm count was significantly increased with the 0.4 SAR. Abnormalities of sperm motility or morphology and the histological appearance of seminiferous tubules, including the stage of the spermatogenic cycle, were not observed. Thus, under the present exposure conditions, no testicular toxicity was evident.

Indulski JA, Makowiec-Dabrowska T, Zmyslony M, Siedlecka J, [Electromagnetic poles and reproduction]. Med Pr 48(5):585-603, 1997. [Article in Polish] (Review)

The authors review epidemiological data concerning the relationship between reproduction disorders and the exposure to electromagnetic fields (EMF) emitted by power lines, industrial power-charged devices, diagnostic and therapeutical appliances, video display terminals (VDTs) and electric household devices. The studies involved the analysis of the EMF effect on female and male reproduction, including the risk of spontaneous abortion, still birth and premature birth, low birth weight and congenital malformations as well as on the progeny gender proportion, among persons employed under the condition of EMF exposure. It was observed that the findings were frequently inconsistent, i.e. under the same conditions of EMF exposure some date indicated its negative effect on the reproduction process and some did not. No data confirming an acute effect of occupational exposure to EMF on the risk of spontaneous abortion, low birth weight, congenital malformations or other reproduction disorders were obtained, however, the negative effect of EMF cannot be explicitly excluded.

(E) Ingole IV, Ghosh SK. Effect of exposure to radio frequency radiation emitted by cell phone on the developing dorsal root ganglion of chick embryo: a light microscopic study. Nepal Med Coll J. 14(4):337-341, 2012. (CE, DE, IU, ME, NU)

With an ever increasing number of cell phone users since late twenty first century, magnitude of the problem of exposure to radiation emitted by cell phone is self evident. Extensive research had been devoted to incriminate or absolve it as a health hazard. Radiofrequency radiation emitted by cell phone had been stated to be a potent carcinogen, cytotoxic, genotoxic, mutagenic and neurobehavioral teratogen. Its effect on the brain had been a subject of extensive research evidently due to its proximity to the user's brain. While considering the biological effects of radiofrequency radiation, its intensity, frequency and the duration of exposure are important determinants. Nevertheless the results of these different studies have not been unequivocal.

Considering the contradictory reports, the present work was undertaken to study the effect of such an exposure on the developing neural tissue of chick embryo. The processes of cell division and differentiation are fundamental to the development of any living being and are a sensitive index of any insult sustained at this stage. Neurons of dorsal root ganglion were selected for the present study as these ganglia were fully differentiated as early as fourth day of embryonic life. By varying duration of exposure, the embryos were exposed to different doses of radiation, sacrificed at different periods of incubation and subjected to histological processing. On light microscopic study it was observed that developing neurons of dorsal root ganglion suffered a damage which was dose dependent and persisted in spite of giving the exposure-free period between two exposures.

Irani M, Aradmehr M, Ghorbani M, Baghani R. Electromagnetic Field Exposure and Abortion in Pregnant Women: A Systematic Review and Meta-Analysis. Malays J Med Sci 30(5):70-80, 2023. (Review)

This study examined the effects of exposure to electromagnetic fields (EMF) on pregnancy and the risk of miscarriage. We performed a systematic search for relevant studies published to August 2021 in the medical databases of PubMed, CINAHL, Scopus, Web of Science, Google Scholar and Cochrane Library. The following key terms were used: 'electromagnetic field,' 'mobile phones,' 'mobile phone base stations,' 'watching TV,' 'using Internet,' 'miscarriage,' 'abortions,' 'spontaneous abortion,' 'early abortion' and 'late abortion'. All case-control and cohort studies that investigated the effect of EMF exposure on the risk of miscarriage were included without any restriction of language or time. Statistical analyses were done using Comprehensive Meta-Analysis software (version 2.0). A random-effects model was performed to calculate the overall effect size. A primary search revealed a total of 982 relevant studies; six articles (N = 3,187 participants) met the inclusion criteria for the meta-analysis. The results of the random-effects meta-analysis indicated that EMF exposure had a significant effect on miscarriage: rate ratio (RR) = 1.699; 95% confidence interval (CI): 1.121, 2.363 ($P < 0.001$); and heterogeneity (I2) = 84.55% ($P < 0.001$). The findings showed that pregnant woman who were exposed to high levels of EMF had an increased risk of miscarriage.

(E) Irgens A, Kruger K, Ulstein M, The effect of male occupational exposure in infertile couples in Norway. J Occup Environ Med 41(12):1116-1120, 1999. (CE, HU, M)

The objective of the study was to assess whether reduced semen quality in infertile couples is associated with occupational exposures known to be hazardous to fertility. Results of the first semen analysis were linked to occupational exposure data from a self-administered questionnaire. Reduced semen quality was found in men exposed to electromagnetic fields (odds ratio, 3.22; confidence interval, 1.46 to 7.09). A tendency toward reduced semen quality was seen in commuters (OR, 1.52; CI, 0.89 to 2.59), shift workers (OR, 1.46; CI, 0.89 to 2.40), and men exposed to heavy metals (OR, 1.47; CI, 0.76 to 2.87). In general, the impact of occupational exposure on semen quality in infertile couples in Norway seemed to be minor. However, occupational exposure mapping is still important in individual infertility investigations.

(E)Islam MS, Islam MM, Rahman MM, Islam K. 4G mobile phone radiation alters some immunogenic and vascular gene expressions, and gross and microscopic and biochemical parameters in the chick embryo model. Vet Med Sci 9(6):2648-2659, 2023. (CE, GE, IU, ME, VO) (no dosimetry data)

Background: The risks to human health have grown over the past 10 years due to the excessive use of mobile phones. **Objectives:** The study was designed to determine the harmful effects of 4G mobile phone radiation on the expression of immunogenic and vascular genes and gross, microscopic and biochemical alterations in the development of chicken embryos. **Methods:** Sixty individuals in the exposure group were subjected to mobile phones with a specific absorption rate of 1.4 W/kg and a frequency of 2100 MHz positioned at a distance of 12 cm in the incubator for 60 min/night for 14 days. The histopathological examination involved hematoxylin and eosin staining, whereas cresyl violet staining was used to evaluate the condition and number of neurons in the brain. The biochemical parameters of amniotic fluid were analysed using the photometry method, and the expression of VEGF-A and immunity genes (AvBD9, IL6) was measured using the real-time PCR (qPCR) technique. **Results:** Compared to the control, the exposure group's body weight and length significantly decreased ($p < 0.05$). Subcutaneous bleeding was seen in the exposure group. Urea, creatinine, alkaline phosphatase, aspartate aminotransferase and alanine aminotransferase levels were all significantly higher than in the control group ($p < 0.05$). The exposed group showed pathological lesions in the liver and degenerated neurons with lightly stained nuclei in the cerebral cortex. Hyperchromatic neurons were significantly higher in the exposure group (58.8 ± 2.28) compared to the control (6.6 ± 0.44) ($p < 0.05$). 4G exposure reduced lymphocyte count in the caecal tonsil (86.8 ± 5.38) compared to the control (147.2 ± 9.06) ($p < 0.05$). Vascular gene mRNA expression was higher, but immune gene expression was lower in the exposed group. **Conclusion:** Exposure to mobile phone radiation may result in gross, microscopic and biochemical changes, as well as alterations in gene expression that could hinder embryonic development.

Jensh RP, Behavioral teratologic studies using microwave radiation: is there an increased risk from exposure to cellular phones and microwave ovens? Reprod Toxicol 11(4):601-611, 1997. (Review)

The objective of the investigations presented in this review was to determine if there are adverse effects due to chronic prenatal microwave exposure in rats at term and/or alterations in neonatal and adult offspring psychophysiologic development and growth. Following the establishment of a nonhyperthermal power density level of microwave radiation, pregnant rats were exposed throughout pregnancy to continuous wave 915 MHz, 2450 MHz, or 6000 MHz radiation at power density levels of 10, 20, or 35 mW/cm2, respectively. Teratologic evaluation included the following parameters: maternal weight and weight gain; mean litter size; maternal organ weight and organ weight/body weight ratios; body weight ratios of brain, liver, kidneys, and ovaries; maternal peripheral blood parameters including hematocrit, hemoglobin, and white cell counts; number of resorptions and resorption rate; number of abnormalities and abnormality rate; mean term fetal weight. Mothers were rebred, and the second, nonexposed litters were evaluated for teratogenic effects. Exposed offspring were evaluated using the following perinatal and adult tests: eye opening, surface righting, negative geotaxis, auditory startle, air righting, open field, activity wheel, swimming, and

forelimb hanging. Offspring were also monitored for weekly weight and weight gain. Animals exposed to 915 MHz did not exhibit any consistent significant alterations in any of the above parameters. Exposure to 2450 MHz resulted only in a significantly increased adult offspring activity level compared to nonexposed offspring. Offspring exposed to 6000 MHz radiation exhibited an initial slight, but significant, retardation in term weight, while mothers had a significantly reduced monocyte count. No changes in any of the other term parameters were observed. A few postnatal parameters were affected in offspring exposed to 6000 MHz. Weekly weights were lower in the exposed offspring, but they recovered by the fifth week. Eye opening was delayed, and there were changes in the water T-maze and open field performance levels. Several organ/body weight ratios differed from those of the control offspring. These results indicate that exposure to 6000 MHz radiation at this power density level may result in subtle long-term neurophysiologic alterations. However, in the absence of a hyperthermic state, the microwave frequencies tested, which included frequencies used in cellular phones and microwave ovens, do not induce a consistent, significant increase in reproductive risk as assessed by classical morphologic and postnatal psychophysiologic parameters.

(NE)Jin YB, Choi H-D, Kim BC, Pack J-K, Kim N, Lee Y-S. Effects of simultaneous combined exposure to CDMA and WCDMA electromagnetic fields on serum hormone levels in rats. J Radiat Res 54(3):430-437, 2013. (CE, MO, VO)

Despite more than a decade of research on the endocrine system, there have been no published studies about the effects of concurrent exposure of radiofrequency electromagnetic fields (RF-EMF) on this system. The present study investigated the several parameters of the endocrine system including melatonin, thyroid stimulating hormone, stress hormone and sex hormone after code division multiple access (CDMA, 849 MHz) and wideband code division multiple access (WCDMA, 1.95 GHz) signals for simultaneous exposure in rats. Sprague-Dawley rats were exposed to RF-EMF signals for 45 min/day, 5 days/week for up to 8 weeks. The whole-body average specific absorption rate (SAR) of CDMA or WCDMA was 2.0 W/kg (total 4.0 W/kg). At 4 and 8 weeks after the experiment began, each experimental group's 40 rats (male 20, female 20) were autopsied. Exposure for 8 weeks to simultaneous CDMA and WCDMA RF did not affect serum levels in rats of melatonin, thyroid stimulating hormone (TSH), triiodothyronine (T3) and thyroxin (T4), adrenocorticotropic hormone (ACTH) and sex hormones (testosterone and estrogen) as assessed by the ELISA method.

(E) Jing J, Yuhua Z, Xiao-qian Y, Rongping J, Dong-mei G, Xi C. The influence of microwave radiation from cellular phone on fetal rat brain. Electromagn Biol Med. 31(1):57-66, 2012. (CE, IU, MO, OX, VO) (No dosimetry data)

The increasing use of cellular phones in our society has brought focus on the potential detrimental effects to human health by microwave radiation. The aim of our study was to evaluate the intensity of oxidative stress and the level of neurotransmitters in the brains of fetal rats chronically exposed to cellular phones. The experiment was performed on pregnant rats exposed to different intensities of microwave radiation from cellular

phones. Thirty-two pregnant rats were randomly divided into four groups: CG, GL, GM, and GH. CG accepted no microwave radiation, GL group radiated 10 min each time, GM group radiated 30 min, and GH group radiated 60 min. The 3 experimental groups were radiated 3 times a day from the first pregnant day for consecutively 20 days, and on the 21st day, the fetal rats were taken and then the contents of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), noradrenaline (NE), dopamine (DA), and 5-hydroxyindole acetic acid (5-HT) in the brain were assayed. Compared with CG, there were significant differences ($P<0.05$) found in the contents of SOD, GSH-Px, and MDA in GM and GH; the contents of SOD and GSH-Px decreased and the content of MDA increased. The significant content differences of NE and DA were found in fetal rat brains in GL and GH groups, with the GL group increased and the GH group decreased. Through this study, we concluded that receiving a certain period of microwave radiation from cellular phones during pregnancy has certain harm on fetal rat brains.

(E) Jonwal C, Sisodia R, K Saxena VK, Kesari KK. Effect of 2.45 GHz microwave radiation on the fertility pattern in male mice. Gen Physiol Biophys 37(4):453-460, 2018. (CE, GE, M, ME, MO, OX, VO) (Low SAR)

A number of studies have reported that male reproductive organs are susceptible to electromagnetic fields (EMFs). The aim of this study was to explore the effects of microwave radiation exposures on 6-8 weeks old male Swiss albino mice. Mice were divided into two groups: group I - sham-exposed (Control), and group II - microwaves-exposed (MWs). Mice were exposed to 2.45 GHz with power density 0.25 mW/cm2 and specific absorbtion rate (SAR) 0.09 W/kg. Exposure was given in Plexiglas cages for 2 h/day for 30 days. Results showed that 2.45 GHz microwave radiation resulted in a significant increase ($p < 0.001$) in catalase (CAT), malondialdehyde (MDA), reactive oxygen species (ROS) and decrease ($p < 0.001$) in the levels of glutathione peroxidase (GPx), testosterone and superoxide dismutase (SOD) ($p < 0.05$). Flow cytometer analysis of blood showed the formation of micronuclei in microwave-exposed group. Histopathological changes were also seen in seminiferous tubules of microwave-exposed group as compared to the sham-exposed group. It is concluded that 2.45 GHz microwave radiation exposure causes oxidative stress in testes and it may lead to detrimental and injurious effects on fertility potential of the male reproductive system of Swiss albino mice.

(E) Kamali K, Atarod M, Sarhadi S, Nikbakht J, Emami M, Maghsoudi R, Salimi H, Fallahpour B, Kamali N, Momtazan A, Ameli M. Effects of electromagnetic waves emitted from 3G+wi-fi modems on human semen analysis. Urologia. 84(4):209-214, 2017. (AE, FC, HU, M, IV)

OBJECTIVE: The purpose of this study was to evaluate the effects of 3G+wifi modems on human sperm quality. A total of 40 semen specimens were gathered between March and September 2015, from healthy adult men. METHODS: The sperm samples were divided into two groups - 3G+wi-fi exposed and unexposed groups. In the unexposed group, the specimens were shielded by aluminum foil in three layers and put into an incubator at a temperature of 37°C for 50 minutes. The exposed group was positioned in another room in an incubator at a temperature of 37°C for 50 minutes. A 3G+wi-fi modem was put into the

same incubator and a laptop computer was connected to the modem and was downloading for the entire 50 minutes. Semen analysis was done for each specimen and comparisons between parameters of the two groups were done by using Kolmogorov-Smirnov study and a paired t-test. RESULTS: Mean percentage of sperm with class A and B motility were not significantly different in two groups (p = 0.22 and 0.54, respectively). In class C, it was significantly lower in the exposed group (p = 0.046), while in class D it was significantly higher (p = 0.022). Velocity curvilinear, velocity straight line, velocity average path, mean angular displacement, lateral displacement and beat cross frequency were significantly higher in the unexposed group. The limitation was the in vitro design. CONCLUSIONS: Electromagnetic waves (EMWs) emitted from 3G+wi-fi modems cause a significant decrease in sperm motility and velocity, especially in non-progressive motile sperms. Other parameters of semen analysis did not change significantly. EMWs, which are used in communications worldwide, are a suspected cause of male infertility. Many studies evaluated the effects of cell phones and wi-fi on fertility. To our knowledge, no study has yet been done to show the effects of EMWs emitted from 3G+wi-fi modems on fertility. Our study revealed a significant decrease in the quality of human semen after exposure to EMWs emitted from 3G+wi-fi modems.

Kaplan S, Deniz OG, Önger ME, Türkmen AP, YurtKK, Aydın I, Altunkaynak BZ, Da vis D. Electromagnetic field and brain development. J Chem Neuroanat 75(Pt B):52-61, 2016. (Review)

Rapid advances in technology involve increased exposures to radio-frequency/microwave radiation from mobile phones and other wireless transmitting devices. As cell phones are held close to the head during talking and often stored next to the reproductive organs, studies are mostly focused on the brain. In fact, more research is especially needed to investigate electromagnetic field (EMF)'s effects on the central nervous system (CNS). Several studies clearly demonstrate that EMF emitted by cell phones could affect a range of body systems and functions. Recent work has demonstrated that EMF inhibit the formation and differentiation of neural stem cells during embryonic development and also affect reproductive and neurological health of adults that have undergone prenatal exposure. The aim of this review is to discuss the developing CNS and explain potential impacts of EMF on this system.

(E) Karadayı A, Ünal N, Gülbahçe-Mutlu Elif, Engiz, BK, Ahmet A, Varol S. Effects of Exposure to Radiofrequency at 2.45 GHz on Structural Changes Associated with Lipid Peroxidation in Prepubertal Rat Testicular Tissue. European Journal of Therapeutics. 2023. doi: 10.58600/eurjther1875. (CE, IU, H, ME, OX, PN, VO)

Objective: The increasing use of electronic devices, accompanied by advancing technologies, has led to heightened exposure to non-ionizing electromagnetic radiation (EMR). This exposure instigates the accumulation of free radicals and oxidative damage in tissues, consequently impacting biological systems. Notably, the testis is among the tissues adversely affected by EMR. Numerous studies have highlighted the pivotal role of the testis in sperm production, emphasizing the potential implications of any damage on the reproductive system. This study aims to assess the levels of lipid peroxidation through histological evaluation in the testicular tissue of prepubertal male rats exposed to electromagnetic radiation at varying electric field intensities within the 2.45 GHz radiofrequency (RF) range. Methods: The experimental group

comprises six subdivisions, including a sham control group, as well as groups exposed to varying electric field strengths (EFS) of 0.6 V/m, 1.9 V/m, 5 V/m, 10 V/m, and 15 V/m, respectively. Excluding the sham control group, the remaining subgroups were subjected to a daily 2.45 GHz RF exposure for 1 hour starting immediately after fertilization. This exposure to different electric field intensities continued for 45 days post-birth. Results: The samples obtained from the RF radiation-exposed rats exhibited elevated malondialdehyde (MDA) values and decreased glutathione (GSH) values in the testicular tissue. Furthermore, a comparative analysis between the microwave radiation-exposed group and the control group revealed distinct histological alterations in the testicular tissue. Conclusion: In conclusion, our findings indicate that exposure to microwave radiation at an electric field intensity of 15 V/m can lead to significant histopathological and oxidative parameter changes in Wistar rats. These results underscore the potential effects of such exposure on human health.

(E) Karaman MI, Gökçe AM, Koca O, Karaman B, Öztürk MI, Yurdakul N, Ercan F. The effects of electromagnetic waves emitted by the cell phones on the testicular tissue. Arch Ital Urol Androl. 86(4):274-277, 2014. (CE, M, ME, VO)

OBJECTIVES: Various risks have emerged in parallel to the rapidly increasing use of **cell phones**. Herein we studied the effects of **cell phone** emitted electromagnetic waves (EMW) on rat testes. MATERIAL AND METHODS: Twenty one adult male Albino rats were grouped into 3 groups each consisting of 7 rats. The first group was exposed to EMW on talk mode for 8 hours per day for 20 days and then their testes were extracted. The testes of the second group were extracted after 20 days of whole day EMW exposure. The third group was the control group. For the statistical analysis Mann- Whitney U analysis was performed. RESULTS: At light microscopic examination of the testicular tissue, the existence of a high number of immature cells in the lumen of the seminiferous tubule in addition to the normal seminiferous tubules, besides irregular tubules with a reduction in the spermatogenic **cell** lines and tubules without lumen were observed in groups 1 and 2. Histopathological alterations were scored as 0 = none, 1 = low, 2 = medium, 3 = serious. The average scores of the three groups were found to be 4.25 ± 1.5 for the group 1, 4.33 ± 3.9 for the group 2 and 0.37 ± 1.1 for the group 3 respectively. As a result of the statistical evaluation, group 1 and group 2 had significantly higher scores than the control group (p = 0.001). CONCLUSION: Infertility is one of the current problems of today due to a rapid increase in its incidence and cost. The negative effects of the EMWs on the testis should be taken into account and the necessary measures should be taken for prevention.

Kashani ZA, Pakzad R, Fakari FR, Haghparast MS, Abdi F, Kiani Z, Talebi A, Haghgo o SM. Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis. Open Med (Wars) 18(1):20230697, 2023. (Review)

Today, in the modern world, people are often exposed to electromagnetic waves, which can have undesirable effects on cell components that lead to differentiation and abnormalities in cell proliferation, deoxyribonucleic acid (DNA) damage, chromosomal abnormalities, cancers, and birth defects. This study aimed to investigate the effect of electromagnetic waves on fetal and childhood abnormalities. PubMed, Scopus, Web of Science, ProQuest, Cochrane Library, and Google Scholar were searched on 1 January 2023. The Cochran's Q-test and I 2 statistics were

applied to assess heterogeneity, a random-effects model was used to estimate the pooled odds ratio (OR), standardized mean difference (SMD), and mean difference for different outcomes, and a meta-regression method was utilized to investigate the factors affecting heterogeneity between studies. A total of 14 studies were included in the analysis, and the outcomes investigated were: change in gene expression, oxidant parameters, antioxidant parameters, and DNA damage parameters in the umbilical cord blood of the fetus and fetal developmental disorders, cancers, and childhood development disorders. Totally, the events of fetal and childhood abnormalities were more common in parents who have been exposed to EMFs compared to those who have not (SMD and 95% confidence interval [CI], 0.25 [0.15-0.35]; I^2, 91%). Moreover, fetal developmental disorders (OR, 1.34; CI, 1.17-1.52; I^2, 0%); cancer (OR, 1.14; CI, 1.05-1.23; I^2, 60.1%); childhood development disorders (OR, 2.10; CI, 1.00-3.21; I^2, 0%); changes in gene expression (mean difference [MD], 1.02; CI, 0.67-1.37; I^2, 93%); oxidant parameters (MD, 0.94; CI, 0.70-1.18; I^2, 61.3%); and DNA damage parameters (MD, 1.01; CI, 0.17-1.86; I^2, 91.6%) in parents who have been exposed to EMFs were more than those in parents who have not. According to meta-regression, publication year has a significant effect on heterogeneity (coefficient: 0.033; 0.009-0.057). Maternal exposure to electromagnetic fields, especially in the first trimester of pregnancy, due to the high level of stem cells and their high sensitivity to this radiation, the biochemical parameters of the umbilical cord blood examined was shown increased oxidative stress reactions, changes in protein gene expression, DNA damage, and increased embryonic abnormalities. In addition, parental exposure to ionizing and non-ionizing radiation can lead to the enhancement of different cell-based cancers and developmental disorders such as speech problems in childhood.

Kaur P, Rai U, Singh R. Genotoxic Risks to Male Reproductive Health from Radiofrequency Radiation. Cell 12(4):594, 2023. (Review)

During modern era, mobile phones, televisions, microwaves, radio, and wireless devices, etc., have become an integral part of our daily lifestyle. All these technologies employ radiofrequency (RF) waves and everyone is exposed to them, since they are widespread in the environment. The increasing risk of male infertility is a growing concern to the human population. Excessive and long-term exposure to non-ionizing radiation may cause genetic health effects on the male reproductive system which could be a primitive factor to induce cancer risk. With respect to the concerned aspect, many possible RFR induced genotoxic studies have been reported; however, reports are very contradictory and showed the possible effect on humans and animals. Thus, the present review is focusing on the genomic impact of the radiofrequency electromagnetic field (RF-EMF) underlying the male infertility issue. In this review, both in vitro and in vivo studies have been incorporated explaining the role of RFR on the male reproductive system. It includes RFR induced-DNA damage, micronuclei formation, chromosomal aberrations, SCE generation, etc. In addition, attention has also been paid to the ROS generation after radiofrequency radiation exposure showing a rise in oxidative stress, base adduct formation, sperm head DNA damage, or cross-linking problems between DNA & protein.

Kawai H, Nagaoka T, Watanabe S, Saito K, Takahashi M, Ito K. Computational dosimetry in embryos exposed to electromagnetic plane waves over the frequency

range of 10 MHz-1.5 GHz. Phys Med Biol. 55(1):N1-11, 2010. (Dosimetry)

This paper presents calculated specific absorption rate (SAR) dosimetry in 4 and 8 week Japanese pregnant-woman models exposed to plane waves over the frequency range of 10 MHz-1.5 GHz. Two types of 2 mm spatial-resolution pregnant-woman models comprised a woman model, which is similar to the average-sized Japanese adult female in height and weight, with a cubic (4 week) embryo or spheroidal (8 week) one. The averaged SAR in the embryos exposed to vertically and horizontally polarized plane waves at four kinds of propagation directions are calculated from 10 MHz to 1.5 GHz. The results indicate that the maximum average SAR in the embryos exposed to plane waves is lower than 0.08 W kg(-1) when the incident power density is at the reference level of ICNIRP guideline for general public environment.

(E) Keleş AI. Morphological changes in the vertebrae and central canal of rat pups born after exposure to the electromagnetic field of pregnant rats. Acta Histochem 122(8):151652, 2020. (CE, DE, IU, ME, VO)

Several studies have investigated the effects of the electromagnetic field (EMF) on the central nervous system. However, we encountered no studies of the effects of EMF applied in the prenatal period on the offspring vertebrae. The aim of this study is to investigate the effect of a 900 megahertz (MHz) EMF applied to rat dams in the prenatal period on the vertebrae of rat pups. Female Sprague Dawley rats weighing 180-250 g were used in the experiment. Rats identified as pregnant were divided into two groups, control (n = 3) and EMF (n = 3). No EMF was applied to the control group pregnant rats. EMF was applied to the EMF group rats for 1 h daily on an equal and standard basis on prenatal days 13-21. All newborn rat pups were divided into pup control (n = 6) (PC) and pup EMF (n = 6) (PEMF) groups, and no treatment was performed on either. All animals were decapitated on day 32, and the spinal cord in the upper thoracic region was harvested. Vertebral tissues were subjected to routine histological procedures. Histopathological examination revealed that PEMF group vertebral cartilage had been converted into bone tissue. Comparison of central canal diameter and area values between the PEMF group and the PC group revealed statistically significant increases in the PEMF group ($p = 0.000$ and $p = 0.001$, respectively). Statistical analysıs revealed no significant difference in mean body weights between the two groups ($p > 0.530$). Based on these findings, we think that 900 MHz EMF applied in the prenatal period affects the development of the vertebrae. This effect causes pathological changes in the rat pup vertebrae. These findings now raise the question of whether EMF also has an impact on neurological and neurosurgical diseases involving the vertebrae.

(E) Kesari KK, Behari J. Microwave exposure affecting reproductive system in male rats. Appl Biochem Biotechnol. Microwave exposure affecting reproductive system in male rats 31(6):495-498, 2010. (CE, FC, M, OX, VO) (Low SAR)

The object of present study is to investigate the effects of 50 GHz microwave frequency electromagnetic fields on reproductive system of male rats. Male rats of Wistar strain were used in the study. Animals 60 days old were divided into two groups-group I sham exposed and group II experimental (microwave exposed). During exposure, rats were confined in Plexiglas cages with drilled ventilation holes for 2 h a day for 45 days

continuously at a specified specific absorption rate of 8.0 x 10(-4) W/kg. After the last exposure, the rats were sacrificed immediately and sperms were collected. Antioxidant enzyme (superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase), histone kinase, apoptosis, and cell cycle were analyzed in sperm cells. Result shows a significant decrease in the level of sperm GPx and SOD activity (p </= 0.05), whereas catalase shows significant increase in exposed group of sperm samples as compared with control (p < 0.02). We observed a statistically significant decrease in mean activity of histone kinase as compared to the control (p < 0.016). The percentage of cells dividing in a spermatogenesis was estimated by analyzing DNA per cell by flow cytometry. The percentage of apoptosis in electromagnetic field exposed group shows increased ratio as compared to sham exposed (p < 0.004). There were no significant differences in the G(0)/G(1) phase; however, a significant decrease (p < 0.026) in S phase was obtained. Results also indicate a decrease in percentage of G(2)/M transition phase of cell cycle in exposed group as compared to sham exposed (p < 0.019). We conclude that these radiations may have a significant effect on reproductive system of male rats, which may be an indication of male infertility.

(E) Kesari KK, Kumar S, Behari J. Mobile phone usage and male infertility in Wistar rats. Indian J Exp Biol. 48(10):987-992, 2010. (CE, FC, M, ME, OX, VO)

A significant decrease in protein kinase C and total sperm count along with increased apoptosis were observed in male Wistar rats exposed to mobile phone frequencies (2 h/day x 35 days at 0.9 W/kg specific absorption rate). The results suggest that a reduction in protein kinase activity may be related to overproduction of reactive oxygen species (ROS) under microwave field exposure. Decrease in sperm count and an increase in apoptosis may be causative factor due to mobile radiation exposure leading to infertility.

(E) Kesari KK, Kumar S, Behari J. Effects of Radiofrequency Electromagnetic Wave Exposure from Cellular Phones on the Reproductive Pattern in Male Wistar Rats. Appl Biochem Biotechnol. 164(4):546-559, 2011. (CE, FC, M, OX, VO)

The present study investigates the effect of free radical formation due to mobile phone exposure and effect on fertility pattern in 70-day-old male Wistar rats (sham exposed and exposed). Exposure took place in Plexiglas cages for 2 h a day for 35 days to mobile phone frequency. The specific absorption rate was estimated to be 0.9 W/kg. An analysis of antioxidant enzymes glutathione peroxidase (P < 0.001) and superoxide dismutase (P < 0.007) showed a decrease, while an increase in catalase (P < 0.005) was observed. Malondialdehyde (P < 0.003) showed an increase and histone kinase (P = 0.006) showed a significant decrease in the exposed group. Micronuclei also show a significant decrease (P < 0.002) in the exposed group. A significant change in sperm cell cycle of G(0)-G(1) (P = 0.042) and G(2)/M (P = 0.022) were recorded. Generation of free radicals was recorded to be significantly increased (P = 0.035). Our findings on antioxidant, malondialdehyde, histone kinase, micronuclei, and sperm cell cycle are clear indications of an infertility pattern, initiated due to an overproduction of reactive oxygen species. It is concluded that radiofrequency electromagnetic wave from commercially available cell phones might affect the fertilizing potential of spermatozoa.

(E) Kesari KK, Behari J. Evidence for mobile phone radiation exposure effects on reproductive pattern of male rats: Role of ROS. Electromagn Biol Med. 31(3):213-222, 2012. (CE, M, ME, MO, VO) (Similar effects observed in offspring of exposed rats). (ROS not studied.) (SAR 0.9 W/kg)

The relationship between radiofrequency electromagnetic fields emitted from mobile phone and infertility is a matter of continuing debate. It is postulated that these radiations may affect the reproduction pattern spell by targeting biochemistry of sperm. In an attempt to expedite the issue, 70 days old Wistar rats (n = 6) were exposed to mobile phone radiofrequency (RF) radiation for 2 h per day for 45 days and data compared with sham exposed (n = 6) group. A significant decrease ($P < 0.05$) in the level of testosterone and an increase in caspase-3 activity were found in the RF-exposed animals. Distortions in sperm head and mid piece of sperm mitochondrial sheath were also observed as captured by Transmission Electron Microscope (TEM). In addition, progeny from RF-exposed rats showed significant decreases in number and weight as compared with that of sham-exposed animals. A reduction in testosterone, an increase in caspase-3, and distortion in spermatozoa could be caused by overproduction of reactive oxygen species (ROS) in animals under mobile phone radiation exposure. Our findings on these biomarkers are clear indications of possible health implications of repeated exposure to mobile phone radiation.

Kesari KK, Kumar S, Nirala J, Siddiqui MH, Behari J. Biophysical Evaluation of Radiofrequency Electromagnetic Field Effects on Male Reproductive Pattern. Cell Biochem Biophys. 65(2): 85-96, 2013. (Review)

There are possible hazardous health effects of exposure to radiofrequency electromagnetic radiations emitted from mobile phone on the human reproductive pattern. It is more effective while keeping mobile phones in pocket or near testicular organs. Present review examines the possible concern on radio frequency radiation interaction and biological effects such as enzyme induction, and toxicological effects, including genotoxicity and carcinogenicity, testicular cancer, and reproductive outcomes. Testicular infertility or testicular cancer due to mobile phone or microwave radiations suggests an increased level of reactive oxygen species (ROS). Though generation of ROS in testis has been responsible for possible toxic effects on physiology of reproduction, the reviews of last few decades have well established that these radiations are very harmful and cause mutagenic changes in reproductive pattern and leads to infertility. The debate will be focused on bio-interaction mechanism between mobile phone and testicular cancer due to ROS formation. This causes the biological damage and leads to several changes like decreased sperm count, enzymatic and hormonal changes, DNA damage, and apoptosis formation. In the present review, physics of mobile phone including future research on various aspects has been discussed.

Keshvari J, Lang S. Comparison of radio frequency energy absorption in ear and eye region of children and adults at 900, 1800 and 2450 MHz. Phys Med Biol. 50(18):4355-4369, 2005. (Dosimetry)

The increasing use of mobile communication devices, especially mobile phones by children, has triggered discussions on whether there is a larger radio frequency (RF) energy absorption in the heads of children compared to that of adults. The objective of this study was to clarify possible differences in RF energy absorption in the head region of children and adults using computational techniques. Using the finite-difference time-domain (FDTD) computational method, a set of specific absorption rate (SAR) calculations were performed for anatomically correct adult and child head models. A half-wave dipole was used as an exposure source at 900, 1800 and 2450 MHz frequencies. The ear and eye regions were studied representing realistic exposure scenarios to current and upcoming mobile wireless communication devices. The differences in absorption were compared with the maximum energy absorption of the head model. Four magnetic resonance imaging (MRI) based head models, one female, one adult, two child head models, aged 3 and 7 years, were used. The head models greatly differ from each other in terms of size, external shape and the internal anatomy. The same tissue dielectric parameters were applied for all models. The analyses suggest that the SAR difference between adults and children is more likely caused by the general differences in the head anatomy and geometry of the individuals rather than age. It seems that the external shape of the head and the distribution of different tissues within the head play a significant role in the RF energy absorption.

Keshvari J, Heikkilä T. Volume-averaged SAR in adult and child head models when using mobile phones: a computational study with detailed CAD-based models of commercial mobile phones. Prog Biophys Mol Biol. 107(3):439-442, 2011. (Dosimetry)

Previous studies comparing SAR difference in the head of children and adults used highly simplified generic models or half-wave dipole antennas. The objective of this study was to investigate the SAR difference in the head of children and adults using realistic EMF sources based on CAD models of commercial mobile phones. Four MRI-based head phantoms were used in the study. CAD models of Nokia 8310 and 6630 mobile phones were used as exposure sources. Commercially available FDTD software was used for the SAR calculations. SAR values were simulated at frequencies 900 MHz and 1747 MHz for Nokia 8310, and 900 MHz, 1747 MHz and 1950 MHz for Nokia 6630. The main finding of this study was that the SAR distribution/variation in the head models highly depends on the structure of the antenna and phone model, which suggests that the type of the exposure source is the main parameter in EMF exposure studies to be focused on. Although the previous findings regarding significant role of the anatomy of the head, phone position, frequency, local tissue inhomogeneity and tissue composition specifically in the exposed area on SAR difference were confirmed, the SAR values and SAR distributions caused by generic source models cannot be extrapolated to the real device exposures. The general conclusion is that from a volume averaged SAR point of view, no systematic differences between child and adult heads were found.

Keshvari J, Keshvari R, Lang S. The effect of increase in dielectric values on specific absorption rate (SAR) in eye and head tissues following 900, 1800 and 2450 MHz radio frequency (RF) exposure. Phys Med Biol. 51(6):1463-1477, 2006. (Dosimetry)

Numerous studies have attempted to address the question of the RF energy absorption difference between children and adults using computational methods. They have

assumed the same dielectric parameters for child and adult head models in SAR calculations. This has been criticized by many researchers who have stated that child organs are not fully developed, their anatomy is different and also their tissue composition is slightly different with higher water content. Higher water content would affect dielectric values, which in turn would have an effect on RF energy absorption. The objective of this study was to investigate possible variation in specific absorption rate (SAR) in the head region of children and adults by applying the finite-difference time-domain (FDTD) method and using anatomically correct child and adult head models. In the calculations, the conductivity and permittivity of all tissues were increased from 5 to 20% but using otherwise the same exposure conditions. A half-wave dipole antenna was used as an exposure source to minimize the uncertainties of the positioning of a real mobile device and making the simulations easily replicable. Common mobile telephony frequencies of 900, 1800 and 2450 MHz were used in this study. The exposures of ear and eye regions were investigated. The SARs of models with increased dielectric values were compared to the SARs of the models where dielectric values were unchanged. The analyses suggest that increasing the value of dielectric parameters does not necessarily mean that volume-averaged SAR would increase. Under many exposure conditions, specifically at higher frequencies in eye exposure, volume-averaged SAR decreases. An increase of up to 20% in dielectric conductivity or both conductivity and permittivity always caused a SAR variation of less than 20%, usually about 5%, when it was averaged over 1, 5 or 10 g of cubic mass for all models. The thickness and composition of different tissue layers in the exposed regions within the human head play a more significant role in SAR variation compared to the variations (5-20%) of the tissue dielectric parameters.

(E) Khayat S, Fanaei H, Lakzaee N. Effects of prenatal mobile phone radiation exposure on MMP9 expression: Implications for inflammation, oxidative stress, and sensory-motor impairment after neonatal hypoxia- ischemia in rats. Toxicol Rep 11:378-384, 2023. (CE, GE, IU, IX, MO, OX, VO) (900 MHz, 0.045 μW/cm^2) (MMP-2 and MMP-9 are collagenases involved in degradation of extracellular matrix)

Objective: Non-ionizing radiofrequency radiation, which finds application in various sectors such as industry, commerce, medicine, and particularly in mobile phone technology, has emerged as a topic of significant concern during pregnancy. The aim of this study was to investigate the effect of cell phone radio-frequency (RF) radiation during pregnancy on the Matrix metalloproteinase 2 (MMP-2) and (MMP-9) 9 expressions after neonatal hypoxia-ischemia (HI) in rats. **Materials and methods:** Two groups were formed by randomly assigning female Wistar rats: Group 1 consisted of female rats that were not exposed to RF radiation during pregnancy, while Group 2 comprised female rats that were exposed to RF radiation during pregnancy. After delivery, male offspring were divided into four groups including: (a) SHAM, (b) Exposure (EXP), (c) hypoxia-ischemia (HI), (d) HI/Exposure (HI/EXP). Seven days after HI induction, neurobehavioral tests were performed, and then brain tissue was taken from the skull to measure MMP-2 and MMP-9 expressions, inflammation, oxidative stress, infarct volume and cerebral edema. **Results:** MMP-9 mRNA expression in the HI/EXP group was significantly higher than the HI, SHAM and EXP groups. MMP-2 mRNA expression levels in the HI group were significantly higher than Sham and the EXP groups. TNF-α and Total oxidant capacity (TOC) levels in the HI/EXP group were significantly higher than HI, EXP and SHAM

groups. Total antioxidant capacity (TAC) level in the HI/EXP group were significantly lower than HI, EXP and SHAM groups. Cerebral edema and infarct volume in the HI/EXP group were significantly greater than the HI group. Sensory-motor function was significantly weaker in HI/EXP as compared HI group. **Conclusion:** Our findings indicate that during pregnancy, exposure to mobile phone RF radiation intensifies damage from HI in rat pups by elevating MMP-9 activity.

(E) Khoshbakht S, Motejaded F, Karimi S, Jalilvand N, Ebrahimzadeh-Bideskan A. Protective effects of selenium on electromagnetic field-induced apoptosis, aromatase P450 activity, and leptin receptor expression in rat testis. Iran J Basic Med Sci 24(3):322-330, 2021. (CE, M, ME, MO, VO) (No dosimetry data available)

Objectives: Electromagnetic field (EMF) emitted by mobiles may affect the male reproductive system. Selenium, as an antioxidant, may protect against electromagnetic field-induced tissue damage. Theis study aimed to investigate the effects of selenium on rat testis exposed to electromagnetic fields. **Materials and methods:** Twenty-four male Wistar rats were divided into four groups, namely EM group (2100 MHZ), EM/SE group (2100 MHZ + selenium (0.2 mg/kg), SE group (selenium 0.2 mg/kg), CONT (control group). Serum LH, FSH, testosterone, leptin and aromatase levels, testis weight and volume index, sperm parameters (count and abnormal percent), seminiferous tubule diameters, germinal epithelia thickness, immunoreactivity of leptin receptor and caspase-3 (for apoptotic cells in germinal epithelium) were investigated. **Results:** Our results showed that serum LH, FSH, GnRH, testosterone level, sperm count, germinal epithelium thickness, and seminiferous tubule diameter were significantly declined in the EM group compared with the CONT group (P<0.05). However, in the EM group, the serum leptin level, sperm abnormality, aromatase enzyme level, apoptotic cells, and leptin receptor were increased compared with the CONT group (P<0.05). Furthermore, an increase in sperm count, germinal epithelium thickness, seminiferous diameters, serum LH, FSH, and GnRH, and testosterone levels, and a significant decrease in sperm abnormality, leptin receptor and apoptotic cells in the EM/SE group compared with the EM group were also observed (P<0.05). **Conclusion:** This study showed that electromagnetic radiation may have detrimental impacts on the male reproductive system, which can be prevented by use of selenium.

(E) Kilic A, Ustunova S, Bulut H, Meral I. Pre and postnatal exposure to 900 MHz electromagnetic fields induce inflammation and oxidative stress, and alter renin-angiotensin system components differently in male and female offsprings. Life Sci 321:121627, 2023. (CE, IU, PN, VO) (6 V/m)

Aims: This study was designed to investigate inflammation, oxidative stress and renin-angiotensin system components in brain and kidney tissues of female and male rats prenatally and/or postnatally exposed to 900 MHz electromagnetic field (EMF). It is aimed to evaluate the biological effects of 900 MHz EMF exposure due to the increase in mobile phone use and especially the more widespread use of the GSM 900 system. **Main methods:** Male and female Wistar albino offsprings were divided into four groups of control, prenatal, postnatal, and prenatal+postnatal exposed to 900 MHz EMF for 1 h/day (23 days during pregnancy for prenatal period, 40 days for postnatal period). The brain and kidney tissues were collected when they reached puberty. **Key findings:** It was found that the total oxidant status, IL-2, IL-6, and TNF-α levels increased ($p < 0.001$) and the total antioxidant status

levels decreased ($p < 0.001$) in all three EMF groups comparing to controls in both male and female brain and kidney tissues. The renin- angiotensin system components such as angiotensinogen, renin, angiotensin type 1 and type 2 receptors, and MAS1-like G protein-coupled receptor expression were higher ($p < 0.001$) in all three EMF exposure groups comparing to controls in both male and female brain and kidney tissues. Although there are some differences of the levels of proinflammatory markers, ROS components and RAS components in brain and kidney tissues between males and females, the common result of all groups was increase in oxidative stress, inflammation markers and angiotensin system components with exposure to 900 MHz EMF. **Significance:** In conclusion, our study suggested that the 900 MHz EMF can activate brain and kidney renin-angiotensin system, and this activation is maybe related to inflammation and oxidative stress in both male and female offsprings.

Kim S, Han D, Ryu J, Kim K, Kim YH. Effects of mobile phone usage on sperm quality - No time-dependent relationship on usage: A systematic review and updated meta-analysis. Environ Res 202:111784, 2021. (Review)

Background: Mobile phones emit radiofrequency (RF) electromagnetic waves (EMWs), a low-level RF that can be absorbed by the human body and exert potential adverse effects on the brain, heart, endocrine system, and reproductive function. Owing to the novel findings of numerous studies published since 2012 regarding the effect of mobile phone use on sperm quality, we conducted a systematic review and updated meta-analysis to determine whether the exposure to RF-EMWs affects human sperm quality. **Methods:** This study was conducted in accordance with the PRISMA guidelines. The outcome measures depicting sperm quality were motility, viability, and concentration, which are the most frequently used parameters in clinical settings to assess fertility. **Results:** We evaluated 18 studies that included 4280 samples. Exposure to mobile phones is associated with reduced sperm motility, viability, and concentration. The decrease in sperm quality after RF-EMW exposure was not significant, even when the mobile phone usage increased. This finding was consistent across experimental in vitro and observational in vivo studies. **Discussion:** Accumulated data from in vivo studies show that mobile phone usage is harmful to sperm quality. Additional studies are needed to determine the effect of the exposure to EMWs from new mobile phone models used in the present digital environment.

(E) Kismali G, Ozgur E, Guler G, Akcay A, Sel T, Seyhan N. The influence of 1800 MHz GSM-like signals on blood chemistry and oxidative stress in non-pregnant and pregnant rabbits. Int J Radiat Biol. 88(5):414-419, 2012. (CE, MO, VO) (0.052 mW/cm^2)

PURPOSE: Environmental electromagnetic fields originate from man-made sources, such as mobile phones and base stations, and have led to increasing public concern about their possible adverse health effects. We aimed to investigate the possible effects of radiofrequency radiation (RFR) generated from these devices on oversensitive animals, such as pregnant rabbits. MATERIALS AND METHODS: In the present study, the effects of whole body 1800 MHz Global System for Mobile Communications (GSM)-like RFR exposure for 15 min/day for seven days on blood chemistry and lipid peroxidation levels in both non-pregnant and pregnant New Zealand White rabbits were investigated. Thirteen-month-old rabbits were studied in the following four groups: Non-pregnant control, non-pregnant RFR-exposed, pregnant control and pregnant RFR-exposed. RESULTS: Lipid peroxidation, namely malondialdehyde (MDA) levels, did not change after RFR exposure.

However, blood chemistry parameters, such as cholesterol (CHO), total protein (TP), albumin (ALB), uric acid, creatinin and creatine kinase (CK) and creatine kinase-myocardial band isoenzyme (CK-MB) changed due to both pregnancy and RFR exposure. CONCLUSION: Our investigations have been shown that no indication for oxidative stress was detected in the blood of pregnant rabbits upon RF exposure at specific conditions employed in the present study. Minor changes in some blood chemistry parameters were detected but CK-MB and CK increases were found remarkable. Studies on RFR exposure during pregnancy will help establish international standards for the protection of pregnant women from environmental RFR.

(NE) Klug S, Hetscher M, Giles S, Kohlsmann S, Kramer K, The lack of effects of nonthermal RF electromagnetic fields on the development of rat embryos grown in culture. Life Sci 61(18):1789-1802, 1997. (AE, DE, IU, ME, MO)

Rat embryos (9.5 days old) were exposed for up to 36 h to various radio frequency (RF) electric and magnetic fields (modulation frequency: 16, 60, 120 Hz; electric field strength: 60, 600 V/m; magnetic induction: 0.2, 2.0 microT). A resonator technique was used to generate standing waves thus fulfilling three conditions: The site of maximum electric and magnetic oscillations could be separated, the field strengths were known exactly and a high homogeneity over the sample volume was achieved. In each frequency region the transmitter power levels were set to give specific absorption rate (SAR) values spreading from far below to far above the values met in the field of telecommunication (0.2, 1.0 and 5.0 W/kg). The criteria used to examine the embryos on day 11.5 for possible structural effects consisted of a scoring system, photographs, histology using both light and electron microscopy and determination of the protein content. All these data have been taken as sets of different intermediate frequency (IF) amplitude modulation of the RF carriers. Neither the electric nor the magnetic fields tested interfered significantly with the normal growth and differentiation of the embryos in vitro.

(E) Köktürk S, Yardimoglu M, Celikozlu SD, Dolanbay EG, Cimbiz A. Effect of Lycopersicon esculentum extract on apoptosis in the rat cerebellum, following prenatal and postnatal exposure to an electromagnetic field. Exp Ther Med. 6(1):52-56, 2013. (CE, DE, IU, ME, PN) (No dosimetry data)

The expansion of mobile phone technology has raised concerns regarding the effect of 900-MHz electromagnetic field (EMF) exposure on the central nervous system. At present, the developing human brain is regularly exposed to mobile telephones, pre- and postnatally. Several studies have demonstrated the acute effects of EMF exposure during pre- or postnatal periods; however, the chronic effects of EMF exposure are less understood. Thus, the aim of the present study was to determine the chronic effects of EMF on the pre- and postnatal rat cerebellum. The control group was maintained in the same conditions as the experimental groups, without the exposure to EMF. In the EMF1 group, the rats were exposed to EMF during pre- and postnatal periods (until postnatal day 80). In the EMF2 group, the rats were also exposed to EMF pre- and postnatally; in addition, however, they were provided with a daily oral supplementation of *Lycopersicon*

esculentum extract (~2 g/kg). The number of caspase-3-labeled Purkinje neurons and granule cells present in the rats in the control and experimental groups were then counted. The neurodegenerative changes were studied using cresyl violet staining, and these changes were evaluated. In comparison with the control animals, the EMF1 group demonstrated a significant increase in the number of caspase-3-labeled Purkinje neurons and granule cells present in the cerebellum (P<0.001). However, in comparison with the EMF1 group, the EMF2 group exhibited significantly fewer caspase-3-labeled Purkinje neurons and granule cells in the cerebellum. In the EMF1 group, the Purkinje neurons were revealed to have undergone dark neuron degenerative changes. However, the presence of dark Purkinje neurons was reduced in the EMF2 group, compared with the EMF1 group. The results indicated that apoptosis and neurodegeneration in rats exposed to EMF during pre- and postnatal periods may be reduced with *Lycopersicon esculentum* extract therapy.

(E) Koldayev VM, Shchepin YV. Effects of electromagnetic radiation on embryos of sea-urchins. Bioelectrochem Bioenerg 43:161-164, 1997. (AE, DE, MO, IU, MO, OX, VO)

Electromagnetic radiation (EMR) causes a decrease in the number of fertilized eggs and an increase in the number of zygotes with abnormal fertilization envelopes in sea-urchins. The microstructural impairments of the cellular surface, the increase of lipid peroxidation and the changes of amino acid metabolism show that the impairments of the development of embryos exposed to EMR are caused by the damages of the membrane structures.

(E) Kolodynski AA, Kolodynska VV, Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. Sci Total Environ 180(1):87-93, 1996. (CE, BE, DE, HU)

This paper presents the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased.

(E)Koohestanidehaghi Y, Khalili MA, Fesahat F, Seify M, Mangoli E, Kalantar SM, Not tola S, Macchiarelli G, Palmerini MG. Detrimental effects of radiofrequency electromagnetic waves emitted by mobile phones on morphokinetics, oxidative stress, and apoptosis in mouse preimplantation embryos. Environ Pollut 336:122411, 2023. (AE, F, GE, IV, ME, OX) (0.636-1.8 W/kg**)**

Due to the increasing use of smart mobile phones, the impact of radiofrequency electromagnetic radiation (RF-EMR) on reproductive health has become a serious concern. This study investigated the effect of mobile phone RF-EMR with frequency 900-1800 MHZ on the mouse embryo morphokinetics and genotoxic effect in laboratory conditions. After ovarian stimulation in mice, the MII oocytes were collected and underwent by in vitro fertilization (IVF) method. The generated zygotes were divided into control and exposed groups. Then, the zygotes with 30 min of exposure to mobile phone RF-EMR, and the control zygotes without exposure, were

incubated in the time-lapse for 5 days. The intracellular reactive oxygen species (ROS) level, morphokinetic, embryo viability rate, and Gene expression were evaluated. Exposure of zygotes to RF-EMR by inducing ROS caused a significant decrease in blastocyst viability (87.85 ± 2.86 versus 94.23 ± 2.44), delay in cleavage development (t3-t12) and also increased the time (in hours) to reach the blastocyst stage (97.44 ± 5.21 versus 92.56 ± 6.7) compared to the control group. A significant increase observed in mRNA levels of Hsp70 in exposed animals; while Sod gene expression showed a significant down-regulation in this group compared to the controls, respectively. However, there was no significant change in the transcript level of proapoptotic and antiapoptotic genes in embryos of the exposed group compared to the controls. RF-EMR emitted by mobile phone with a frequency of 900-1800 MHZ, through inducing the production of ROS and oxidative stress, could negatively affect the growth and development as well as the transcript levels of oxidative stress associated genes in the preimplantation embryos of mice.

Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M. Detrimental impact of cell phone radiation on sperm DNA integrity. Clin Exp Reprod Med 2024 Jan 24. doi: 10.5653/cerm.2023.06121. Online ahead of print. (Review)

Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones-generally the most widely used devices-can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.

(E) Krause CM, Bjornberg CH, Pesonen M, Hulten A, Liesivuori T, Koivisto M, Revonsuo A, Laine M, Hamalainen H. Mobile phone effects on children's event-related oscillatory EEG during an auditory memory task. Int J Radiat Biol. 82(6):443-450, 2006. (AE, BE, HU, NU)

Purpose: To assess the effects of electromagnetic fields (EMF) emitted by mobile phones (MP) on the 1 - 20 Hz event-related brain oscillatory EEG (electroencephalogram) responses in children performing an auditory memory task (encoding and recognition). Materials and methods: EEG data were gathered while 15 subjects (age 10 - 14 years) performed an auditory memory task both with and without exposure to a digital 902 MHz MP in counterbalanced order. Results: During memory encoding, the active MP modulated the event-related desynchronization/synchronization (ERD/ERS) responses in the approximately 4 - 8 Hz EEG frequencies. During recognition, the active MP transformed these brain oscillatory responses in the approximately 4 - 8 Hz and approximately 15 Hz frequencies. Conclusions: The current findings suggest that EMF emitted by mobile phones has effects on brain oscillatory responses during cognitive processing in children.

(E) Kubinyi G, Thuroczy G, Bakos J, Boloni E, Sinay H, Szabo LD, Effect of continuous-wave and amplitude-modulated 2.45 GHz microwave radiation on the liver

and brain aminoacyl-transfer RNA synthetases of in utero exposed mice. Bioelectromagnetics 17(6):497-503, 1996. (CE, GE, IU, MO, VO)

Investigations have been carried out concerning the effects of microwave (MW) exposure on the aminoacyl-transfer ribonucleic acid (tRNA) synthetase of the progeny of females that were exposed during their entire period of gestation (19 days). The changes caused by continuous-wave (CW) and amplitude-modulated (AM) MW radiation have been compared. CFLP mice were exposed to MW radiation for 100 min each day in an anechoic room. The MW frequency was 2.45 GHz, and the amplitude modulation had a 50 Hz rectangular waveform (on/off ratio, 50/50%). The average power density exposure was 3 mW/cm^2, and the whole body specific absorption rate (SAR) was 4.23 +/- 0.63 W/kg. The weight and mortality of the progeny were followed until postnatal day 24. Aminoacyl-tRNA synthetase enzymes and tRNA from the brains and livers of the offspring (461 exposed, 487 control) were isolated. The aminoacyl-tRNA synthetase activities were determined. The postnatal increase of body weight and organ weight was not influenced by the prenatal MW radiation. The activity of enzyme isolated from the brain showed a significant decrease after CW MW exposure, but the changes were not significant after 50 Hz AM MW exposure. The activity of the enzyme isolated from liver increased under CW and 50 Hz modulated MW.

Kühn S, Jennings W, Christ A, Kuster N. Assessment of induced radio-frequency electromagnetic fields in various anatomical human body models. Phys Med Biol. 54(4):875-890, 2009. (Dosimetry)

The reference levels for testing compliance of human exposure with radio-frequency (RF) safety limits have been derived from very simplified models of the human. In order to validate these findings for anatomical models, we investigated the absorption characteristics for various anatomies ranging from 6 year old child to large adult male by numerical modeling. We address the exposure to plane-waves incident from all major six sides of the humans with two orthogonal polarizations each. Worst-case scattered field exposure scenarios have been constructed in order to test the implemented procedures of current in situ compliance measurement standards (spatial averaging versus peak search). Our findings suggest that the reference levels of current electromagnetic (EM) safety guidelines for demonstrating compliance as well as some of the current measurement standards are not consistent with the basic restrictions and need to be revised.

(E) Kumar S, Kesari KK, Behari J. Influence of microwave exposure on fertility of male rats. Fertil Steril. 95(4):1500-1502, 2011. (Spermatozoa were studied.) (CE, FC, M, OX, VO) (Low SAR)

The present study investigates the effect of 10-GHz microwave radiation on the fertility pattern of 70-day-old male rats (sham exposed and exposed), which were exposed for 2 h/d for 45 days continuously at a specific absorption rate of 0.014 W/kg and a power density of 0.21 mW/cm(2). Results show a significant change in the level of reactive oxygen species, histone kinase, apoptotic cells, and percentage of G(2)/M transition phase of cell cycle in the exposed group compared with the sham-exposed group. The study concludes that there is a significant effect of microwave radiations on the reproductive pattern in male rats, which is a causative factor of male infertility.

(E) Kumar S, Kesari KK, Behari J. The therapeutic effect of a pulsed electromagnetic

field on the reproductive patterns of male Wistar rats exposed to a 2.45-GHz microwave field. Clinics (Sao Paulo). 66(7):1237-1245, 2011. (CE, M, MO, OX, VO) (Low SAR 0.014W/kg)

INTRODUCTION: Environmental exposure to man-made electromagnetic fields has been steadily increasing with the growing demand for electronic items that are operational at various frequencies. Testicular function is particularly susceptible to radiation emitted by electromagnetic fields. OBJECTIVES: This study aimed to examine the therapeutic effects of a pulsed electromagnetic field (100 Hz) on the reproductive systems of male Wistar rats (70 days old). METHODS: The experiments were divided into five groups: microwave sham, microwave exposure (2.45 GHz), pulsed electromagnetic field sham, pulsed electromagnetic field (100 Hz) exposure, and microwave/pulsed electromagnetic field exposure. The animals were exposed for 2 hours/day for 60 days. After exposure, the animals were sacrificed, their sperm was used for creatine and caspase assays, and their serum was used for melatonin and testosterone assays. RESULTS: The results showed significant increases in caspase and creatine kinase and significant decreases in testosterone and melatonin in the exposed groups. This finding emphasizes that reactive oxygen species (a potential inducer of cancer) are the primary cause of DNA damage. However, pulsed electromagnetic field exposure relieves the effect of microwave exposure by inducing Faraday currents. CONCLUSIONS: Electromagnetic fields are recognized as hazards that affect testicular function by generating reactive oxygen species and reduce the bioavailability of androgen to maturing spermatozoa. Thus, microwave exposure adversely affects male fertility, whereas pulsed electromagnetic field therapy is a non-invasive, simple technique that can be used as a scavenger agent to combat oxidative stress.

(E) Kumar S, Behari J, Sisodia R. Impact of microwave at X-band in the aetiology of male infertility. Electromagn Biol Med. 31(3):223-232, 2012. (CE, M, MO, OX, VO) (Low SAR)

Reports of declining male fertility have renewed interest in assessing the role of environmental and occupational exposures to electromagnetic fields (EMFs) in the aetiology of human infertility. Testicular functions are particularly susceptible to electromagnetic fields. The aim of the present work was to investigate the effect of 10-GHz EMF on male albino rat's reproductive system and to investigate the possible causative factor for such effect of exposure. The study was carried out in two groups of 70-day old adult male albino rats: a sham-exposed and a 10-GHz-exposed group (2 h a day for 45 days). Immediately after completion of the exposure, animals were sacrificed and sperms were extracted from the cauda and caput part of testis for the analysis of MDA, melatonin, and creatine kinase. Creatine kinase results revealed an increased level of phosphorylation that converts creatine to creatine phosphate in sperms after EMF exposure. EMF exposure also reduced the level of melatonin and MDA. It is concluded that microwave exposure could adversely affect male fertility by reducing availability of the above parameters. These results are indications of deleterious effects of these radiations on reproductive pattern of male rats.

(E) Kumar S, Behari J, Sisodia R. Influence of electromagnetic Fields on reproductive system of male rats. Int J Radiat Biol. 89(3):149-154, 2013. (CE, GE, M, ME, MO, VO)

(Low SAR)

Purpose: Reports of declining male fertility have renewed interest in the role of environmental and occupational exposures in the etiology of human infertility. The aim of the present work is to investigate the effect of 10 GHz exposure on male Wistar rat's reproductive system and to find out the possible causative factors. Materials and methods: The study was divided into sham exposed and exposed groups. Seventy days old rats were exposed to 10 GHz microwave radiation for two hours per day for 45 days at power density 0.21mW/cm(2) and specific absorption rate (SAR) of 0.014W/kg. After the end of the experiment, blood samples were collected for the estimation of in vivo chromosomal aberration damage and micronucleus test. Spermatozoa were taken out for estimation of caspase3, comet assay, testosterone and electron microscopy and compared with sham exposed. Results: The study of scanning electron microscopic revealed shrinkage of the lumen of the seminiferous tubules. Apoptotic bodies were found in exposed group. A flow cytometry examination showed formation of micronuclei body in lymphocytes of exposed group. Comet assay confirmed DNA (deoxyribonucleic acid) strand break. Testosterone level was found significantly decreased with the shrinkage of testicular size. Conclusions: 10 GHz field has an injurious effect on fertility potential of male exposed animals.

(NE) Kumlin T, Iivonen H, Miettinen P, Juvonen A, van Groen T, Puranen L, Pitkäaho R, Juutilainen J, Tanila H. Mobile phone radiation and the developing brain: behavioral and morphological effects in juvenile rats. Radiat Res. 168(4):471-479, 2007. (CE, BE, DE, ME, NU, VO) (Improve learning and memory in water-maze test).

The increasing use of mobile phones by children and teenagers has raised concerns about their safety. Addressing such concerns is difficult, because no data are available on possible effects from long-term exposure to radiofrequency (RF) fields during the development of the nervous system. Possible morphological and functional changes were evaluated in the central nervous system of young male Wistar rats exposed to 900 MHz mobile phone signal for 2 h/day on 5 days/week. After 5 weeks of exposure at whole-body average specific energy absorption rates of 0.3 or 3.0 W/kg or sham exposure, six rats per group were examined histologically, and the remaining 18 rats per group were subjected to behavioral tests. No degenerative changes, dying neurons, or effects on the leakage of the blood-brain barrier were detected. No group differences were observed in the open-field test, plus maze test or acoustic startle response tests. In the water maze test, however, significantly improved learning ($P = 0.012$) and memory ($P = 0.01$) were detected in rats exposed to RF fields. The results do not indicate a serious threat to the developing brain from mobile phone radiation at intensities relevant to human exposure. However, the interesting finding of improved learning and memory warrants further studies.

(E) Kunjilwar KK, Behari J Effect of amplitude-modulated radio frequency radiation on cholinergic system of developing rats. Brain Res 601(1-2):321-324, 1993. (CE, DE, MO, NU, VO) (Low SAR 0.1-0.14 W/kg)

We examined the effect of long-term exposure to radio frequency radiation 147 MHz and its sub-harmonics 73.5 and 36.75 MHz amplitude modulated at 16 and 76 Hz (30-35 days, 3 h

per day) on cholinergic systems in developing rat brain. A significant decrease in acetylcholine esterase activity was found in exposed rats as compared to the control. Decrease in acetylcholine esterase (AChE) activity was independent of carrier wave frequencies. A short-term exposure did not have any significant effect on AChE activity.

(NE) Kuribayashi M, Wang J, Fujiwara O, Doi Y, Nabae K, Tamano S, Ogiso T, Asamoto M, Shirai T. Lack of effects of 1439 MHz electromagnetic near field exposure on the blood-brain barrier in immature and young rats. Bioelectromagnetics. 26(7):578-588, 2005. (CE, DE, GE, FC, VO)

Possible effects of 1439 MHz electromagnetic near field (EMF) exposure on the blood-brain barrier (BBB) were investigated using immature (4 weeks old) and young (10 weeks old) rats, equivalent in age to the time when the BBB development is completed and the young adult, respectively. Alteration of BBB related genes, such as those encoding p-glycoprotein, aquaporin-4, and claudin-5, was assessed at the protein and mRNA levels in the brain after local exposure of the head to EMF at 0, 2, and 6 W/kg specific energy absorption rates (SARs) for 90 min/day for 1 or 2 weeks. Although expression of the 3 genes was clearly decreased after administration of 1,3-dinitrobenzene (DNB) as a positive control, when compared with the control values, there were no pathologically relevant differences with the EMF at any exposure levels at either age. Vascular permeability, monitored with reference to transfer of FITC-dextran, FD20, was not affected by EMF exposure. Thus, these findings suggest that local exposure of the head to 1439 MHz EMF exerts no adverse effects on the BBB in immature and young rats.

(E) Kuybulu AE, Öktem F, Çiriş İM, Sutcu R, Örmeci AR, Çömlekçi S, Uz E. Effects of long-term pre- and post-natal exposure to 2.45 GHz wireless devices on developing male rat kidney. Ren Fail. 38(4):571-580, 2016. (CE, IU, ME, MO, OX, PN) (Low SAR 0.143 W/kg)

Purpose The aim of the present study was to investigate oxidative stress and apoptosis in kidney tissues of male Wistar rats that pre- and postnatally exposed to wireless electromagnetic field (EMF) with an internet frequency of 2.45 GHz for a long time. Methods The study was conducted in three groups of rats which were pre-natal, post-natal. and sham exposed groups. Oxidative stress markers and histological evaluation of kidney tissues were studied. Results Renal tissue malondialdehyde (MDA) and total oxidant (TOS) levels of pre-natal group were high and total antioxidant (TAS) and superoxide dismutase (SOD) levels were low. Spot urine NAG/creatinine ratio was significantly higher in pre- and post-natal groups ($p < 0.001$). Tubular injury was detected in most of the specimens in post-natal groups. Immunohistochemical analysis showed low-intensity staining with Bax in cortex, high-intensity staining with Bcl-2 in cortical and medullar areas of pre-natal group (p values, 0.000, 0.002, 0.000, respectively) when compared with sham group. Bcl2/Bax staining intensity ratios of medullar and cortical area was higher in pre-natal group than sham group ($p = 0.018$, $p = 0.011$). Conclusion Based on this study, it is thought that chronic pre- and post-natal period exposure to wireless internet frequency of EMF may cause chronic kidney damages; staying away from EMF source in especially pregnancy and early childhood period may reduce negative effects of exposure on kidney.

(NE) Kwon MS, Huotilainen M, Shestakova A, Kujala T, Näätänen R, Hämäläinen H. No effects of mobile phone use on cortical auditory change-detection in children: An ERP study. Bioelectromagnetics.31(3):191-199, 2010. (AE, BE, HU, NU)

We investigated the effect of mobile phone use on the auditory sensory memory in children. Auditory event-related potentials (ERPs), P1, N2, mismatch negativity (MMN), and P3a, were recorded from 17 children, aged 11-12 years, in the recently developed multi-feature paradigm. This paradigm allows one to determine the neural change-detection profile consisting of several different types of acoustic changes. During the recording, an ordinary GSM (Global System for Mobile Communications) mobile phone emitting 902 MHz (pulsed at 217 Hz) electromagnetic field (EMF) was placed on the ear, over the left or right temporal area (SAR(1g) = 1.14 W/kg, SAR(10g) = 0.82 W/kg, peak value = 1.21 W/kg). The EMF was either on or off in a single-blind manner. We found that a short exposure (two 6 min blocks for each side) to mobile phone EMF has no statistically significant effects on the neural change-detection profile measured with the MMN. Furthermore, the multi-feature paradigm was shown to be well suited for studies of perception accuracy and sensory memory in children. However, it should be noted that the present study only had sufficient statistical power to detect a large effect size.

(E) Larsen AI, Olsen J, Svane O, Gender-specific reproductive outcome and exposure to high-frequency electromagnetic radiation among physiotherapists. Scand J Work Environ Health 17(5):324-329, 1991. (DE, HU)

The aim of this case-referent study was to investigate reproductive hazards other than congenital malformations after exposure to high-frequency electromagnetic radiation. Cases and referents were sampled from a cohort of pregnancies of members of the Union of Danish Physiotherapists through linkage of the union file with national medical registers. Case groups were spontaneous abortions and children with low birth-weight prematurity, and stillbirth/death within one year. Exposure to high-frequency electromagnetic radiation before and during pregnancy was assessed through telephone interviews. As referents to the 270 cases, 316 pregnancies were randomly sampled. A total of 8.4% did not participate. Only 23.5% of the children born by the highly exposed mothers were boys. This value is a statistically significantly altered gender ratio showing a dose-response pattern. High-frequency electromagnetic radiation was furthermore associated with low birthweight, but only for male newborns. The other outcomes were not statistically significantly associated with exposure to high-frequency electromagnetic radiation.

(NE) Laudisi F, Sambucci M, Nasta F, Pinto R, Lodato R, Altavista P, Lovisolo GA, Marino C, Pioli C. Prenatal exposure to radiofrequencies: Effects of WiFi signals on thymocyte development and peripheral T cell compartment in an animal model. Bioelectromagnetics. 33(8):652-661, 2012. (CE, IU, ME, VO) SAR discussed but not provided.) (see Sambucci et al. 2011)

Wireless local area networks are an increasing alternative to wired data networks in workplaces, homes, and public areas. Concerns about possible health effects of this type of signal, especially when exposure occurs early in life, have been raised. We examined the effects of prenatal (in utero) exposure to wireless fidelity (WiFi) signal-associated electromagnetic fields (2450 MHz center-frequency band) on T cell development and

function. Pregnant mice were exposed whole body to a specific absorption rate of 4 W/kg, 2 h per day, starting 5 days after mating and ending 1 day before the expected delivery. Sham-exposed and cage control groups were used as controls. No effects on cell count, phenotype, and proliferation of thymocytes were observed. Also, spleen cell count, CD4/CD8 cell frequencies, T cell proliferation, and cytokine production were not affected by the exposure. These findings were consistently observed in the male and female offspring at early (5 weeks of age) and late (26 weeks of age) time points. Nevertheless, the expected differences associated with aging and/or gender were confirmed. In conclusion, our results do not support the hypothesis that the exposure to WiFi signals during prenatal life results in detrimental effects on the immune T cell compartment.

La Vignera S, Condorelli RA, Vicari E, D'Agata R, Calogero AE. Effects of the exposure to mobile phones on male reproduction: a review of the literature. J Androl 33(3):350-356, 2012. (Review)

The use of mobile phones is now widespread. A great debate exists about the possible damage that the radiofrequency electromagnetic radiation (RF-EMR) emitted by mobile phones exerts on different organs and apparatuses. The aim of this article was to review the existing literature exploring the effects of RF-EMR on the male reproductive function in experimental animals and humans. Studies have been conducted in rats, mice, and rabbits using a similar design based upon mobile phone RF exposure for variable lengths of time. Together, the results of these studies have shown that RF-EMR decreases sperm count and motility and increases oxidative stress. In humans, 2 different experimental approaches have been followed: one has explored the effects of RF-EMR directly on spermatozoa and the other has evaluated the sperm parameters in men using or not using mobile phones. The results showed that human spermatozoa exposed to RF-EMR have decreased motility, morphometric abnormalities, and increased oxidative stress, whereas men using mobile phones have decreased sperm concentration, decreased motility (particularly rapid progressive motility), normal morphology, and decreased viability. These abnormalities seem to be directly related to the duration of mobile phone use.

(NE) Lee HJ, Lee JS, Pack JK, Choi HD, Kim N, Kim SH, Lee YS. Lack of teratogenicity after combined exposure of pregnant mice to CDMA and WCDMA radiofrequency electromagnetic fields. Radiat Res. 172(5):648-652, 2009. (CE, DE, IU, ME)

Concern about the possible adverse effects of radiofrequency (RF)-field exposure on public health has increased because of the extensive use of wireless mobile phones and other telecommunication devices in daily life. The murine fetus is a very sensitive indicator of the effects of stress or stimuli in the environment. Therefore, we investigated the teratogenic effects of multi-signal radiofrequency electromagnetic fields (RF EMFs) on mouse fetuses. Pregnant mice were simultaneously exposed to two types of RF signals, single code division multiple access (CDMA) and wideband code division multiple access (WCDMA). Mice received two 45-min RF-field exposures, separated by a 15-min interval, daily throughout the entire gestation period. The whole-body average specific absorption rate (SAR) of CDMA or WCDMA was 2.0 W/kg. The animals were killed humanely on the 18th day of gestation and fetuses were examined for mortality, growth retardation, changes in head size and other morphological abnormalities. From

the results, we report for the first time that simultaneous experimental exposure to CDMA and WCDMA RF EMFs did not cause any observable adverse effects on mouse fetuses.

(NE) Lee HJ, Pack JK, Kim TH, Kim N, Choi SY, Lee JS, Kim SH, Lee YS. The lack of histological changes of CDMA cellular phone-based radio frequency on rat testis. Bioelectromagnetics.31(7):528-534, 2010. (CE, M, ME, MO, VO)

We examined the histological changes by radiofrequency (RF) fields on rat testis, specifically with respect to sensitive processes such as spermatogenesis. Male rats were exposed to 848.5 MHz RF for 12 weeks. The RF exposure schedule consisted of two 45-min RF exposure periods, separated by a 15-min interval. The whole-body average specific absorption rate (SAR) of RF was 2.0 W/kg. We then investigated correlates of testicular function such as sperm counts in the cauda epididymis, malondialdehyde concentrations in the testes and epididymis, frequency of spermatogenesis stages, germ cell counts, and appearance of apoptotic cells in the testes. We also performed p53, bcl-2, caspase 3, p21, and PARP immunoblotting of the testes in sham- and RF-exposed animals. Based on these results, we concluded that subchronic exposure to 848.5 MHz with 2.0 W/kg SAR RF did not have any observable adverse effects on rat spermatogenesis.

(NE) Lee HJ, Jin YB, Kim TH, Pack JK, Kim N, Choi HD, Lee JS, Lee YS. The effects of simultaneous combined exposure to CDMA and WCDMA electromagnetic fields on rat testicular function. Bioelectromagnetics. 33(4):356-364, 2012. (CE, M, ME, MO, VO)

Wireless mobile phones and other telecommunication devices are used extensively in daily life. We therefore examined the effects of combined exposure to radiofrequency electromagnetic fields (RF-EMF) on rat testicular function, specifically with respect to sensitive processes such as spermatogenesis. Male rats were exposed to single code division multiple access (CDMA) and wideband code division multiple access (WCDMA) RF signals for 12 weeks. The RF exposure schedule comprised 45 min/day, 5 days/week for a total of 12 weeks. The whole-body average specific absorption rate (SAR) of CDMA and WCDMA was 2.0 W/kg each or 4.0 W/kg in total. We then investigated the correlates of testicular function such as sperm count in the cauda epididymis, testosterone concentration in the blood serum, malondialdehyde concentrations in the testes and epididymis, frequency of spermatogenesis stages, and appearance of apoptotic cells in the testes. We also immunoblotted for p53, bcl2, GADD45, cyclin G, and HSP70 in the testes of sham- and combined RF-exposed animals. Based on the results, we concluded that simultaneous exposure to CDMA and WCDMA RF-EMFs at 4.0 W/kg SAR did not have any observable adverse effects on rat spermatogenesis.

(E) Lee W, Yang KL. Using medaka embryos as a model system to study biological effects of the electromagnetic fields on development and behavior. Ecotoxicol Environ Saf. 108:187-164, 2014. (BE, CE, DE, IU) (Medaka is 'Japanese rice fish'.)

The electromagnetic fields (EMFs) of anthropogenic origin are ubiquitous in our environments. The health hazard of extremely low frequency and radiofrequency EMFs has been investigated for decades, but evidence remains inconclusive, and animal studies are

urgently needed to resolve the controversies regarding developmental toxicity of EMFs. Furthermore, as undersea cables and technological devices are increasingly used, the lack of information regarding the health risk of EMFs to aquatic organisms needs to be addressed. Medaka embryos (Oryzias latipes) have been a useful tool to study developmental toxicity in vivo due to their optical transparency. Here we explored the feasibility of using medaka embryos as a model system to study biological effects of EMFs on development. We also used a white preference test to investigate behavioral consequences of the EMF developmental toxicity. Newly fertilized embryos were randomly assigned to four groups that were exposed to an EMF with 3.2 kHz at the intensity of 0.12, 15, 25, or 60μT. The group exposed to the background 0.12μT served as the control. The embryos were exposed continually until hatch. They were observed daily, and the images were recorded for analysis of several developmental endpoints. Four days after hatching, the hatchlings were tested with the white preference test for their anxiety-like behavior. The results showed that embryos exposed to all three levels of the EMF developed significantly faster. The endpoints affected included the number of somites, eye width and length, eye pigmentation density, midbrain width, head growth, and the day to hatch. In addition, the group exposed to the EMF at 60μT exhibited significantly higher levels of anxiety-like behavior than the other groups did. In conclusion, the EMF tested in this study accelerated embryonic development and heightened anxiety-like behavior. Our results also demonstrate that the medaka embryo is a sensitive and cost-efficient in vivo model system to study developmental toxicity of EMFs.

Lerchl A. Animal studies on growth and development. Prog Biophys Mol Biol 107(3):404-407, 2011. (Review)

Despite the fact that no plausible biological mechanism has yet been identified how electromagnetic fields below recommended exposure limits could negatively affect health of animals or humans, many experiments have been performed in various animal species, mainly mice and rats, to investigate the possible effects on growth and development. While older studies often suffered from sub-optimal exposure conditions, recent investigations, using sophisticated exposure devices and thus preventing thermal effects, have been performed without these limitations. In principle, two types of studies can be addressed: those which have investigated the carcinogenic or co-carcinogenic effects of exposure in developing animals, and those which have been done in developing animals without the focus on carcinogenic or co-carcinogenic effects. In both areas, the vast majority of publications did not show adverse effects. The largest study so far has been done in normal mice which have been chronically exposed to UMTS signals up to 1.3 W/kg SAR, thus 16 times higher than the whole-body exposure limit for humans. Even after four generations, no systematic or dose-dependent alterations in development or fertility could be found, supporting the view that negative effects on humans are very unlikely. Ongoing experiments in our laboratory investigate the effects of head-only exposure in rats (up to 10 W/kg local SAR) which are exposed from 14 days of age daily for 2 h. A battery of behavioral tests is performed in young, adult, and pre-senile animals. The results will help to clarify possible effects of exposure on brain development.

(NE) Lewis RC, Mínguez-Alarcón L, Meeker JD, Williams PL, Mezei G, Ford JB, Hauser R; EARTH Study Team. Self-reported mobile phone use and semen parameters among men from a fertility clinic. Reprod Toxicol. 71:165, 2017. (CE, HU, M, ME)

There is increasing concern that use of mobile phones, a source of low-level radio-frequency electromagnetic fields, may be associated with poor semen quality, but the epidemiologic evidence is limited and conflicting. The relationship between mobile phone use patterns and markers of semen quality was explored in a longitudinal cohort study of 153 men that attended an academic fertility clinic in Boston, Massachusetts. Information on mobile phone use duration, headset or earpiece use, and the body location in which the mobile phone was carried was ascertained via nurse-administered questionnaire. Semen samples (n=350) were collected and analyzed onsite. To account for multiple semen samples per man, linear mixed models with random intercepts were used to investigate the association between mobile phone use and semen parameters. Overall, there was no evidence for a relationship between mobile phone use and semen quality.

Li C, Chen Z, Yang L, Lv B, Liu J, Varsier N, Hadjem A, Wiart J, Xie Y, Ma L, Wu T. Generation of infant anatomical models for evaluating electromagnetic field exposures. Bioelectromagnetics. 36(1):10-26, 2015. (Dosimetry)

Realistic anatomical modeling is essential in analyzing human exposure to electromagnetic fields. Infants have significant physical and anatomical differences compared with other age groups. However, few realistic infant models are available. In this work, we developed one 12-month-old male whole body model and one 17-month-old male head model from magnetic resonance images. The whole body and head models contained 28 and 30 tissues, respectively, at spatial resolution of 1 mm × 1 mm × 1 mm. Fewer identified tissues in the whole body model were a result of the low original image quality induced by the fast imaging sequence. The anatomical and physical parameters of the models were validated against findings in published literature (e.g., a maximum deviation as 18% in tissue mass was observed compared with the data from International Commission on Radiological Protection). Several typical exposure scenarios were realized for numerical simulation. Dosimetric comparison with various adult and child anatomical models was conducted. Significant differences in the physical and anatomical features between adult and child models demonstrated the importance of creating realistic infant models. Current safety guidelines for infant exposure to radiofrequency electromagnetic fields may not be conservative.

Li C, Wu T. Dosimetry for infant exposures to electronic article surveillance system: Posture, physical dimension and anatomy. Bioelectromagnetics. 36(4):319-324, 2015. (Dosimetry)

The use of electronic article surveillance (EAS) systems has become popular in many public sites. As a consequence, concern has risen about infant exposure to magnetic fields (MFs) from this kind of device. To evaluate infant exposure to MFs of an EAS system (operating at 125 kHz and 13.56 MHz), we numerically compared dosimetric results among adult, child and infant models. Results revealed that postures insignificantly influenced dosimetric

results if there was a similar cross-sectional area under exposure. Although safety limits are unlikely to be exceeded, the infant has higher SAR values for brain and central nervous system tissues compared with adult (1.5x at 125 kHz and 112x at 13.56 MHz), which deserve further investigation. Infant's specific anatomy (e.g., non-proportionally large head and high fat content) did not induce higher SAR values. The numerical models developed in the study (stroller and postured infant models) could be freely used for nonprofit academic research.

(E)Li R, Ma M, Li L, Zhao L, Zhang T, Gao X, Zhang D, Zhu Y, Peng Q, Luo X, Wang M. The Protective Effect of Autophagy on DNA Damage in Mouse Spermatocyte-Derived Cells Exposed to 1800 MHz Radiofrequency Electromagnetic Fields. Cell Physiol Biochem 48(1):29-41, 2018. (AE, M, GE, IV, MO, OX) autophagy

Background/aims: The effects of exposure to radiofrequency electromagnetic fields (RF-EMFs) on the male reproductive system have raised public concern and studies have shown that exposure to RF-EMFs can induce DNA damage and autophagy. However, there are no related reports on the role of autophagy in DNA damage in spermatocytes, especially after exposure to RF-EMFs. The aim of the present study was to determine the mechanism and role of autophagy induced by RF-EMFs in spermatozoa cells. **Methods:** Mouse spermatocyte-derived cells (GC-2) were exposed to RF-EMFs 4 W/kg for 24 h. The level of reactive oxygen species (ROS) was determined by ROS assay kit. Comet assay was utilized to detect DNA damage. Autophagy was detected by three indicators: LC3II/LC3I, autophagic vacuoles, and GFP-LC3 dots, which were measured by western blot, transmission electron microscopy, and transfection with GFP-LC3, respectively. The expression of the molecular signaling pathway AMP-activated protein kinase (AMPK)/mTOR was determined by western blot. **Results:** The results showed that RF-EMFs induced autophagy and DNA damage in GC-2 cells via ROS generation, and the autophagy signaling pathway AMPK/mTOR was activated by ROS generation. Furthermore, following inhibition of autophagy by knockdown of AMPKα, increased DNA damage was observed in GC-2 cells following RF-EMFs exposure, and overexpression of AMPKα promoted autophagy and attenuated DNA damage. **Conclusions:** These findings demonstrated that the autophagy which was induced by RF-EMFs via the AMPK/mTOR signaling pathway could prevent DNA damage in spermatozoa cells.

(E) Li Z-Q, Zhang Y, Wan Y-M, Zhou Q, Liu H-X, Mu Y-Z, He Y-F, Rauniyar R, Wu X-N. Testing of behavioral and cognitive development in rats after prenatal exposure to 1800 and 2400 MHz radiofrequency fields. J Radiat Res 61(2):197-206, 2020. (BE, CE, GE, IU, MO, VO) (No dosimetry data)

The objective of the study was to explore the effects of behavioral and cognitive development in rats after prenatal exposure to 1800 and 2400 MHz radiofrequency fields. Pregnant female rats were exposed to radiofrequency fields beginning on the 21st day of pregnancy. The indicators of physiological and behavioral development were observed and measured in the offspring rats: Y maze measured at 3-weeks postnatal, open field at 7-weeks postnatal, and the expression of N-methyl-D-aspartate receptors (NMDARs) measured by reverse transcription-PCR in the hippocampus at 9-weeks postnatal. The body weight of the 1800 MHz group and the 1800 MHz + WiFi group showed a downward trend. The eye opening time of newborn rats was much

earlier in the WiFi group than in the control group. Compared to the control group, the overall path length of the 1800 MHz + WiFi group was shortened and the stationary time was delayed. The path length of the WiFi group was shortened and the average velocity was increased in the error arm. The 1800 MHz + WiFi group displayed an increased trend in path length, duration, entry times and stationary time in the central area. In both the 1800 MHz + WiFi and WiFi groups, NR2A and NR2B expression was down-regulated, while NR2D, NR3A and NR3B were up-regulated. Moreover, NR1 and NR2C in the WiFi group were also up-regulated. Prenatal exposure to 1800 MHz and WiFi radiofrequency may affect the behavioral and cognitive development of offspring rats, which may be associated with altered mRNA expression of NMDARs in the hippocampus.

(E) Liddle CG, Putnam JP, Huey OP, Alteration of life span of mice chronically exposed to 2.45 GHz CW microwaves. Bioelectromagnetics 15(3):177-181, 1994. (CE, DE, VO)

Female CD1 mice were exposed from the thirty-fifth day of age for the remainder of their lives to 2.45 GHz, CW-microwave radiation at a power density of 3 or 10 mW/cm2 (SAR = 2.0 or 6.8 W/kg). Exposures took place 1 h/day, 5 day/week in an anechoic chamber at an ambient temperature of 22 degrees C and a relative humidity of 50%. There were 25 animals in each exposure group, and an equal number of controls were concurrently sham exposed. The average life span of animals exposed at 10 mW/cm2 was significantly shorter than that of sham-exposed controls (572 days vs. 706 days; P = .049; truncation > 20%). In contrast, the average lifespan of the animals exposed at 3 mW/cm2 was slightly, but not significantly, longer (738 days) than that of controls (706 days).

Lim H, Choi J, Joo H, Ha M. Exposures to radio-frequency electromagnetic fields and their impacts on children's health – What the science knows? Current Opinion in Environmental Science & Health. 32:100456, 2023. (Review)

The possible health effects of radiofrequency electromagnetic radiation on children have become a public concern due to biological vulnerability of developing children. To evaluate the evidence for possible adverse health effects on children, we systematically reviewed epidemiological studies, and briefly reviewed the experimental animal or mechanistic studies. Using a search strategy and risk-of-bias assessment, we summarized the existing data on cancer, birth outcome, neurocognitive development, and behavioral problems. There was no sufficient evidence to determine the adverse effects. Recent large-scale animal studies have shown carcinogenic findings, but the biological mechanism has not yet been elucidated. A well-designed future study is needed to produce high-quality scientific evidence of the possible harmful effects of radiofrequency electromagnetic radiation exposure in children.

(E) Lin Y-Y, Wu T, Liu J-Y, Gao P, Li K-C, Guo Q-Y, Yuan M, Lang H-Y, Zeng L-H, Guo G-Z. 1950 MHz Radio Frequency Electromagnetic Radiation Inhibits Testosterone Secretion of Mouse Leydig Cells. Int J Environ Res Public Health 15(1):17, 2017. (AE, IV, M, ME, MO)

More studies that are focused on the bioeffects of radio-frequency (RF) electromagnetic radiation that is generated from the communication devices, but there were few reports with confirmed results about the bioeffects of RF radiation on reproductive cells. To explore the effects of 1950 MHz RF electromagnetic radiation (EMR) on mouse Leydig (TM3) cells. TM3 cells were irradiated or sham-irradiated continuously for 24 h by the specific absorption rate (SAR) 3 W/kg radiation. At 0, 1, 2, 3, 4, and 5 days after irradiation, cell proliferation was detected by cell counting kit-8 (CCK-8) method, cell cycle distribution, percentage of apoptosis, and cellular reactive oxygen species (ROS) were examined by flow cytometry, Testosterone level was measured using enzyme-linked immunosorbent assay (ELISA) assay, messenger ribonucleic acid (mRNA) expression level of steroidogenic acute regulatory protein (StAR) and P450scc in TM3 cells was detected by real-time polymerase chain reaction (PCR). After being irradiated for 24 h, cell proliferation obviously decreased and cell cycle distribution, secretion capacity of Testosterone, and P450scc mRNA level were reduced. While cell apoptosis, ROS, and StAR mRNA level did not change significantly. The current results indicated that 24 h of exposure at 1950 MHz 3 W/kg radiation could cause some adverse effects on TM3 cells proliferation and Testosterone secretion, further studies about the biological effects in the reproductive system that are induced by RF radiation are also needed.

(E) Liu C, Gao P, Xu SC, Wang Y, Chen CH, He MD, Yu ZP, Zhang L, Zhou Z. Mobile phone radiation induces mode-dependent DNA damage in a mouse spermatocyte-derived cell line: a protective role of melatonin. Int J Radiat Biol. 89(11):993-1001, 2013. (CE, GE, IV, M, OX) (No dosimetry data)

Purpose: To evaluate whether exposure to mobile phone radiation (MPR) can induce DNA damage in male germ cells. Materials and methods: A mouse spermatocyte-derived GC-2 cell line was exposed to a commercial mobile phone handset once every 20 minutes in standby, listen, dialed or dialing modes for 24 h. DNA damage was determined using an alkaline comet assay. Results: The levels of DNA damage were significantly increased following exposure to MPR in the listen, dialed and dialing modes. Moreover, there were significantly higher increases in the dialed and dialing modes than in the listen mode. Interestingly, these results were consistent with the radiation intensities of these modes. However, the DNA damage effects of MPR in the dialing mode were efficiently attenuated by melatonin pretreatment. Conclusions: These results regarding mode-dependent DNA damage have important implications for the safety of inappropriate mobile phone use by males of reproductive age and also suggest a simple preventive measure, keeping our body from mobile phones as far away as possible, not only during conversations but during "dialed" and "dialing" operation modes as well. Since the "dialed" mode is actually part of the standby mode, mobile phones should be kept at a safe distance from our body even during standby operation. Furthermore, the protective role of melatonin suggests that it may be a

promising pharmacological candidate for preventing mobile phone use-related reproductive impairments.

(E) Liu K, Zhang G, Wang Z, Liu Y, Dong J, Dong X, Liu J, Cao J, Ao L, Zhang S. The protective effect of autophagy on mouse spermatocyte derived cells exposure to 1800MHz radiofrequency electromagnetic radiation. Toxicol Lett. 228(3):216-224, 2014. (AE, FC, IV, ME, OX)

The increasing exposure to radiofrequency (RF) radiation emitted from mobile phone use has raised public concern regarding the biological effects of RF exposure on the male reproductive system. Autophagy contributes to maintaining intracellular homeostasis under environmental stress. To clarify whether RF exposure could induce autophagy in the spermatocyte, mouse spermatocyte-derived cells (GC-2) were exposed to 1800MHz Global System for Mobile Communication (GSM) signals in GSM-Talk mode at specific absorption rate (SAR) values of 1 w/kg, 2 w/kg or 4 w/kg for 24h, respectively. The results indicated that the expression of LC3-II increased in a dose- and time-dependent manner with RF exposure, and showed a significant change at the SAR value of 4 w/kg. The autophagosome formation and the occurrence of autophagy were further confirmed by GFP-LC3 transient transfection assay and transmission electron microscopy (TEM) analysis. Furthermore, the conversion of LC3-I to LC3-II was enhanced by co-treatment with Chloroqrine (CQ), indicating autophagic flux could be enhanced by RF exposure. Intracellular ROS levels significantly increased in a dose- and time-dependent manner after cells were exposed to RF. Pretreatment with anti-oxidative NAC obviously decreased the conversion of LC3-I to LC3-II and attenuated the degradation of p62 induced by RF exposure. Meanwhile, phosphorylated extracellular-signal-regulated kinase (ERK) significantly increased after RF exposure at the SAR value of 2w/kg and 4w/kg. Moreover, we observed that RF exposure did not increase the percentage of apoptotic cells, but inhibition of autophagy could increase the percentage of apoptotic cells. These findings suggested that autophagy flux could be enhanced by 1800MHz GSM exposure (4w/kg), which is mediated by ROS generation. Autophagy may play an important role in preventing cells from apoptotic cell death under RF exposure stress.

(E) Lokhmatova SA, [The effect of low-intensity prolonged impulse electromagnetic irradiation in the UHF range on the testes and the appendages of the testis in rats]. Radiats Biol Radioecol 34(2):279-285, 1994. [Article in Russian] (CE, M, ME, VO)

The influence of the long (4 months, 2 hr/day) impulsive electromagnetic irradiation with the power density of 0.25 mW/cm2 on the testes and epididymides was studied. The results demonstrate the high sensitivity of the rat testes and epididymides to electromagnetic field of 3 GHz. Some destructive changes both in the seminiferous tubules and testicular tissue were found. The full recovery has not been observed even 4 months after irradiation was finished.

(E) Lukac N, Massanyi P, Roychoudhury S, Capcarova M, Tvrda E, Knazicka Z, Kolesarova A, Danko J. In vitro effects of radiofrequency electromagnetic waves on bovine spermatozoa motility. J Environ Sci Health A Tox Hazard Subst Environ Eng. 46(12):1417-1423, 2011. (AE, FC, IV, M)

In this study the effects of 1800 MHz GSM-like radiofrequency electromagnetic waves (RF-EMW) exposure on bovine semen was monitored. The experimental samples were analyzed in vitro in four time periods (0, 30, 120 and 420 min) and compared with unexposed samples (control). Spermatozoa motility was determined by computer assisted semen analyzer (CASA). Evaluation of the percentage of motile spermatozoa showed significant ($P < 0.001$) decrease in experimental groups after 120 and 420 min of culture when exposed to microwaves, in comparison to control. Similar spermatozoa motility inhibition was detected for the percentage of progressively motile spermatozoa, too. Average path distance decreased significantly ($p < 0.001$) in experimental groups after 30 and 420 min of culture. Path velocity increased in the experimental groups exposed to RF-EMW after 30 minutes of culture, but subsequently decreased after 420 min of culture, in comparison to control. This indicates a possible initial stimulation and subsequent velocity inhibition of bovine spermatozoa under RF-EMW exposure. Changes in spermatozoa motility were also detected for some fine parameters, too. A significant decrease ($P < 0.001$) was noted for amplitude of lateral head displacement in the experimental group after 420 minutes of culture. Detailed in vitro motility analysis of bovine spermatozoa exposed to microwave radiation suggested that the parameters of path and velocity at the beginning of the culture significantly increase, but after longer culture (420 minutes) a significant decrease occur in the experimental group as compared to control. In general, results of this experiment indicate a negative time-dependent effect of 1800 MHz RF-EMW radiation on bovine spermatozoa motility.

(E) Luo Q, Jiang Y, Jin M, Xu J, Huang HF. Proteomic Analysis on the Alteration of Protein Expression in the Early-Stage Placental Villous Tissue of Electromagnetic Fields Associated With Cell Phone Exposure. Reprod Sci. 20(9):1055-1061, 2013. (AE, F, HU, MO)

Background:To explore the possible adverse effects and search for cell phone electromagnetic field (EMF)-responsive proteins in human early reproduction, a proteomics approach was employed to investigate the changes in protein expression profile induced by cell phone EMF in human chorionic tissues of early pregnancy in vivo. Methods: Volunteer women about 50 days pregnant were exposed to EMF at the average absorption rate of 1.6 to 8.8 W/kg for 1 hour with the irradiation device placed 10 cm away from the umbilicus at the midline of the abdomen. The changes in protein profile were examined using 2-dimensional electrophoresis (2-DE). Results: Up to 15 spots have yielded significant change at least 2- to 2.5-folds up or down compared to sham-exposed group. Twelve proteins were identified- procollagen-proline, eukaryotic translation elongation factor 1 delta, chain D crystal structure of human vitamin D-binding protein, thioredoxin-like 3, capping protein, isocitrate dehydrogenase 3 alpha, calumenin, Catechol-O-methyltransferase protein, proteinase inhibitor 6 (PI-6; SerpinB6) protein, 3,2-trans-enoyl-CoA isomerase protein, chain B human erythrocyte 2,3-bisphosphoglycerate mutase, and nucleoprotein. Conclusion: Cell phone EMF might alter the protein profile of chorionic tissue of early pregnancy, during the most sensitive stage of the embryos. The exposure to EMF may cause adverse effects on cell proliferation and development of nervous system in early embryos. Furthermore, 2-DE coupled with mass spectrometry is a promising approach to elucidate the effects and search for new biomarkers for environmental toxic effects.

(E) Magras, IN, Xenos, TD, RF radiation-induced changes in the prenatal development of mice. Bioelectromagnetics 18(6):455-461, 1997. (CE, FC, VO)

The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an "antenna park." At these locations RF power densities between 168 nW/cm2 and 1053 nW/cm2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved.

Mahaldashtian M, Khalili MA, Anbari F, Seify M, Belli M. Challenges on the effect of cell phone radiation on mammalian embryos and fetuses: a review of the literature. Zygote 2021 Sep 29;1-7. doi: 10.1017/S0967199421000691. Online ahead of print. (Review)

Cell phones operate with a wide range of frequency bands and emit radiofrequency-electromagnetic radiation (RF-EMR). Concern on the possible health hazards of RF-EMR has been growing in many countries because these RF-EMR pulses may be absorbed into the body cells, directly affecting them. There are some in vitro and in vivo animal studies related to the consequences of RF-EMR exposure from cell phones on embryo development and offspring. In addition, some studies have revealed that RF-EMR from cellular phone may lead to decrease in the rates of fertilization and embryo development, as well as the risk of the developmental anomalies, other studies have reported that it does not interfere with in vitro fertilization or intracytoplasmic sperm injection success rates, or the chromosomal aberration rate. Of course, it is unethical to study the effect of waves generated from cell phones on the forming human embryos. Conversely, other mammals have many similarities to humans in terms of anatomy, physiology and genetics. Therefore, in this review we focused on the existing literature evaluating the potential effects of RF-EMR on mammalian embryonic and fetal development.

(E) Mahmoudabadi FS, Ziaei S, Firoozabadi M, Kazemnejad A. Use of mobile phone during pregnancy and the risk of spontaneous abortion. J Environ Health Sci Eng. 13:34, 2015. (CE, FC, HU. IU)

BACKGROUND: Exposure to electromagnetic fields of cell phones increasingly occurs, but the potential influence on spontaneous abortion has not been thoroughly investigated. METHODS: In a case-control study, 292 women who had an unexplained spontaneous abortion at < 14 weeks gestation and 308 pregnant women > 14 weeks gestation were enrolled. Two data collection forms were completed; one was used to collect data about socioeconomic and obstetric characteristics, medical and reproductive history, and lifestyles. Another was used to collect data about the use of cell phones during pregnancy. For the consideration of cell phone effects, we measured the average calling time per day, the location of the cell phones when not in use, use of hands-free equipment, use of phones for other applications, the specific absorption rate (SAR) reported by the manufacturer and the

average of the effective SAR (average duration of calling time per day × SAR). Analyses were carried out with statistical package state software(SPSS)v.16. RESULTS: All the data pertaining to mobile phones were different between the two groups except the use of hands free devices ($p < 0.001$). CONCLUSION: Our result suggests that use of mobile phones can be related to the early spontaneous abortions.

(E) Mailankot M, Kunnath AP, Jayalekshmi H, Koduru B, Valsalan R. Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. Clinics (Sao Paulo). 64(6):561-565, 2009. (CE, FC, M, ME, OX, VO) (No dosimetry data)

INTRODUCTION: Mobile phones have become indispensable in the daily lives of men and women around the globe. As cell phone use has become more widespread, concerns have mounted regarding the potentially harmful effects of RF-EMR from these devices. OBJECTIVE: The present study was designed to evaluate the effects of RF-EMR from mobile phones on free radical metabolism and sperm quality. MATERIALS AND METHODS: Male albino Wistar rats (10-12 weeks old) were exposed to RF-EMR from an active GSM (0.9/1.8 GHz) mobile phone for 1 hour continuously per day for 28 days. Controls were exposed to a mobile phone without a battery for the same period. The phone was kept in a cage with a wooden bottom in order to address concerns that the effects of exposure to the phone could be due to heat emitted by the phone rather than to RF-EMR alone. Animals were sacrificed 24 hours after the last exposure and tissues of interest were harvested. RESULTS: One hour of exposure to the phone did not significantly change facial temperature in either group of rats. No significant difference was observed in total sperm count between controls and RF-EMR exposed groups. However, rats exposed to RF-EMR exhibited a significantly reduced percentage of motile sperm. Moreover, RF-EMR exposure resulted in a significant increase in lipid peroxidation and low GSH content in the testis and epididymis. CONCLUSION: Given the results of the present study, we speculate that RF-EMR from mobile phones negatively affects semen quality and may impair male fertility.

(E) Makler A, Tatcher M, Vilensky A, Brandes JM. Factors affecting sperm motility. III. Influence of visible light and other electromagnetic radiations on human sperm velocity and survival. Fertil Steril. 33(4):439-444, 1980. (AE, FC, HU, IV, M) (No dosimetry data) (27 MHz electric field, 0.6 v/m)

Specimens of semen from fertile and infertile patients were exposed to different electromagnetic radiations, including visible light, ultraviolet (UV) light, x-rays, and high-frequency radio waves. Sperm motility was analyzed before, during, and after irradiation by the multiple exposure photography (MEP) method. No significant difference was found between controls and specimens exposed to various doses of visible and UV light and x-rays either immediately or several hours after exposure. In contrast to spermatozoa of other species that were reported to be adversely affected by visible and UV light and x-rays, human spermatozoa seem to be highly resistant to similar doses of these radiations. A deleterious influence was observed when high-frequency radio waves were applied to human spermatozoa. This may be attributed to an intracellular diathermic effect. The informative value of this study in relation to routine semen analyses and experimental studies in the physiology and comparative anatomy of spermatozoa is discussed.

(E) Malavolti M, Malagoli C, Wise LA, Poli M, Notari B, Taddei I, Fabbi S, Teggi S, Balboni E, Pancaldi A, Palazzi G, Vinceti M, Filippini T. Residential exposure to magnetic fields from transformer stations and risk of childhood leukemia. Environ Res. 245:118043, 2023. (CE, HU, VO) (cancer)

Background: Several studies have documented an increased risk of leukemia among children exposed to magnetic fields, with some evidence of dose-response relation. However, findings in some studies have been inconsistent, and data on the effects of different sources of exposure are lacking. In this study, we evaluated the relation of childhood leukemia risk to exposure to magnetic fields from transformer stations. Methods: We conducted a population-based case-control study in a pediatric population of two Northern Italian provinces of Modena and Reggio Emilia. We included 182 registry-identified childhood leukemia cases diagnosed during 1998-2019 and 726 population controls match on age, sex and province. We assessed exposure by calculating distance from childhood residence to the nearest transformer station within a geographical information system, computing disease odds ratios (ORs) and 95% confidence intervals (CIs) using conditional logistic regression, adjusting for potential confounders. We evaluated exposure using two buffers (15m and 25m radius) and assessed two case groups: leukemia (all subtypes) and acute lymphoblastic leukemia (ALL). Results: Residing within 15 m of a transformer station (vs. ≥15 m) was not appreciably associated with risk of leukemia (all subtypes) or ALL. We found similar results using a less stringent exposure buffer (25 m). Among children aged ≥5 years, the multivariable ORs were 1.3 (95% CI 0.1-12.8) for leukemia and 1.3 (95% CI 0.1-12.4) for ALL using the 15 m buffer, while they were 1.7 (95% CI 0.4-7.0) for leukemia and 0.6 (95% CI 0.1-4.8) for ALL using the 25 m buffer. Conclusions: While we found no overall association between residential proximity to transformer stations and childhood leukemia, there was some evidence for elevated risks of childhood leukemia among children aged ≥5 years. Precision was limited by the low numbers of exposed children.

(E) Manta AK, Papadopoulou D, Polyzos AP, Fragopoulou AF, Skouroliakou AS, Thanos D, Stravopodis DJ, Margaritis LH. Mobile-phone radiation-induced perturbation of gene-expression profiling, redox equilibrium and sporadic-apoptosis control in the ovary of Drosophila melanogaster. Fly (Austin). 11(2):75-95, 2017. (AE, F, GE, ME, OX, VO) (Low SAR)

The daily use by people of wireless communication devices has increased exponentially in the last decade, begetting concerns regarding its potential health hazards. Drosophila melanogaster four days-old adult female flies were exposed for 30 min to radiation emitted by a commercial mobile phone at a SAR of 0.15 W/kg and a SAE of 270 J/kg. ROS levels and apoptotic follicles were assayed in parallel with a genome-wide microarrays analysis. ROS cellular contents were found to increase by 1.6-fold (x), immediately after the end of exposure, in follicles of pre-choriogenic stages (germarium - stage 10), while sporadically generated apoptotic follicles (germarium 2b and stages 7-9) presented with an averaged 2x upregulation in their sub-population mass, 4 h after fly's irradiation with mobile device. Microarray analysis revealed 168 genes being differentially expressed, 2 h post-exposure, in response to radiofrequency (RF) electromagnetic field-radiation exposure (≥1.25x, $P < 0.05$) and associated with multiple and critical biological processes, such as basic metabolism and

cellular subroutines related to stress response and apoptotic death. Exposure of adult flies to mobile-phone radiation for 30 min has an immediate impact on ROS production in animal's ovary, which seems to cause a global, systemic and non-targeted transcriptional reprogramming of gene expression, 2 h post-exposure, being finally followed by induction of apoptosis 4 h after the end of exposure. Conclusively, this unique type of pulsed radiation, mainly being derived from daily used mobile phones, seems capable of mobilizing critical cytopathic mechanisms, and altering fundamental genetic programs and networks in D. melanogaster.

(E) Manta AK, Stravopodis DJ, Papassideri IS, Margaritis LH. Reactive oxygen species elevation and recovery in Drosophila bodies and ovaries following short-term and long-term exposure to DECT base EMF. Electromagn Biol Med. 33(2):118-131, 2014. (AE, F, OX, VO) (Low SAR)

The objective of this study was to approach the basic mechanism(s) underlying reported ovarian apoptotic cell death and fecundity decrease induced by nonionizing radiation (NIR) in Drosophila melanogaster. ROS (Reactive Oxygen Species) levels were measured in the bodies and the ovaries of (sexually mature) 4-day-old flies, following exposure for 0.5, 1, 6, 24 and 96 h to a wireless DECT (Digital Enhanced Cordless Telephone) base radiation (1.88-1.90 GHz). Electrical field intensity was 2.7 V/m, measured within the fly vials and calculated SAR (Specific Absorption Rate) value = 0.009 W/Kg. Male and female bodies showed twofold increase in ROS levels ($p < 0.001$) after 6 h of exposure, slightly increasing with more irradiation (24 and 96 h). Ovaries of exposed females had a quick response in ROS increase after 0.5 h (1.5-fold, $p < 0.001$), reaching 2.5-fold after 1 h with no elevation thereafter at 6, 24 and 96 h. ROS levels returned to normal, in the male and the female bodies 24 h after 6 h of exposure of the flies ($p < 0.05$) and in the ovaries 4 h after 1 h exposure of the females ($p < 0.05$). It is postulated that the pulsed (at 100 Hz rate and 0.08 ms duration) idle state of the DECT base radiation is capable of inducing free radical formation albeit the very low SAR, leading rapidly to accumulation of ROS in a level-saturation manner under continuous exposure, or in a recovery manner after interruption of radiation, possibly due to activation of the antioxidant machinery of the organism.

(E) Manta AK, Papadopoulou D, Polyzos AP, Fragopoulou AF, Skouroliakou AS, Thanos D, Stravopodis DJ, Margaritis LH. Mobile-phone Radiation-induced Perturbation of Gene-expression Profiling, Redox Equilibrium and Sporadic-apoptosis Control in the Ovary of Drosophila melanogaster. Fly (Austin). 11(2): 75-95, 2017. (AE, F, GE, OX, VO) (Low SAR)

BACKGROUND: The daily use by people of wireless communication devices has increased exponentially in the last decade, begetting concerns regarding its potential health hazards. METHODS: Drosophila melanogaster four days-old adult female flies were exposed for 30 min to radiation emitted by a commercial mobile phone at a SAR of 0.15 W/kg and a SAE of 270 J/kg. ROS levels and apoptotic follicles were assayed in parallel with a genome-wide microarrays analysis. RESULTS: ROS cellular contents were found to increase by 1.6 fold (x), immediately after the end of exposure, in follicles of pre-choriogenic stages

(germarium - stage 10), while sporadically generated apoptotic follicles (germarium 2b and stages 7-9) presented with an averaged 2x upregulation in their sub-population mass, 4 h after fly's irradiation with mobile device. Microarray analysis revealed 168 genes being differentially expressed, 2 h post-exposure, in response to radiofrequency (RF) electromagnetic field-radiation exposure (≥1.25x, P<0.05) and associated with multiple and critical biological processes, such as basic metabolism and cellular subroutines related to stress response and apoptotic death. CONCLUSION: Exposure of adult flies to mobile-phone radiation for 30 min has an immediate impact on ROS production in animal's ovary, which seems to cause a global, systemic and non-targeted transcriptional reprogramming of gene expression, 2 h post-exposure, being finally followed by induction of apoptosis 4 h after the end of exposure. Conclusively, this unique type of pulsed radiation, mainly being derived from daily used mobile phones, seems capable of mobilizing critical cytopathic mechanisms, and altering fundamental genetic programs and networks in D. melanogaster.

(E) Margaritis LH, Manta AK, Kokkaliaris CD, Schiza D, Alimisis K, Barkas G, Georgiou E, Giannakopoulou O, Kollia I, Kontogianni G, Kourouzidou A, Myari A, Roumelioti F, Skouroliakou A, Sykioti V, Varda G, Xenos K, Ziomas K. Drosophila oogenesis as a bio-marker responding to EMF sources. Electromagn Biol Med. 33(3)165-189, 2014. (CE, FC, ME, VO) (No dosimetry data)

The model biological organisms Drosophila melanogaster and Drosophila virilis have been utilized to assess effects on apoptotic cell death of follicles during oogenesis and reproductive capacity (fecundity) decline. A total of 280 different experiments were performed using newly emerged flies exposed for short time daily for 3-7 d to various EMF sources including: GSM 900/1800 MHz mobile phone, 1880-1900 MHz DECT wireless base, DECT wireless handset, mobile phone-DECT handset combination, 2.44 GHz wireless network (Wi-Fi), 2.44 GHz blue tooth, 92.8 MHz FM generator, 27.15 MHz baby monitor, 900 MHz CW RF generator and microwave oven's 2.44 GHz RF and magnetic field components. Mobile phone was used as a reference exposure system for evaluating factors considered very important in dosimetry extending our published work with D. melanogaster to the insect D. virilis. Distance from the emitting source, the exposure duration and the repeatability were examined. All EMF sources used created statistically significant effects regarding fecundity and cell death-apoptosis induction, even at very low intensity levels (0.3 V/m blue tooth radiation), well below ICNIRP's guidelines, suggesting that Drosophila oogenesis system is suitable to be used as a biomarker for exploring potential EMF bioactivity. Also, there is no linear cumulative effect when increasing the duration of exposure or using one EMF source after the other (i.e. mobile phone and DECT handset) at the specific conditions used. The role of the average versus the peak E-field values as measured by spectrum analyzers on the final effects is discussed.

Martinez-Burdalo M, Martin A, Anguiano M, Villar R. Comparison of FDTD-calculated specific absorption rate in adults and children when using a mobile phone at 900 and 1800 MHz. Phys Med Biol. 49(2):345-354, 2004. (Dosimetry)

In this paper, the specific absorption rate (SAR) in scaled human head models is analysed

to study possible differences between SAR in the heads of adults and children and for assessment of compliance with the international safety guidelines, while using a mobile phone. The finite-difference time-domain method (FDTD) has been used for calculating SAR values for models of both children and adults, at 900 and 1800 MHz. Maximum 1 g averaged SAR (SAR1 g) and maximum 10 g averaged SAR (SAR10 g) have been calculated in adults and scaled head models for comparison and assessment of compliance with ANSI/IEEE and European guidelines. Results show that peak SAR1 g and peak SAR10 g all trend downwards with decreasing head size but as head size decreases, the percentage of energy absorbed in the brain increases. So, higher SAR in children's brains can be expected depending on whether the thickness of their skulls and surrounding tissues actually depends on age. The SAR in eyes of different sizes, as a critical organ, has also been studied and very similar distributions for the full size and the scaled models have been obtained. Standard limits can only be exceeded in the unpractical situation where the antenna is located at a very short distance in front of the eye.

McIntosh RL, Deppeler L, Oliva M, Parente J, Tambuwala F, Turner S, Winship D, Wood AW. Comparison of radiofrequency exposure of a mouse dam and foetuses at 900 MHz. Phys Med Biol. 55(4):N111-122, 2010. (Dosimetry)

In vivo studies involving radiofrequency (RF) exposure of rodents require detailed dosimetric analysis to enable correct interpretation of biological outcomes. Detailed anatomical models of mice--a female, a pregnant female, a male and a foetus--have been developed for analyses using finite difference numerical techniques. The mouse models, consisting of 49 tissues, will be made freely available to the research community. In this note, the pregnant mouse model, which included eight mature foetuses, was utilized specifically to consider (a) the RF dosimetry in a radial cavity exposure system operated at a frequency of 900 MHz and (b) a 900 MHz plane wave exposure. A comparison was made between the exposure of the mouse dam and the foetuses as specified by the specific energy absorption rate (SAR) and the resultant temperature change. In general, the SAR levels in the foetuses were determined to be slightly lower (around 14% lower than the average values of the dam) and the peak temperature increase was significantly lower (45%) than the values in the dam.

(E) **Meena R, Kumari K, Kumar J, Rajamani P, Verma HN, Kesari KK. Therapeutic approaches of melatonin in microwave radiations-induced oxidative stress-mediated toxicity on male fertility pattern of Wistar rats. Electromagn Biol Med. 33(2):81-91, 2014. (CE, GE, M, OX, VO) (Low SAR)**

Microwave (MW) radiation produced by wireless telecommunications and a number of electrical devices used in household or in healthcare institutions may adversely affects the reproductive pattern. Present study aimed to investigate the protective effects of melatonin (is well known antioxidant that protects DNA, lipids and proteins from free radical damage) against oxidative stress-mediated testicular impairment due to long-term exposure of MWs. For this, 70-day-old male Wistar rats were divided into four groups (n = 6/group): Sham exposed, Melatonin (Mel) treated (2 mg/kg), 2.45 GHz MWs exposed and MWs + Mel treated. Exposure took place in Plexiglas cages for 2 h a day for 45 days where, power density (0.21 mW/cm^2) and specific absorption rate (SAR

0.14 W/Kg) were estimated. After the completion of exposure period, rats were sacrificed and various stress related parameters, that is LDH-X (lactate dehydrogenase isoenzyme) activity, xanthine oxidase (XO), ROS (reactive oxygen species), protein carbonyl content, DNA damage and MDA (malondialdehyde) were performed. Result shows that melatonin prevent oxidative damage biochemically by significant increase ($p < 0.001$) in the levels of testicular LDH-X, decreased ($p < 0.001$) levels of MDA and ROS in testis ($p < 0.01$). Meanwhile, it reversed the effects of MWs on XO, protein carbonyl content, sperm count, testosterone level and DNA fragmentation in testicular cells. These results concluded that the melatonin has strong antioxidative potential against MW induced oxidative stress mediated DNA damage in testicular cells.

(E) Meo SA, Al-Drees AM, Husain S, Khan MM, Imran MB. Effects of mobile phone radiation on serum testosterone in Wistar albino rats. Saudi Med J. 31(8):869-873, 2010. (CE, M, MO, VO) (No dosimetry data)

OBJECTIVE: To investigate the effects of electromagnetic field radiation generated by mobile phones on serum testosterone levels in Wistar albino rats. METHODS: This experimental interventional control study was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia during the period December 2006 to April 2008. A total of 34 male Albino rats [Wistar strain], 2 months of age, weighing 150-160 gm were used for the experiment. These animals were divided into 3 groups. The first group containing 6 rats was assigned as a control group. The second group containing 14 rats was exposed to mobile phone radiation for 30 minutes daily and the third group containing 14 rats was exposed to mobile phone radiation for 60 minutes daily for the total period of 3 months. At the end of experimental period, blood was collected into the container, and serum testosterone was analyzed using double-antibody radioimmunoassay method by Coat-A-Count. RESULTS: Exposure to mobile phone radiation for 60 minutes/day for the total period of 3 months significantly decrease the serum testosterone level [p=0.028] in Wistar Albino rats compared to their matched control. CONCLUSION: Long-term exposure to mobile phone radiation leads to reduction in serum testosterone levels. Testosterone is a primary male gender hormone and any change in the normal levels may be devastating for reproductive and general health.

(E) Meo SA, Arif M, Rashied S, Khan MM, Vohra MS, Usmani AM, Imran MB, Al-Drees AM. Hypospermatogenesis and spermatozoa maturation arrest in rats induced by mobile phone radiation. J Coll Physicians Surg Pak. 21(5):262-265, 2011. (CE, M, MC, VO) (No dosimetry data)

OBJECTIVE: To determine the morphological changes induced by mobile phone radiation in the testis of Wistar albino rats. STUDY DESIGN: Cohort study. Place and Duration of Study: Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia, from April 2007 to June 2008. METHODOLOGY: Forty male Wistar albino rats were divided in three groups. First group of eight served as the control. The second group [group B, n=16] was exposed to mobile phone radiation for 30 minutes/day and the third group [group C, n=16] was exposed to mobile phone radiation for 60 minutes/day for a total period of 3 months. Morphological changes in the testes induced by mobile phone radiations were observed under a light microscope. RESULTS: Exposure to mobile phone radiation for 60

minutes/day caused 18.75% hypospermatogenesis and 18.75% maturation arrest in the testis of albino rats compared to matched controls. However, no abnormal findings were observed in albino rats that were exposed to mobile phone radiation for 30 minutes/day for a total period of 3 months. CONCLUSION: Long-term exposure to mobile phone radiation can cause hypospermatogenesis and maturation arrest in the spermatozoa in the testis of Wistar albino rats.

Merhi M. Challenging cell phone impact on reproduction: a review. J Assist Reprod Genet 29(4):293-297, 2012. (Review)

Purpose: The radiofrequency electromagnetic radiation (RF-EMR) produced by cell phones can enhance the excitability of the brain and has recently been classified as carcinogenic. The suggested use of hands-free kits lowers the exposure to the brain, but it might theoretically increase exposure to the reproductive organs. This report summarizes the potential effects of RF-EMR on reproductive potentials in both males and females. **Methods:** A critical review of the literature pertaining to the impact of cell phone RF-EMR on reproduction in male and female animals and humans was performed, with a focus on gonad metabolism, apoptosis of reproductive cells, fertility status, and serum reproductive hormones. **Results:** While some animal and human studies revealed alterations in reproductive physiology in both males and females, others did not report any association. The in vitro and in vivo studies to date are highly diverse, very inconsistent in conduct and, in many cases, report different primary outcomes. **Conclusion:** The increasing use of cell phone warrants well-designed studies to ascertain the effect of their RF-EMR on reproduction.

(E) Mezhevikina LM, Khramov RN, Lepikhov KA , [The simulation of the cooperative effect of development in a culture of early mouse embryos after irradiation with electromagnetic waves in the millimeter range]. *Ontogenez* 31(1):27-31, 2000. [Article in Russian] (AE, DE, IV)

We have found that two-cell mouse embryos cultured in vitro can be stimulated by electromagnetic irradiation in the millimeter range. After 30 min of exposure, they acquire the ability to develop in culture on their own and can reach the stage of blastocyst in a relatively large volume of Whitten cultural medium (150 microliters) without serum or growth factors. It is proposed that millimeter range electromagnetic waves activate metabolic processes and specifically the synthesis of factors controlling early embryonic development in culture.

(E) Mjøen G, Saetre DO, Lie RT, Tynes T, Blaasaas KG, Hannevik M, Irgens LM. Paternal occupational exposure to radiofrequency electromagnetic fields and risk of adverse pregnancy outcome. Eur J Epidemiol. 21(7):529-535, 2006. (CE, DE. HU) (Birth defects)

BACKGROUND: During the last decades, public concern that radiofrequency radiation (RFR) may be related to adverse reproductive outcomes has been emerging. Our objective was to assess associations between paternal occupational exposure to RFR and adverse pregnancy outcomes including birth defects using population-based data from Norway. METHODS: Data on reproductive outcomes derived from the Medical Birth Registry of Norway were linked with data on paternal occupation derived from the general population

censuses. An expert panel categorized occupations according to exposure. Using logistic regression, we analyzed 24 categories of birth defects as well as other adverse outcomes. RESULTS: In the offspring of fathers most likely to have been exposed, increased risk was observed for preterm birth (odds ratio (OR): 1.08, 95% confidence interval (CI): 1.03, 1.15). In this group we also observed a decreased risk of cleft lip (OR: 0.63, 95% CI: 0.41, 0.97). In the medium exposed group, we observed increased risk for a category of "other defects" (OR: 2.40, 95% CI: 1.22, 4.70), and a decreased risk for a category of "other syndromes" (OR: 0.75, 95% CI: 0.56, 0.99) and upper gastrointestinal defects (OR: 0.61, 95% CI: 0.40, 0.93). CONCLUSION: The study is partly reassuring for occupationally exposed fathers.

Morales-Suárez-Varela M, Llopis-Morales A, Doccioli C, Donzelli G. Relationship between parental exposure to radiofrequency electromagnetic fields and primarily hematopoietic neoplasms (lymphoma, leukemia) and tumors in the central nervous system in children: a systematic review. Rev Environ Health. 2023 Mar 22. doi: 10.1515/reveh-2022-0248. (Review)

Low-frequency electromagnetic fields have grown exponentially in recent years due to technological development and modernization. The World Health Organization (WHO)/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields (RF-EMFs) as possibly carcinogenic to humans (Group 2B), and recent studies have investigated the association between exposure to electromagnetic fields in parents and possible health effects in children, especially the development of tumours of the central nervous system (CNS). The objective of this systematic review was to collate all evidence on the relationship between parental occupational exposure to electromagnetic fields and the development of CNS cancer in children and to evaluate this association. This review was prepared according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, Embase, and Web of Science were searched from January 1990 to April 2021. The search was conducted using the following search string: "occupational" AND "child" AND "electromagnetic" AND "cancer". Seventeen articles met our inclusion criteria: 13 case-control studies, two cohort studies, and 2 meta-analyses. Most of the studies showed several methodological weaknesses that limited their results. Due to a lack of consistency regarding the outcome as well as the heterogeneity in the reviewed studies, the body of evidence for the effects of parental exposure to electromagnetic fields is not clear. Methodological heterogeneity in the way that studies were conducted could be responsible for the lack of consistency in the findings. Overall, the body of evidence allows no conclusion on the question of whether parental exposure to electromagnetic.

(NE) Mortazavi SM, Shirazi KR, Mortazavi G. The study of the effects of ionizing and non-ionizing radiations on birth weight of newborns to exposed mothers. J Nat Sci Biol Med. 4(1):213-217, 2013. (CE, DE, HU)

OBJECTIVES: Life evolved in an environment filled with a wide variety of ionizing and non-ionizing radiation. It was previously reported that medical exposures to pregnant women increases the risk of low birth weight. This study intends to investigate the relationship between exposure to ionizing and non-ionizing radiation and the risk of low birth weight. MATERIALS AND METHODS: One thousand two hundred mothers with their first-term labor (vaginal or cesarean) whose newborns' history had been registered in neonates' screening program in Shiraz were interviewed and surveyed. Data collection was performed by the assessment of mother's history of radiography before and during pregnancy, physical examination of the mother for height and weight and weighing and examining the newborn for any diagnosis of disease and anomalies. RESULTS: There were no statistical significant differences between the mean weight of newborns whose mothers had been exposed to some common sources of ionizing and non-ionizing radiations such as dental or non dental radiographies, mobile phone, cordless phone and cathode ray tube (CRT) and those of non-exposed mothers. CONCLUSIONS: The findings of this study cast doubt on previous reports, which indicated that exposure to ionizing radiation during pregnancy increased the risk of low birth weight.

(E) Mortazavi S, Parsanezhad M, Kazempour M, Ghahramani P, Mortazavi A, Davari M. Male reproductive health under threat: Short term exposure to radiofrequency radiations emitted by common mobile jammers. J Hum Reprod Sci. 6(2):124-128, 2013. (CE, HU, M)

BACKGROUND: Modern life prompted man to increasingly generate, transmit and use electricity that leads to exposure to different levels of electromagnetic fields (EMFs). Substantial evidence indicates that exposure to common sources of EMF such as mobile phones, laptops or wireless internet-connected laptops decreases human semen quality. In some countries, mobile jammers are occasionally used in offices, shrines, conference rooms and cinemas to block the signal. AIMS: To the best of our knowledge, this is the first study to investigate the effect of short term exposure of human sperm samples to radiofrequency (RF) radiations emitted by common mobile jammers. SUBJECTS AND METHODS: Fresh semen samples were collected by masturbation from 30 healthy donors who had referred to Infertility Treatment Center at the Mother and Child Hospital with their wives. Female problem was diagnosed as the reason for infertility in these couples. STATISTICAL ANALYSIS: T-test and analysis of variance were used to show statistical significance. RESULTS: The motility of sperm samples exposed to jammer RF radiation for 2 or 4 h were significantly lower than those of sham-exposed samples. These findings lead us to the conclusion that mobile jammers may significantly decrease sperm motility and the couples' chances of conception. CONCLUSION: Based on these results, it can be suggested that in countries that have not banned mobile jammer use, legislations should be urgently passed to restrict the use of these signal blocking devices in public or private places.

(E) Movvahedi MM, Tavakkoli-Golpayegani A, Mortazavi SA, Haghani M, Razi Z, Shojaie-Fard MB, Zare M, Mina E, Mansourabadi L, Nazari-Jahromi, Safari A, Shokrpour N, Mortazavi SM. Does exposure to GSM 900 MHz mobile phone radiation affect short-term memory of elementary school students? J Pediatr Neurosci. 9(2):121-124, 2014. (AE, BE, HU)

BACKGROUND: Now-a-days, children are exposed to mobile phone radiation at a very early age. We have previously shown that a large proportion of children in the city of Shiraz, Iran use mobile phones. Furthermore, we have indicated that the visual reaction time (VRT) of university students was significantly affected by a 10 min real/sham exposure to electromagnetic fields emitted by mobile phone. We found that these exposures decreased the reaction time which might lead to a better response to different hazards. We have also revealed that occupational exposures to radar radiations decreased the reaction time in radar workers. The purpose of this study was to investigate whether short-term exposure of elementary school students to radiofrequency (RF) radiation leads to changes in their reaction time and short-term memory. MATERIALS AND METHODS: A total of 60 elementary school children ages ranging from 8 to 10 years studying at a public elementary school in Shiraz, Iran were enrolled in this study. Standardized computer-based tests of VRT and short-term memory (modified for children) were administered. The students were asked to perform some preliminary tests for orientation with the VRT test. After orientation, to reduce the random variation of measurements, each test was repeated ten times in both real and sham exposure phases. The time interval between the two subsequent sham and real exposure phases was 30 min. RESULTS: The mean ± standard deviation reaction times after a 10 min talk period and after a 10 min sham exposure (switched off mobile) period were 249.0 ± 82.3 ms and 252.9 ± 68.2 ms (P = 0.629), respectively. On the other hand, the mean short-term memory scores after the talk and sham exposure periods were 1062.60 ± 305.39, and 1003.84 ± 339.68 (P = 0.030), respectively. Conclusion: To the best of our knowledge, this is the first study to show that short-term exposure of elementary school students to RF radiation leads to the better performance of their short-term memory.

(E) Mugunthan N, Anbalagan J, Samy AS, Rajanarayanan S, Meenachi S. EFFECTS OF CHRONIC EXPOSURE TO 2G AND 3G CELL PHONE RADIATION ON MICE TESTIS – A RANDOMIZED CONTROLLED TRIAL. IJCRR. 7(4): 36-47, 2015. (CE, M, ME, MO, VO) (No dosimetry data)

Objective: The aim of our study is to evaluate possible effects of chronic exposure to 900 - 1800 MHz radiation emitted from 2G cell phone and 1900 -2200 MHz from 3G cell phone on the testis of mice and to compare the effects of 2G and 3G radiation on testis at the histological level. Methods: Mice were exposed to 2G and 3G ultra-high frequency radiation, 48 minutes per day for a period of 30 to 180 days. The sham control mice were exposed to similar conditions without 2G or 3G exposure. Animal's weight of 2G and 3G cell phone exposed group were recorded before sacrificing at the end of 30, 60, 90,120,150 and 180 days. Same numbers of control animals were sacrificed on the same period. Blood samples were collected to measure plasma testosterone. Both the testes were dissected and its size, weight and volume were measured. The testes were processed for histomorphometric study. Results: Following chronic exposure of 2G and 3G cell phone radiation in mice, there was significant reduction of animal weight at first, second and fourth month. The mean testis weight and volume of 2G and 3G radiation exposed mice were significantly reduced in the first three months. The comparison between 2G and 3G exposed groups, showed no significant changes in mean body weight, mean testis weight and mean testis volume. The mean density of seminiferous tubule, mean seminiferous tubule diameter, mean number of Sertoli and Leydig cells of 2G and 3G exposed groups had significantly lower value than the

control. The following microscopic changes were observed in the 2G and 3G radiation exposed mice testis over control. 1. Wide interstitium 2. Detachment of Sertoli cells and spermatogonia from the basal lamina. 3. Vacuolar degeneration and desquamation of seminiferous epithelium. 4. Peripheral tubules showed reduced thickness of seminiferous epithelium and maturation arrest in the spermatogenesis. 5. Seminiferous tubules scored 7 to 9 using Johnson testicular biopsy score count. The mean total serum testosterone level of first, second, third, fourth and sixth month 2G and 3G exposed mice had significantly lower serum testosterone level than control. However, comparison between 2G and 3G showed no significant difference in the mean serum testosterone level. Conclusion: Chronic exposure to ultra-high frequency radiation emitted from 2G and 3G cell phone could cause microscopic changes in the seminiferous epithelium, reduction of serum testosterone level, reduction in the number of Sertoli cells and Leydig cells.

Nagaoka T, Togashi T, Saito K, Takahashi M, Ito K, Ueda T, Osada H, Ito H, Watanabe S. An anatomically realistic voxel model of the pregnant woman and numerical dosimetry for a whole-body exposure to RF electromagnetic fields.Conf Proc IEEE Eng Med Biol Soc. 1:5463-5467, 2006. (Dosimetry)

The numerical dosimetry of pregnant women is one of the most important issues in electromagnetic-field safety. We have recently developed a whole-body numerical female model of an adult Japanese (non-pregnant) average figure. Therefore, a new fetus model including inherent tissues of pregnant women was constructed based on abdominal MRI data of a 7-month pregnant woman. A whole-body pregnant woman model was developed by combining the new fetus and the female models. The anatomical details of the developed pregnant woman model and basic SAR characteristics for whole-body exposure to RF electromagnetic fields are demonstrated.

Nagaoka T, Watanabe S. Estimation of variability of specific absorption rate with physical description of children exposed to electromagnetic field in the VHF band. Conf Proc IEEE Eng Med Biol Soc. 2009:942-945, 2009. (Dosimetry)

Recently, there has been an increasing concern regarding the effects of electromagnetic waves on the health of humans. The safety of radio frequency electromagnetic fields (RF-EMFs) is evaluated by the specific absorption rate (SAR). In recent years, SAR has been estimated by numerical simulation using fine-resolution and anatomically realistic reference whole-body voxel models of people of various ages. The variation in SAR with a change in the physical features of a real person is hardly studied, although every person has different physical features. In this study, in order to estimate the individual variability in SAR of persons, we obtained considerable 3D body shape data from actual three-year-old children and developed several homogeneous models of these children. The variability in SAR of the homogeneous models of three-year-old children for whole-body exposure to RF electromagnetic fields in the very high frequency (VHF) band calculated using the finite-difference time-domain method has been described.

Nagaoka T, Saito K, Takahashi M, Ito K, Watanabe S. Anatomically realistic reference models of pregnant women for gestation ages of 13, 18, and 26 weeks. Conf Proc

IEEE Eng Med Biol Soc. 2008:2817-2820, 2008. (Dosimetry)

The safety of a human body exposed to radio-frequency (RF) electromagnetic fields (EMFs) has become important today. In recent times, conducting numerical dosimetry on the mother and the fetus during pregnancy has become a particularly important issue. This paper outlines the development of pregnant woman models that were adjusted to the reference values of physiological characteristics of maternal tissues in pregnant women for gestation ages of 13, 18, and 26 weeks The models are composed of voxels of 2 x 2 x 2 mm(3), and there are 56 tissue types. The basic specific absorption rate (SAR) characteristics in the pregnant woman models for whole-body exposure to RF electromagnetic fields that were calculated using the finite-difference time-domain (FDTD) method are described here.

Nagaoka T, Kunieda E, Watanabe S. Proportion-corrected scaled voxel models for Japanese children and their application to the numerical dosimetry of specific absorption rate for frequencies from 30 MHz to 3 GHz. Phys Med Biol. 53(23):6695-6711, 2008. (Dosimetry)

The development of high-resolution anatomical voxel models of children is difficult given, inter alia, the ethical limitations on subjecting children to medical imaging. We instead used an existing voxel model of a Japanese adult and three-dimensional deformation to develop three voxel models that match the average body proportions of Japanese children at 3, 5 and 7 years old. The adult model was deformed to match the proportions of a child by using the measured dimensions of various body parts of children at 3, 5 and 7 years old and a free-form deformation technique. The three developed models represent average-size Japanese children of the respective ages. They consist of cubic voxels (2 mm on each side) and are segmented into 51 tissues and organs. We calculated the whole-body-averaged specific absorption rates (WBA-SARs) and tissue-averaged SARs for the child models for exposures to plane waves from 30 MHz to 3 GHz; these results were then compared with those for scaled down adult models. We also determined the incident electric-field strength required to produce the exposure equivalent to the ICNIRP basic restriction for general public exposure, i.e., a WBA-SAR of 0.08 W kg(-1).

(E) Nakamura, H, Seto, T, Nagase, H, Yoshida, M, Dan, S, Ogino, K, Effects of exposure to microwaves on cellular immunity and placental steroids in pregnant rats. Occup Environ Med 54(9):676-680, 1997. (AE, F, ME, MO, VO) (Pregnancy-specific effects) (SAR 1.8-2.2 W/kg)

OBJECTIVES: Microwaves produce various detrimental changes based on actions of heat or non-specific stress, although the effects of microwaves on pregnant organisms has not been uniform. This study was designed to clarify the effect of exposure to microwaves during pregnancy on endocrine and immune functions. METHODS: Natural killer cell activity and natural killer cell subsets in the spleen were measured, as well as some endocrine indicators in blood--corticosterone and adrenocorticotrophic hormone (ACTH) as indices of the hypothalamic-pituitary-adrenal axis--beta-endorphin, oestradiol, and progesterone in six female virgin rats and six pregnant rats (nine to 11 days gestation) exposed to microwaves at 10 mW/cm^2 incident power density at 2450 MHz for 90 minutes. The same measurements were performed in control rats (six virgin and six pregnant rats). RESULTS:

Skin temperature in virgin and pregnant rats increased immediately after exposure to microwaves. Although splenic activity of natural killer cells and any of the subset populations identified by the monoclonal antibodies CD16 and CD57 did not differ in virgin rats with or without exposure to microwaves, pregnant rats exposed to microwaves showed a significant reduction of splenic activity of natural killer cells and CD16+CD57-. Although corticosterone and ACTH increased, and oestradiol decreased in exposed virgin and pregnant rats, microwaves produced significant increases in beta-endorphin and progesterone only in pregnant rats. CONCLUSIONS: Microwaves at the power of 10 mW/cm^2 produced activation of the hypothalamic-pituitary-adrenal axis and increased oestradiol in both virgin and pregnant rats, suggesting that microwaves greatly stress pregnant organisms. These findings in pregnant rats suggest that--with exposure to microwaves--pregnancy induces immunosuppression, which could result in successful maintainance of pregnancy. This enhancement of adaptability to heat stress with pregnancy may be mediated by activation of placental progesterone and placental or pituitary beta-endorphin.

(E) Nakamura, H, Seto, T, Hatta, K, Matsuzaki, I, Nagase, H, Yoshida, M, Ogino, K, Natural killer cell activity reduced by microwave exposure during pregnancy is mediated by opioid systems. Environ Res 79(2):106-113, 1998. (AE, F, MO, VO) (SAR 0.36-0.44 W/kg)

We have previously demonstrated immunosuppression including reduced splenic natural killer cell activity (NKCA) in pregnant rats exposed to microwaves produced mainly by their thermal action. To examine the involvement of opioid systems in reduced NKCA in pregnant rats exposed to microwaves at a relatively low level (2 mW/cm^2 incident power density at 2450 MHz for 90 min), we assayed beta-endorphin (betaEP) in blood, pituitary lobes, and placenta as well as splenic NKCA in virgin and/or pregnant rats. Although microwaves elevated colonic temperatures by 0.8 degreesC for virgin and 0.9 degreesC for pregnant rats, and betaEP in blood and anterior pituitary lobes (AP) significantly, it did not change blood corticosterone as an index of hypothalamic-pituitary adrenal axis. There were significant interactions between pregnancy and microwave exposure on splenic NKCA, betaEP in both blood and AP, and blood progesterone. Intra-peritoneal administration of opioid receptor antagonist naloxone prior to microwave exposure increased NKCA, blood, and placental betaEP in pregnant rats. Alterations in splenic NKCA, betaEP and progesterone in pregnant rats exposed to microwaves may be due to both thermal and nonthermal actions. These results suggest that NKCA reduced by microwaves during pregnancy is mediated by the pituitary opioid system.

(NE) Nakamura H, Matsuzaki I, Hatta K, Nobukuni Y, Kambayashi Y, Ogino K. Nonthermal effects of mobile-phone frequency microwaves on uteroplacental functions in pregnant rats. Reprod Toxicol 2003 17(3):321-326, 2003. (AE, F, ME, MO, VO)

Exposure to high-density microwaves can cause detrimental effects on the testis, eye, and other tissues, and induce significant biologic changes through thermal actions. To examine nonthermal effect of continuous wave (CW) 915MHz microwaves used in cellular phones, we compared the effects of microwaves with those of heat. Thirty-six pregnant rats were assigned to six groups: rats exposed to microwaves at 0.6 or 3 mW/cm(2) incident power density at 915 MHz for 90min, rats immersed in water at 38 or 40 degrees C, which induces

about the same increase in colonic temperature of 1.0 or 3.5 degrees C as 0.6 or 3 mW/cm(2) microwaves, respectively; rats immersed in water at 34 degrees C, which is considered to be thermoneutral; and control rats. We identified significant differences in the uteroplacental circulation, and in placental endocrine and immune functions between pregnant rats immersed in water at 34 and 38 degrees C, but not between rats immersed at 38 degrees C and those exposed to microwaves at 0.6 mW/cm(2). By contrast, we observed significant decreases in uteroplacental blood flow and estradiol in rats exposed to microwaves at 3 mW/cm(2) as compared with those immersed in water at 40 degrees C. These results suggest microwaves at 0.6 mW/cm(2) at 915MHz, equal to a specific absorption rate (SAR) of 0.4 W/kg, which is the maximum permissible exposure level recommended by the American National Standards Institute (ANSI), do not exert nonthermal effects on blood estradiol and progesterone, on splenic natural killer cell activity, on the uteroplacental circulation.

(NE) Nakatani-Enomoto S, Okutsu M, Suzuki S, Suganuma R, Groiss SJ, Kadowaki S, Enomoto H, Fujimori K, Ugawa Y. Effects of 1950 MHz W-CDMA-like signal on human spermatozoa. Bioelectromagnetics. 37(6):373-381, 2016. (AE, FC, GE, M, VO)

There are growing concerns about how electromagnetic waves (EMW) emitted from mobile phones affect human spermatozoa. Several experiments have suggested harmful effects of EMW on human sperm quality, motility, velocity, or the deoxyribonucleic acid (DNA) of spermatozoa. In this study, we analyzed the effects on human spermatozoa (sperm motility and kinetic variables) induced by 1 h of exposure to 1950 MHz Wideband Code Division Multiple Access (W-CDMA)-like EMW with specific absorption rates of either 2.0 or 6.0 W/kg, using a computer-assisted sperm analyzer system. We also measured the percentage of 8-hydroxy-2'-deoxyguanosine (8-OHdG) positive spermatozoa with flow cytometry to evaluate damage to DNA. No significant differences were observed between the EMW exposure and the sham exposure in sperm motility, kinetic variables, or 8-OHdG levels. We conclude that W-CDMA-like exposure for 1 h under temperature-controlled conditions has no detectable effect on normal human spermatozoa. Differences in exposure conditions, humidity, temperature control, baseline sperm characteristics, and age of donors may explain inconsistency of our results with several previous studies.

(E) Narayanan SN, Lukose ST, Arun G, Mohapatra N, Pamala J, Concessao PL, Jetti R, Kedage V, Nalini K, Gopalakrishna Bhat P. Modulatory effect of 900 MHz radiation on biochemical and reproductive parameters in rats. Bratisl Lek Listy 119(9):581-587, 2018. (CE, M, ME, OX, VO)

In the present study, the effect of 900 MHz radiation exposure on blood biochemical and reproductive parameters was evaluated in adolescent rats. Male albino Wistar rats (8-10 weeks of age) were exposed to 900 MHz radiation (1hr/day, power density - 146.60 µW/cm2) from a mobile phone for 28 days. On 29th day the animals were euthanized and malondialdehyde (MDA), total antioxidants (TA) levels and Glutathione-S transferase (GST) activity were studied in the blood. Reproductive parameters such as total sperm count, percentage of non-motile sperms, and sperm morphology were determined. Testes sections were stained with H(et)E staining and their cellular integrity was evaluated. Caspase-3 activity in the testes was also determined. MDA concentration was increased but TA levels and GST activity were not found to

be different in 900 MHz group compared to controls. Sperm motility was found to be slightly reduced in 900 MHz group. Percentage of abnormal sperm was significantly elevated in 900 MHz group. Additionally, loss of germ cells particularly spermatocytes and spermatids was found in the testes of 900 MHz group. Testes caspase-3 activity was slightly elevated in 900 MHz exposed rats. Chronic 900 MHz exposure induced oxidative damage in the blood and lead to alterations in reproductive parameters in rats (Fig. 4, Ref. 33).

Negi P, Singh R. Association between reproductive health and nonionizing radiation exposure. Electromagn Biol Med 40(1):92-102, 2021. (Review)

Recently, a decreasing rate of fertility has to be credited to an array of factors such as environmental, health and lifestyle. Male infertility is likely to be affected by the strong exposure to heat and radiations. The most common sources of nonionizing radiations are cell phones, laptops, Wi-Fi and microwave ovens, which may participate to the cause of male infertility. One of the major sources of daily exposure to non-ionizing radiation is mobile phones. A mobile phone is now basically dominating our daily life through better services such as connectivity, smartphone devices. However, the health consequences are linked with their usage are frequently ignored. Constant exposure to non-ionizing radiations produced from a cell phone is one of the possible reasons for growing male infertility. Recently, several studies have shown that cell phone users have altered sperm parameters causing declining reproductive health. Cell phone radiation harms male fertility by affecting the different parameters like sperm motility, sperm count, sperm morphology, semen concentration, morphometric abnormalities, increased oxidative stress along with some hormonal changes. This review is focusing on the prevailing literature from in vitro and in vivo studies suggesting that non-ionizing exposure negatively affects human male infertility.

(E) Noor NA, Mohammed HS, Ahmed NA, Radwan NM. Variations in amino acid neurotransmitters in some brain areas of adult and young male albino rats due to exposure to mobile phone radiation. Eur Rev Med Pharmacol Sci. 15(7):729-742, 2011.(CE, MO, NU, VO) (difference between adult and young rats)

BACKGROUND AND OBJECTIVES: Mobile phone radiation and health concerns have been raised, especially following the enormous increase in the use of wireless mobile telephony throughout the world. The present study aims to investigate the effect of one hour daily exposure to electromagnetic radiation (EMR) with frequency of 900 Mz (SAR 1.165 w/kg, power density 0.02 mW/cm^2) on the levels of amino acid neurotransmitters in the midbrain, cerebellum and medulla of adult and young male albino rats. **MATERIALS AND METHODS:** Adult and young rats were divided into two main groups (treated and control). The treated group of both adult and young rats was exposed to EMR for 1 hour daily. The other group of both adult and young animals was served as control. The determination of amino acid levels was carried out after 1 hour, 1 month, 2 months and 4 months of EMR exposure as well as after stopping radiation. **RESULTS:** Data of the present study showed a significant increase in both excitatory and inhibitory amino acids in the cerebellum of adult and young rats and midbrain of adult animals after 1 hour of EMR exposure. In the midbrain of adult animals, there was a significant increase in glycine level after 1 month followed by significant increase in GABA after 4 months. Young rats showed significant decreases in the

midbrain excitatory amino acids. In the medulla, the equilibrium ratio percent (ER%) calculations showed a state of neurochemical inhibition after 4 months in case of adult animals, whereas in young animals, the neurochemical inhibitory state was observed after 1 month of exposure due to significant decrease in glutamate and aspartate levels. This state was converted to excitation after 4 months due to the increase in glutamate level. **CONCLUSION:** The present changes in amino acid concentrations may underlie the reported adverse effects of using mobile phones.

(E) Odaci E, Bas O, Kaplan S. Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study. Brain Res. 1238:224-229, 2008. (CE, IU, ME, VO) (SAR 2 W/Kg)

Electromagnetic fields (EMFs) inhibit the formation and differentiation of neural stem cells during embryonic development. In this study, the effects of prenatal exposure to EMF on the number of granule cells in the dentate gyrus of 4-week-old rats were investigated. This experiment used a control (Cont) group and an EMF exposed (EMF) group (three pregnant rats each group). The EMF group consisted of six offspring (n=6) of pregnant rats that were exposed to an EMF of up to 900 megahertz (MHz) for 60 min/day between the first and last days of gestation. The control group consisted of five offspring (n=5) of pregnant rats that were not treated at all. The offspring were sacrificed when they were 4 weeks old. The numbers of granule cells in the dentate gyrus were analyzed using the optical fractionator technique. The results showed that prenatal EMF exposure caused a decrease in the number of granule cells in the dentate gyrus of the rats ($P<0.01$). This suggests that prenatal exposure to a 900 MHz EMF affects the development of the dentate gyrus granule cells in the rat hippocampus. Cell loss might be caused by an inhibition of granule cell neurogenesis in the dentate gyrus.

(E)Odacı E, İkinc A, Yıldırım M, Kaya H, Akça M, Hancı H, Sönmez OF, Aslan A, Okuyan M, Baş O. The Effects of 900 Megahertz Electromagnetic Field Applied in the Prenatal Period on Spinal Cord Morphology and Motor Behavior in Female Rat Pups. NeuroQuantology 11(4) 573-581, 2013. (BE, CE, IU, ME. NU, VO) (0.0256 mW/cm^2)

This study investigated the effect of a 900 megahertz (MHz) electromagnetic field (EMF) applied in the prenatal period on the spinal cord and motor behavior of female rat pups. Beginning of the study, female Sprague Dawley rats (180–250 g) were left to mate with male rats. Rats identified as pregnant were then divided into control (n=3) and EMF groups (n=3). The EMF group was exposed to 1-h 900 MHz EMF daily between days 13 and 21 of pregnancy. At 21 days old, rat pups were removed from their mothers and divided into two newborn rat groups, control (n=13) and EMF (n=10). The rotarod test was applied to the rat pups to assess motor functions and the open field test to evaluate locomotor activity. On day 32 of the study, the rat pups were decapitated, and the spinal cord in the upper thoracic region was removed. Following routine histological tests, they were stained with Cresyl fast violet. Rotarod test results revealed a significant increase in EMF group rat pups' motor functions ($p=0.037$). However, no difference

was observed in the open field test results ($p>0.05$). In the EMF group' rat pups, we observed pathological changes in the spinal cord. On the basis of our results, 900 MHz EMF applied in the prenatal period affected spinal cord development. This effect was observed in the form of pathological changes in the spinal cord of rat pups, and it may be that these pathological changes led to an increase in rat pups' motor activities.

(E) Odacı E, Unal D, Mercantepe T, Topal Z, Hancı H, Türedi S, Erol H, Mungan S, Kaya H, Colakoğlu S. Pathological effects of prenatal exposure to a 900 MHz electromagnetic field on the 21-day-old male rat kidney. Biotech Histochem. 90(2):93-101, 2015. (CE, IU, ME, OX, VO) (Low SAR 0.024 W/kg)

We investigated the effects on kidney tissue of 900 megahertz (MHz) EMF applied during the prenatal period. Pregnant rats were exposed to 900 MHz EMF, 1 h/day, on days 13-21 of pregnancy; no procedure was performed on control group pregnant rats or on mothers or newborns after birth. On postnatal day 21, kidney tissues of male rat pups from both groups were examined by light and electron microscopy. Malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT) and glutathione levels also were investigated. Light microscopy revealed some degenerative changes in the tubule epithelium, small cystic formations in the primitive tubules and large cysts in the cortico-medullary or medullary regions in the experimental group. Electron microscopy revealed a loss of peritubular capillaries and atypical parietal layer epithelial cells in the experimental group. Biochemical analysis showed significantly increased MDA levels in the experimental group and decreased SOD and CAT levels. EMF applied during the prenatal period can caused pathological changes in kidney tissue in 21-day-old male rats owing to oxidative stress and decreased antioxidant enzyme levels.

(E) Odacı E, Özyılmaz C. Exposure to a 900 MHz electromagnetic field for one hour a day over 30 days does change the histopathology and biochemistry of the rat testis. Int J Radiat Biol. 91(7):541-554, 2015. (CE, M, ME, OX, VO) (Low SAR 0.025 W/kg)

PURPOSE: This study investigated the effect of exposure to a 900-megahertz (MHz) electromagnetic field (EMF) on the rat testicle. MATERIALS AND METHODS: Twenty-four adult male rats were divided into control, sham and EMF groups. The EMF group rats were exposed to 900-MHz EMF (1 h / 30 day), and testicles were extracted at the end of the experiment. Malondialdehyde, superoxide dismutase, catalase and glutathione levels and apoptotic index and histopathological damage scores were compared. RESULTS: Histopathologically, EMF group rats exhibited vacuoles in seminiferous tubules basal membrane and edema in the intertubular space. Seminiferous tubule diameters and germinal epithelium thickness were both smaller, and apoptotic index was higher, in the EMF group than in the other groups. Malondialdehyde, superoxide dismutase, catalase and glutathione values in the EMF group decreased significantly compared to those of the control group. CONCLUSIONS: The results show that exposure to 900-MHz EMF causes alterations in adult rat testicular morphology and biochemistry.

(E) Odacı E, Hancı H, Yuluğ E, Türedi S, Aliyazıcıoğlu Y, Kaya H, Çolakoğlu S. Effects of prenatal exposure to a 900 MHz electromagnetic field on 60-day-old rat testis and epididymal sperm quality. Biotech Histochem. 91(1):9-19, 2016. (CE, M, ME, OX, VO) (Low SAR 0.024 W/kg)

We investigated the effects of exposure in utero to a 900 megahertz (MHz) electromagnetic field (EMF) on 60-day-old rat testis and epididymis. Pregnant rats were divided into control (CG; no treatment) and EMF (EMFG) groups. The EMFG was exposed to 900 MHz EMF for 1 h each day during days 13 - 21 of pregnancy. Newborn rats were either newborn CG (NCG) or newborn EMF groups (NEMFG). On postnatal day 60, a testis and epididymis were removed from each animal. Epididymal semen quality, and lipid and DNA oxidation levels, apoptotic index and histopathological damage to the testis were compared. We found a higher apoptotic index, greater DNA oxidation levels and lower sperm motility and vitality in the NEMFG compared to controls. Immature germ cells in the seminiferous tubule lumen, and altered seminiferous tubule epithelium and seminiferous tubule structure also were observed in hematoxylin and eosin stained sections of NEMFG testis. Nuclear changes that indicated apoptosis were identified in TUNEL stained sections and large numbers of apoptotic cells were observed in most of the seminiferous tubule epithelium in the NEMFG. Sixty-day-old rat testes exposed to 900 MHz EMF exhibited altered sperm quality and biochemical characteristics.

(E)Odacı E, Hancı H, İkinci A, Sönmez OF, Aslan A, Şahin A, Kaya H, Çolakoğlu S, Ba ş O. Maternal exposure to a continuous 900-MHz electromagnetic field provokes neuronal loss and pathological changes in cerebellum of 32-day-old female rat offspring. J Chem Neuroanat 75(Pt B):105-110, 2016. (CE, IU, ME, VO)

Large numbers of people are unknowingly exposed to electromagnetic fields (EMF) from wireless devices. Evidence exists for altered cerebellar development in association with prenatal exposure to EMF. However, insufficient information is still available regarding the effects of exposure to 900 megahertz (MHz) EMF during the prenatal period on subsequent postnatal cerebellar development. This study was planned to investigate the 32-day-old female rat pup cerebellum following exposure to 900MHz EMF during the prenatal period using stereological and histopathological evaluation methods. Pregnant rats were divided into control, sham and EMF groups. Pregnant EMF group (PEMFG) rats were exposed to 900MHz EMF for 1h inside an EMF cage during days 13-21 of pregnancy. Pregnant sham group (PSG) rats were also placed inside the EMF cage during days 13-21 of pregnancy for 1h, but were not exposed to any EMF. No procedure was performed on the pregnant control group (PCG) rats. Newborn control group (CG) rats were obtained from the PCG mothers, newborn sham group (SG) rats from the PSG and newborn EMF group (EMFG) rats from the PEMFG rats. The cerebellums of the newborn female rats were extracted on postnatal day 32. The number of Purkinje cells was estimated stereologically, and histopathological evaluations were also performed on cerebellar sections. Total Purkinje cell numbers calculated using stereological analysis were significantly lower in EMFG compared to CG ($p<0.05$) and SG ($p<0.05$). Additionally, some pathological changes such as pyknotic neurons with dark cytoplasm were observed in EMFG sections under light microscopy. In conclusion, our study results show that prenatal exposure to EMF affects the

development of Purkinje cells in the female rat cerebellum and that the consequences of this pathological effect persist after the postnatal period.

(E) Odemer R, Odemer F. Effects of radiofrequency electromagnetic radiation (RF-EMF) on honey bee queen development and mating success. Sci Total Environ 661:553-562, 2019. (CE, DE) (0.95-3.79 V/m)

Mobile phones can be found almost everywhere across the globe, upholding a direct point-to-point connection between the device and the broadcast tower. The emission of radiofrequency electromagnetic fields (RF-EMF) puts the surrounding environment inevitably into contact with this radiation. We have therefore exposed honeybee queen larvae to the radiation of a common mobile phone device (GSM band at 900 MHz) during all stages of their pre-adult development including pupation. After 14 days of exposure, hatching of adult queens was assessed and mating success after further 11 days, respectively. Moreover, full colonies were established of five of the untreated and four of the treated queens to contrast population dynamics. We found that mobile phone radiation had significantly reduced the hatching ratio but not the mating success. If treated queens had successfully mated, colony development was not adversely affected. We provide evidence that mobile phone radiation may alter pupal development, once succeeded this point, no further impairment has manifested in adulthood. Our results are discussed against the background of long-lasting consequences for colony performance and the possible implication on periodic colony losses.

(NE) Ogawa K, Nabae K, Wang J, Wake K, Watanabe S, Kawabe M, Fujiwara O, Takahashi S, Ichihara T, Tamano S, Shirai T. Effects of gestational exposure to 1.95-GHz W-CDMA signals for IMT-2000 cellular phones: Lack of embryotoxicity and teratogenicity in rats. Bioelectromagnetics. 30(3):205-212, 2009. (CE, DE, IU, ME, VO)

The present study was designed to evaluate whether gestational exposure to an EMF targeting the head region, similar to that from cellular phones, might affect embryogenesis in rats. A 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is one applied for the International Mobile Telecommunication 2000 (IMT-2000) system and used for the freedom of mobile multimedia access (FOMA), was employed for exposure to the heads of four groups of pregnant CD(SD) IGS rats (20 per group) for gestational days 7-17. The exposure was performed for 90 min/day in the morning. The spatial average specific absorption rate (SAR) for individual brains was designed to be 0.67 and 2.0 W/kg with peak brain SARs of 3.1 and 7.0 W/kg for low (group 3) and high (group 4) exposures, respectively, and a whole-body average SAR less than 0.4 W/kg so as not to cause thermal effects due to temperature elevation. Control and sham exposure groups were also included. At gestational day 20, all dams were killed and fetuses were taken out by cesarean section. There were no differences in maternal body weight gain. No adverse effects of EMF exposure were observed on any reproductive and embryotoxic parameters such as number of live (243-271 fetuses), dead or resorbed embryos, placental weights, sex ratios, weights or external, visceral or skeletal abnormalities of live fetuses.

(E) Okatan DÖ, Kaya H, Aliyazıcıoğlu Y, Demir S, Çolakoğlu S, Odacı E. Continuous 900-megahertz electromagnetic field applied in middle and late-adolescence causes

qualitative and quantitative changes in the ovarian morphology, tissue and blood biochemistry of the rat. Int J Radiat Biol 94(2):186-198, 2018. (CE, F, ME, VO) (Low SAR 0.0098W/kg)

Purpose: The purpose of this study was to use histological and biochemical methods in order to evaluate changes taking place in the ovarian of rats exposed to the effect of a 900-megahertz (MHz) electromagnetic field (EMF) in middle and late adolescence. **Materials and methods:** Twenty-four 34-d-old female Sprague-Dawley rats were assigned equally to control, sham and EMF groups. EMF group rats were exposed to the effect of a 900-MHz EMF for 1 h a day, at the same time every day between postnatal days 35 and 59, while inside an EMF cage. Sham group rats were kept inside the EMF cage for the same time between postnatal days 35 and 59 without being exposed to any EMF effect. At the end of the study, rats' ovarian were removed and blood specimens were taken. Right ovarium tissues were subjected to routine histological procedures and stained with hematoxylin and eosin, periodic acid shift and Masson's trichrome. Follicles were counted in ovarian sections stained with hematoxylin and eosin. The TUNEL method was used to evaluate apoptosis. Left ovarian tissue and blood specimens were investigated biochemically. **Results:** Histopathological examination of EMF group ovarian tissue revealed thinning in the zona granulosa and theca layers, shrinking in granulosa cells, reduced mitotic activity and leukocyte infiltration in the follicles and stroma. Secondary follicle numbers in the EMF group were significantly lower than in the other groups. In terms of biochemistry, EMF and sham group superoxide dismutase, catalase and anti-Mullerian hormone levels and EMF group 3-nitrotyrosine values increased significantly compared to the control group. EMF and sham group serum catalase and 8-hydroxy-deoxiguanosine values increased significantly compared to the control group, and EMF group total oxidant status and oxidative stress index values were significantly higher compared to the sham and control groups. **Conclusions:** A total of 900-MHz EMF applied in middle and late adolescence may cause changes in the morphology and biochemistry of the rat ovarium.

(E) Oksay T, Naziroğlu M, Doğan S, Güzel A, Gümral N, Koşar PA. Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. Andrologia. 46(1):65-72, 2014. (CE, M, OX, VO) (Low SAR 0.1 W/kg)

Wireless devices have become part of everyday life and mostly located near reproductive organs while they are in use. The present study was designed to determine the possible protective effects of melatonin on oxidative stress-dependent testis injury induced by 2.45-GHz electromagnetic radiation (EMR). Thirty-two rats were equally divided into four different groups, namely cage control (A1), sham control (A2), 2.45-GHz EMR (B) and 2.45-GHz EMR+melatonin (C). Group B and C were exposed to 2.45-GHz EMR during 60 min day(-1) for 30 days. Lipid peroxidation levels were higher in Group B than in Group A1 and A2. Melatonin treatment prevented the increase in the lipid peroxidation induced by EMR. Also reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) levels in Group D were higher than that of exposure group. Vitamin A and E concentrations decreased in exposure group, and melatonin prevented the decrease in vitamin E levels. In conclusion, wireless (2.45 GHz) EMR caused oxidative damage in testis by increasing the levels of lipid peroxidation and decreasing

in vitamin A and E levels. Melatonin supplementation prevented oxidative damage induced by EMR and also supported the antioxidant redox system in the testis.

(NE) Ono T, Saito Y, Komura J, Ikehata H, Tarusawa Y, Nojima T, Goukon K, Ohba Y, Wang J, Fujiwara O, Sato R. Absence of mutagenic effects of 2.45 GHz radiofrequency exposure in spleen, liver, brain, and testis of lacZ-transgenic mouse exposed in utero. Tohoku J Exp Med 202(2):93-103, 2004. (CE, GE, IU, M, VO)

A possible mutagenic effect of 2.45 GHz radiofrequency exposure was examined using lacZ-transgenic Muta mice. Pregnant animals were exposed intermittently at a whole-body averaged specific absorption rate of 0.71 W/kg (10 seconds on, 50 seconds off which is 4.3 W/kg during the 10 seconds exposure). Offspring that were exposed in utero for 16 hours a day, from the embryonic age of 0 to 15 days, were examined at 10 weeks of age. To minimize thermal effects, the exposure was given in repeated bursts of 10 seconds of exposure followed by 50 seconds of no exposure. Mutation frequencies at the lacZ gene in spleen, liver, brain, and **testis** were similar to those observed in non-exposed mice. Quality of mutation assessed by sequencing the nucleotides of mutant DNAs revealed no appreciable difference between exposed and non-exposed samples. The data suggest that the level of radiofrequency exposure studied is not mutagenic when administered in utero in short repeated bursts.

(E) Oral B, Guney M, Ozguner F, Karahan N, Mungan T, Comlekci S, Cesur G. Endometrial Apoptosis Induced by a 900-MHz Mobile Phone: Preventive Effects of Vitamins E and C. Adv Ther. 23(6):957-973, 2006. (CE, F, ME, OX, VO)

Numerous reports have described the effects induced by an electromagnetic field (EMF) in various cellular systems. The purposes of this study were to examine oxidative stress that promotes production of reactive oxygen species induced by a 900-megahertz (MHz) mobile phone and the possible ameliorating effects of vitamins E and C on endometrial tissue against EMF-induced endometrial impairment and apoptosis in rats. Animals were randomly grouped as follows: (1) sham-operated control group (n=8), (2) 900 MHz EMF-exposed group (n=8; 30 min/d for 30 d), and (3) 900 MHz EMF-exposed group, treated with vitamins E and C (n=8; 50 mg/kg intramuscularly and 20 mg/kg body weight intraperitoneally before daily EMF exposure). Malondialdehyde (an index of lipid peroxidation) was used as a marker of oxidative stress-induced endometrial impairment; Bcl-2, Bax, caspase-3, and caspase-8 were assessed immunohistochemically. In this study, increased malondialdehyde levels in endometrial tissue and apoptosis illustrated the role of the oxidative mechanism induced by exposure to a 900-MHz mobile phone-like device and vitamins E and C; via free radical scavenging and antioxidant properties, oxidative tissue injury and apoptosis were ameliorated in rat endometrium. In conclusion, exposure to 900-MHz radiation emitted by mobile phones may cause endometrial apoptosis and oxidative stress, but treatment with vitamins E and C can diminish these changes and may have a beneficial effect in preventing endometrial changes in rats.

(E) Othman H, Ammari M, Sakly M, Abdelmelek H. Effects of prenatal exposure to WIFI signal (2.45 GHz) on postnatal development and behavior in rat: Influence of

maternal restraint. Behav Brain Res. 326:291-302, 2017. (BE, CE, DE, IU, MO, OX, VO) (No dosimetry data)

The present study was carried out to investigate the potential combined influence of maternal restraint stress and 2.45 GHz WiFi signal exposure on postnatal development and behavior in the offspring of exposed rats. 24 pregnant albino Wistar rats were randomly assigned to four groups: Control, WiFi-exposed, restrained and both WiFi-exposed and restrained groups. Each of WiFi exposure and restraint occurred 2 h/day along gestation till parturition. The pups were evaluated for physical development and neuromotor maturation. Moreover, elevated plus maze test, open field activity and stationary beam test were also determined on postnatal days 28, 30 and 31, respectively. After behavioral tests, the rats were anesthetized and their brains were removed for biochemical analysis. Our main findings showed no detrimental effects on gestation progress and outcomes at delivery in all groups. Subsequently, WiFi and restraint, per se and mainly in concert altered physical development of pups with slight differences between genders. Behaviorally, the gestational WiFi irradiation, restraint and especially the associated treatment affected the neuromotor maturation mainly in male progeny. At adult age, we noticed anxiety, motor deficit and exploratory behavior impairment in male offspring co-exposed to WiFi radiation and restraint, and in female progeny subjected to three treatments. The biochemical investigation showed that, all three treatments produced global oxidative stress in brain of both sexes. As for serum biochemistry, phosphorus, magnesium, glucose, triglycerides and calcium levels were disrupted. Taken together, prenatal WiFi radiation and restraint, alone and combined, provoked several behavioral and biochemical impairments at both juvenile and adult age of the offspring.

Otto M, von Mühlendahl KE. Electromagnetic fields (EMF): do they play a role in children's environmental health (CEH)? Int J Hyg Environ Health 210(5):635-644, 2007. (Review)

Possible adverse health effects of exposure to electric, magnetic and electromagnetic fields (EMF), and especially the question of whether there exists a special vulnerability of children, have been a much discussed topic during the last two decades. Static fields produce health effects only in very rare and exceptional circumstances at extremely high field intensities. As for low-frequency EMF, the results of epidemiological research with respect to childhood leukaemia prompted the International Agency for Research on Cancer (IARC) in 2001 to classify these fields as "possibly carcinogenic to humans". Current hypotheses on the mechanism of such action are presented. The effect, if existent, appears to be not very important in relation to established other causes of childhood leukaemia. High-frequency EMF, as used in mobile and wireless communication (mobile telephony according to the GSM and UMTS standard, cordless DECT phones, wireless local area networks (WLAN), Bluetooth) and since many decades also in radio and television technology, are practically omnipresent. At high intensities, the generation of heat is the principal effect. Current guidelines, limits and regulations prevent any such effect. Mobile phone calls may, in certain circumstances, lead to local exposures close to limit values. Base stations typically produce exposures lower by 2-5 magnitudes. The discussion centres on the so-called non-thermal effects, which are supposedly occurring at field intensities, which are by orders of magnitude lower than those responsible for thermal effects. The reproducibility of

these effects is usually poor, and no physiologic or pathogenic mechanism, so far, has been found to explain the alleged effects. Equally, epidemiologic studies have not furnished clear and reproducible data as arguments for negative health effects. Final results of the INTERPHONE study on the risk of brain tumours, acoustic neurinoma and parotid gland tumours associated with the use of mobile phones will be soon available. Preliminary results do not seem to indicate a substantial increase in risk. There are presently no scientific data supporting the concept of a special vulnerability of children and adolescents to high-frequency EMF, even if the usual caveats (developing organisms and structures may be more vulnerable, decades of life to come) are considered. The concept of precautionary measures adapted to such concerns is critically discussed.

(E) Ouellet-Hellstrom R, Stewart WF, Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation. Am J Epidemiol 138(10):775-786, 1993. (CE, DE, HU, IU)

Physical therapists are exposed to radio- and microwave-frequency electromagnetic radiation by operating shortwave and microwave diathermy units. Recent studies suggest that use of shortwave diathermy is associated with an excess risk of birth defects, perinatal deaths, and late spontaneous abortions among the offspring of exposed female therapists. To assess the impact of occupational use of microwave and shortwave diathermy at the time of conception, the authors mailed questionnaires to 42,403 physical therapists in 1989. Both occupational and reproductive histories were obtained. Exposures to shortwave and microwave diathermy were both assessed in the same fashion and were examined in relation to early recognized fetal loss in a nested case-control design. A total of 1,753 case pregnancies (miscarriages) were matched to 1,753 incidence density control pregnancies (other pregnancies except ectopic pregnancies). A pregnancy was considered "exposed" if the mother reported using microwave or shortwave diathermy anytime during the 6 months prior to the first trimester or during the first trimester. Pregnancies of mothers reporting microwave use 6 months prior to the pregnancy or during the first trimester were more likely to result in miscarriage (odds ratio (OR) = 1.28, 95% confidence interval (CI) 1.02-1.59). The odds ratio increased with increasing level of exposure (chi 2 = 7.25, $p < 0.005$). The odds ratio in the highest exposure group (20 or more exposures/month) was 1.59. The overall odds ratio was slightly lower after it was controlled for prior fetal loss (OR = 1.26, 95% CI 1.00-1.59), but the exposure-response effect remained (chi 2 = 5.17, $p < 0.01$). The risk of miscarriage was not associated with reported use of shortwave diathermy equipment (OR = 1.07, 95% CI 0.91-1.24). The odds ratio in the highest exposure group was 0.87.

(E) Oyewopo AO, Badejogbin OC, Ajadi IO, Aturamu A, Ajadi MB, Ebuwa IV, Alebiosu IA, Areloegbe SE, Olaniyi KS. Panax ginseng supplementation protects against testicular damage induced by radiofrequency electromagnetic radiation from cell phone. Nutrire 48, article 47, 2023. (CE, IX, M, ME, MO, OX, VO) (no dosimetry data)

Purpose It is well-documented that radiofrequency electromagnetic radiation (RF-EMR) from the cell phone contributes to testicular dysfunction and subsequently predisposes individuals, especially male to infertility. Panax ginseng (P. ginseng) exerts antioxidant, antidiabetic, neuroprotective, and anti-inflammatory effects in biological systems. However, its protective role against reproductive dysfunction, including testiculopathy is unclear. The objective of this study was to examine the protective effects of P. ginseng extract on testicular damage induced by RF-EMR from cell phones in male Wistar rats.

Methods Twenty adult male Wistar rats (120–150 g) were randomly divided into four groups of n = 5; Control group received vehicle (normal saline, po), P. ginseng group received 200 mg/kg of P. ginseng extract (po), RF-EMR group was exposed to 900MHz of radiation and RF-EMR + P. ginseng group was exposed to 900MHz of radiation and was concomitantly treated with 200 mg/kg of P. ginseng (po). The treatment was done daily for 56 days. The animals were sacrificed, and the biochemical/endocrine parameters and the histology of testes were evaluated. Results There was a significant decrease in spermatogonia, sperm count, sperm motility, and sperm morphology with decrease in progressivity in RF-EMR group compared with control. Likewise, a significant decrease was observed in serum-luteinizing hormone, testosterone and glutathione peroxidase with degeneration of germ cells and Leydig cells, and a distorted interstitium in RF-EMR group compared with control. However, the administration of P. ginseng attenuated these alterations. Conclusion The results of the present study suggest that supplementation with P. ginseng extract ameliorates testicular dysfunction associated with RF-EMR from cell phone by enhancement of antioxidant capacity.

(E)Özgen M, Take G, Kaplanoğlu I , Erdoğan D, Seymen CM. Therapeutic effects of melatonin in long-term exposure to 2100MHz radiofrequency radiation on rat sperm characteristics. Rev Int Androl 21(4):100371, 2023. (CE, IX, M, ME, VO)

Introduction: Radiofrequency electromagnetic fields (RF-EMFs) are one of the risk factors for male reproductive health and melatonin can be an ideal candidate for therapeutic development against RF-induced male fertility problems due to its antioxidant properties. The possible therapeutic role of melatonin in the destructive effects of 2100MHz RF radiation on rat sperm characteristics is investigated in the present study.**Methods:** Wistar albino rats were divided into four groups and the experiment continued for ninety consecutive days; Control, Melatonin (10mg/kg, subcutaneously), RF (2100MHz, thirty minutes per day, whole-body), and RF+Melatonin groups. Left caudal epididymis and ductus deferens tissues were placed in sperm wash solution (at 37°C) and dissected. The sperms were counted and stained. Measurements of the perinuclear ring of the manchette and posterior portion of the nucleus (ARC) were performed and the sperms were examined at an ultrastructural level. All of the parameters were evaluated statistically. **Results:** The percentages of abnormal sperm morphology were significantly increased with RF exposure, while the total sperm count was significantly decreased. RF exposure also showed harmful effects on acrosome, axoneme, mitochondrial sheath, and outer dense fibers at the ultrastructural level. The number of total sperms, sperms with normal morphology increased, and ultrastructural appearance returned to normal by melatonin administration. **Discussion:** The data showed that melatonin may be a beneficial therapeutic agent for long-term exposure of 2100MHz RF radiation-related reproductive impairments.

(E) Ozguner M, Koyu A, Cesur G, Ural M, Ozguner F, Gokcimen A, Delibas N. Biological and morphological effects on the reproductive organ of rats after exposure to electromagnetic field. Saudi Med J. 26(3):405-410, 2005. (CE, M, ME, MO, VO) (1 mW/cm^2)

OBJECTIVE: The biological effect of electromagnetic field (EMF) emitted from mobile phones is a current debate and still a controversial issue. Therefore, little is known on the possible adverse effects on reproduction as mobile phone bio-effects are only a very recent concern. The aim of this experimental study was to determine the biological and morphological effects of 900 MHz radiofrequency (RF) EMF on rat testes. METHODS: The study was performed in the Physiology and Histology Research Laboratories of Suleyman

Demirel University, Faculty of Medicine, Isparta, Turkey in May 2004. Twenty adult male Sprague-Dawley rats weighing 270 - 320 gm were randomized into 2 groups of 10 animals: Group I (control group) was not exposed to EMF and Group II (EMF group) was exposed to 30 minutes per day, 5 days a week for 4 weeks to 900 MHz EMF. Testes tissues were submitted for histologic and morphologic examination. Testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were registered. Serum testosterone, plasma luteinizing hormone (LH) and follicle stimulating hormone (FSH) levels were assayed biochemically. RESULTS: The weight of testes, testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were not significantly different in EMF group compared to the control group. However, the diameter of the seminiferous tubules and the mean height of the germinal epithelium were significantly decreased in EMF group ($p<0.05$). There was a significant decrease in serum total testosterone level in EMF group ($p<0.05$). Therefore, there was an insignificant decrease in plasma LH and FSH levels in EMF group compared to the control group ($p>0.05$). CONCLUSION: The biological and morphological effects resulting from 900 MHz RF EMF exposure lends no support to suggestions of adverse effect on spermatogenesis, and on germinal epithelium. Therefore, testicular morphologic alterations may possibly be due to hormonal changes.

(E) Ozgur E, Kismali G, Guler G, Akcay A, Ozkurt G, Sel T, Seyhan N. Effects of Prenatal and Postnatal Exposure to GSM-Like Radiofrequency on Blood Chemistry and Oxidative Stress in Infant Rabbits, an Experimental Study. Cell Biochem Biophys. 67(2):743-751, 2013. (CE, IU, MO, OX, PN, VO) (No dosimetry data)

We aimed to investigate the potential hazardous effects of prenatal and/or postnatal exposure to 1800 MHz GSM-like radiofrequency radiation (RFR) on the blood chemistry and lipid peroxidation levels of infant rabbits. A total of 72 New Zealand female and male white rabbits aged 1-month were used. Thirty-six female and 36 male were divided into four groups which were composed of nine infants: (i) Group 1 were the sham exposure (control), (ii) Group 2 were exposed to RFR, 15 min daily for 7 days in the prenatal period (between 15th and 22nd days of the gestational period) (prenatal exposure group). (iii) Group 3 were exposed to RFR 15 min/day (14 days for male, whereas 7 days for female) after they reached 1-month of age (postnatal exposure group). (iv) Group 4 were exposed to RFR for 15 min daily during 7 days in the prenatal period (between 15th and 22nd days of the gestational period) and 15 min/day (14 days for male, whereas 7 days for female) after they reached 1-month of age (prenatal and postnatal exposure group). Results showed that serum lipid peroxidation level in both female and male rabbits changed due to the RFR exposure. However, different parameters of the blood biochemistry were affected by exposure in male and female infants. Consequently, the whole-body 1800 MHz GSM-like RFR exposure may lead to oxidative stress and changes on some blood chemistry parameters. Studies on RFR exposure during prenatal and postnatal periods will help to establish international standards for the protection of pregnants and newborns from environmental RFR.

(E) Ozlem Nisbet H, Nisbet C, Akar A, Cevik M, Karayigit MO. Effects of exposure to electromagnetic field (1.8/0.9 GHz) on testicular function and structure in growing

rats. Res Vet Sci. 93(2):1001-1005, 2012. (CE, M, ME, MO, VO) (Low SAR- 0.000011-0.003 W/kg)

The aim of our study was to evaluate the possible effects of whole-body electromagnetic field (EMF) exposure on reproduction in growing male rats. Male albino Wistar rats (2 days old) were exposed to EMF 1800 and 900 MHz for 2 h continuously per day for 90 days. Sham control was kept under similar conditions except that the field was not applied for the same period. After blood samples were collected, the animals were sacrificed 24 h after the last exposure and the tissues of interest were harvested. The mean plasma total testosterone showed similarity among the two study groups and was significantly higher than the sham control rats. The percentage of epididymal sperm motility was significantly higher in the 1800 MHz group ($P<0.05$). The morphologically normal spermatozoa rates were higher and the tail abnormality and total percentage abnormalities were lower in the 900 MHz group ($P<0.05$). Histopathologic parameters in the 1800 MHz group were significantly higher ($P<0.05$). In conclusion, the present study indicated that exposure to electromagnetic wave caused an increase in testosterone level, epididymal sperm motility (forward), and normal sperm morphology of rats. As a consequences, 1800 and 900 MHz EMF could be considered to be a cause of precocious puberty in growing rats.

(E) Panagopoulos DJ, Karabarbounis A, Margaritis LH. Effect of gsm 900-mhz mobile phone radiation on the reproductive capacity of drosophila melanogaster. Electromag Biol Med 23:29-43, 2004. (CE, DE, M, VO) (0.436-6.05 V/m)

Pulsed radio frequency, (RF), electromagnetic radiation from common GSM mobile phones, (Global System for Mobile Telecommunications) with a carrier frequency at 900 MHz, “modulated” by human voice, (speaking emission) decreases the reproductive capacity of the insect Drosophila melanogaster by 50%–60%, whereas the corresponding “nonmodulated” field (nonspeaking emission) decreases the reproductive capacity by 15%–20%. The insects were exposed to the near field of the mobile phone antenna for 6 min per day during the first 2–5 days of their adult lives. The GSM field is found to affect both females and males. Our results suggest that this field-radiation decreases the rate of cellular processes during gonad development in insects.

(E) Panagopoulos DJ. Effect of microwave exposure on the ovarian development of Drosophila melanogaster. Cell Biochem Biophys. 63(2):121-132, 2012. (CE, DE, F, ME, VO) (0.354 mW/cm^2)

In the present experiments the effect of GSM radiation on ovarian development of virgin Drosophila melanogaster female insects was studied. Newly emerged adult female flies were collected and divided into separate identical groups. After the a lapse of certain number of hours-different for each group-the insects (exposed and sham-exposed) were dissected and their intact ovaries were collected and photographed under an optical microscope with the same magnification. The size of the ovaries was compared between exposed and sham-exposed virgin female insects, during the time needed for the completion of oogenesis and maturation of the first eggs in the ovarioles. Immediately after the intact ovaries were photographed, they were further dissected into individual ovarioles and treated for TUNEL and acridine-orange assays to determine the degree of DNA

damage in the egg chamber cells. The study showed that the ovarian size of the exposed insects is significantly smaller than that of the corresponding sham-exposed insects, due to destruction of egg chambers by the GSM radiation, after DNA damage and consequent cell death induction in the egg chamber cells of the virgin females as shown in previous experiments on inseminated females. The difference in ovarian size between sham-exposed and exposed virgin female flies becomes most evident 39-45 h after eclosion when the first eggs within the ovaries are at the late vitellogenic and post-vitellogenic stages (mid-late oogenesis). More than 45 h after eclosion, the difference in ovarian size decreases, as the first mature eggs of the sham-exposed insects are leaving the ovaries and are laid.

(E) Pandey N, Giri S, Das S, Upadhaya P. Radiofrequency radiation (900 MHz)-induced DNA damage and cell cycle arrest in testicular germ cells in swiss albino mice. Toxicol Ind Health. 33(4):373-384, 2017. (CE, FC, GE, M, ME, VO) (Low SAR 0.0054-0.0516 W/kg)

Even though there are contradictory reports regarding the cellular and molecular changes induced by mobile phone emitted radiofrequency radiation (RFR), the possibility of any biological effect cannot be ruled out. In view of a widespread and extensive use of mobile phones, this study evaluates alterations in male germ cell transformation kinetics following RFR exposure and after recovery. Swiss albino mice were exposed to RFR (900 MHz) for 4 h and 8 h duration per day for 35 days. One group of animals was terminated after the exposure period, while others were kept for an additional 35 days post-exposure. RFR exposure caused depolarization of mitochondrial membranes resulting in destabilized cellular redox homeostasis. Statistically significant increases in the damage index in germ cells and sperm head defects were noted in RFR-exposed animals. Flow cytometric estimation of germ cell subtypes in mice testis revealed 2.5-fold increases in spermatogonial populations with significant decreases in spermatids. Almost fourfold reduction in spermatogonia to spermatid turnover (1C:2C) and three times reduction in primary spermatocyte to spermatid turnover (1C:4C) was found indicating arrest in the premeiotic stage of spermatogenesis, which resulted in loss of post-meiotic germ cells apparent from testis histology and low sperm count in RFR-exposed animals. Histological alterations such as sloughing of immature germ cells into the seminiferous tubule lumen, epithelium depletion and maturation arrest were also observed. However, all these changes showed recovery to varied degrees following the post-exposure period indicating that the adverse effects of RFR on mice germ cells are detrimental but reversible. To conclude, RFR exposure-induced oxidative stress causes DNA damage in germ cells, which alters cell cycle progression leading to low sperm count in mice.

(E) Pandey N, Giri S. Melatonin attenuates radiofrequency radiation (900 MHz)-induced oxidative stress, DNA damage and cell cycle arrest in germ cells of male Swiss albino mice. Toxicol Ind Health 34(5):315-327, 2018. (CE, GE, M, ME, OX, VO) (Low SAR 0.0516-0.0054 W/kg)

Increasing male infertility of unknown aetiology can be associated with environmental factors. Extensive use of mobile phones has exposed the general population to unprecedented levels of radiofrequency radiations (RFRs) that may adversely affect male reproductive health. Therefore,

the present study investigated the effect of RFR Global System for Mobile communication (GSM) type, 900 MHz and melatonin supplementation on germ cell development during spermatogenesis. Swiss albino mice were divided into four groups. One group received RFR exposure for 3 h twice/day for 35 days and the other group received the same exposure but with melatonin (N-acetyl-5-methoxytryptamine) (MEL; 5 mg/kg bw/day). Two other groups received only MEL or remain unexposed. Sperm head abnormality, total sperm count, biochemical assay for lipid peroxides, reduced glutathione, superoxide dismutase activity and testis histology were evaluated. Additionally, flow cytometric evaluation of germ cell subtypes and comet assay were performed in testis. Extensive DNA damage in germ cells of RFR-exposed animals along with arrest in pre-meiotic stages of spermatogenesis eventually leading to low sperm count and sperm head abnormalities were observed. Furthermore, biochemical assays revealed excess free radical generation resulting in histological and morphological changes in testis and germ cells morphology, respectively. However, these effects were either diminished or absent in RFR-exposed animals supplemented with melatonin. Hence, it can be concluded that melatonin inhibits pre-meiotic spermatogenesis arrest in male germ cells through its anti-oxidative potential and ability to improve DNA reparative pathways, leading to normal sperm count and sperm morphology in RFR-exposed animals.

(E) Pawlak K, Sechman A, Nieckarz Z. Plasma thyroid hormones and corticosterone levels in blood of chicken embryos and post hatch chickens exposed during incubation to 1800 MHz electromagnetic field. Int J Occup Med Environ Health. 27(1):114-12, 2014. (AE, IU, MO, VO)

INTRODUCTION: This study attempted to determine the effect of a 1800 MHz electromagnetic field (EMF) (only carrier frequency) on thyroxine (T4), triiodothyronine (T3) and corticosterone (CORT) concentrations in the blood plasma of chick embryos, and to investigate the effect of electromagnetic field (EMF) exposure during embryogenesis on the level of these hormones in birds that are ready for slaughter. MATERIAL AND METHODS: Throughout the incubation period, embryos from the experimental group were exposed to a 1800 MHz EMF with power density of 0.1 W/m^2, 10 times during 24 h for 4 min. Blood samples were collected to determine T4, T3 and CORT concentrations on the 12th (E12) and 18th (E18) day of incubation, from newly hatched chicks (D1) and from birds ready for slaughter (D42). RESULTS: The experiment showed that T4 and T3 concentrations decreased markedly and CORT levels increased in the embryos and in the newly hatched chicks exposed to EMF during embryogenesis. However, no changes were found in the level of the analyzed hormones in the birds ready for slaughter. Differences in T4 and T3 plasma concentrations between the EMF-exposed group and the embryos incubated without additional EMF were the highest in the newly hatched chicks, which may be indicative of the cumulative effect of electromagnetic field on the hypothalamo-pituitary-thyroid axis (HPT). DISCUSSION: The obtained results suggest that additional 1800 MHz radio frequency electromagnetic field inhibits function of HPT axis, however, it stimulates hypothalamo-pituitary-adrenal axis by inducing adrenal steroidogenic cells to synthesize corticosterone. Further investigations are needed to elucidate the mechanisms by which radio EMFs affect HPT and HPA axis function in the chicken embryos.

(E)Pawlak K, Nieckarz Z, Sechman A, Wojtysiak D, Bojarski B, Tombarkiewicz B.Effect of a 1800 MHz electromagnetic field emitted during embryogenesis on chick development and hatchability. Anat Histol Embryol 47(3):222-230, 2018. (CE, DE, IU, MO) (o.009 mW/cm^2)

The level of artificial electromagnetic field (EMF) has steadily increased with the development of human civilization. The developing chicken embryo has been considered a good model to study the effects of EMF on living organisms. The aim of the study was to determine the effect of a 1800 MHz electromagnetic field during embryogenesis on the frequency of chick embryo malformations, morphometric parameters of the heart and liver and concentration of corticosterone in blood plasma, lipid and glycogen content in the liver of newly hatched chicks. A 1800 MHz EMF was found to shorten the duration of embryogenesis (earlier pipping and hatching of chicks) while having no effect on the quantity and quality of chicks and on increasing the incidence of embryo malformations. Exposure of chick embryos to EMF caused decreases in relative heart weight and right ventricle wall thickness. The pipping and hatching of chicks can be accelerated by stressful impact of EMF, which is confirmed by a significant increase in plasma corticosterone concentrations and decrease in fat and glycogen in the liver of chicks exposed during embryogenesis on the electromagnetic field with a frequency of 1800 MHz.

Peyman A, Gabriel C, Grant EH, Vermeeren G, Martens L.Variation of the dielectric properties of tissues with age: the effect on the values of SAR in children when exposed to walkie-talkie devices. Phys Med Biol. 54(2):227-241, 2009. (Dosimetry)

In vitro dielectric properties of ageing porcine tissues were measured in the frequency range of 50 MHz-20 GHz, and the total combined uncertainties of the measurements were assessed. The results show statistically significant reduction with age in both permittivity and conductivity of 10 out of 15 measured tissues. At microwave frequencies, the observed variations are mainly due to the reduction in the water content of tissues as an animal ages. The results obtained were then used to calculate the SAR values in children of age 3 and 7 years when they are exposed to RF induced by walkie-talkie devices. No significant differences between the SAR values for the children of either age or for adults were observed.

(E)Piccinetti CC, De Leo A, Cosoli G, Scalise L, Randazzo B, Cerri G, Olivotto I. Measurement of the 100 MHz EMF radiation in vivo effects on zebrafish D. rerio embryonic development: A multidisciplinary study. Ecotoxicol Environ Saf 154:268-279, 2018. (CE, GE, DE, IU) (Low SAR 0.08 W/kg).

The augmented exposure of both environment and human being to electromagnetic waves and the concomitant lack of an unequivocal knowledge about biological consequences of these radiations, raised public interest on electromagnetic pollution. In this context, the present study aims to evaluate the biological effects on zebrafish (ZF) embryos of 100 MHz radiofrequency electromagnetic field (RF-EMF) exposure through a multidisciplinary protocol. Because of the shared synteny between human and ZF genomes that validated its use in biomedical research, toxicology and developmental biology studies, ZF was here selected as experimental model and a measurement protocol and biological analyses have been set up to clearly discriminate between

RF-EMF biological and thermal effects. The results showed that a 100 MHz EMF was able to affect ZF embryonic development, from 24 to 72 h post fertilization (hpf) in all the analyzed pathways. Particularly, at the 48 hpf stage, a reduced growth, an increased transcription of oxidative stress genes, the onset of apoptotic/autophagic processes and a modification in cholesterol metabolism were detected. ZF embryos faced stress induced by EMF radiation by triggering detoxification mechanisms and at 72 hpf they partially recovered from stress reaching the hatching time in a comparable way respect to the control group. Data here obtained showed unequivocally the in vivo effects of RF-EMF on an animal model, excluding thermal outcomes and thus represents the starting point for more comprehensive studies on dose response effects of electromagnetic fields radiations consequences.

(NE) Poulletier de Gannes F, Haro E, Hurtier A, Taxile M, Athane A, Ait-Aissa S, Masuda H, Percherncier Y, Ruffié G, Billaudel B, Dufour P, Veyret B, Lagroye I. Effect of in utero wi-fi exposure on the pre- and postnatal development of rats. Birth Defects Res B Dev Reprod Toxicol. 95(2):130-136, 2012. (CE, DE, IU, VO)

BACKGROUND: The increase in exposure to the Wireless Fidelity (Wi-Fi) wireless communication signal has raised public health concerns especially for young people. Animal studies looking at the effects of early life and prenatal exposure to this source of electromagnetic fields, in the radiofrequency (RF) range, on development and behavior have been considered as high priority research needs by the World Health Organization. METHODS: For the first time, our study assessed the effects of in utero exposure to a 2450 MHz Wi-Fi signal (2 hr/day, 6 days/week for 18 days) on pregnant rats and their pups. Three levels in terms of whole-body specific absorption rate were used: 0.08, 0.4, and 4 W/kg. The prenatal study on fetuses delivered by caesarean (P20) concerned five females/group. The dams and their offspring were observed for 28 days after delivery (15 females/group). RESULTS: For all test conditions, no abnormalities were noted in the pregnant rats and no significant signs of toxicity were observed in the pre- and postnatal development of the pups, even at the highest level of 4 W/kg. CONCLUSIONS: In the present study, no teratogenic effect of repeated exposures to the Wi-Fi wireless communication signal was demonstrated even at the highest level of 4 W/kg. The results from this screening study aimed at investigating Wi-Fi effects, strengthen the previous conclusions that teratology and development studies have not detected any noxious effects of exposures to mobile telephony-related RF fields at exposure levels below standard limits.

(NE) Poulletier de Gannes F, Billaudel B, Haro E, Taxile M, Le Montagner L, Hurtier A, Ait Aissa S, Masuda H, Percherancier Y, Ruffié G, Dufour P, Veyret B, Lagroye I. Rat fertility and embryo fetal development: influence of exposure to the Wi-Fi signal. Reprod Toxicol. 36:1-5, 2013. (CE, DE, F, M, ME, IU, VO)

In recent decades, concern has been growing about decreasing fecundity and fertility in the human population. Exposure to non-ionizing electromagnetic fields (EMF), especially radiofrequency (RF) fields used in wireless communications has been suggested as a potential risk factor. For the first time, we evaluated the effects of exposure to the 2450MHz Wi-Fi signal (1 h/day, 6 days/week) on the reproductive system of male and female Wistar rats, pre-exposed to Wi-Fi during sexual maturation. Exposure lasted 3 weeks (males) or 2 weeks (females), then animals were mated and

couples exposed for 3 more weeks. On the day before delivery, the fetuses were observed for lethality, abnormalities, and clinical signs. In our experiment, no deleterious effects of Wi-Fi exposure on rat male and female reproductive organs and fertility were observed for 1h per days. No macroscopic abnormalities in fetuses were noted, even at the critical level of 4 W/kg.

(NE) Preece AW, Goodfellow S, Wright MG, Butler SR, Dunn EJ, Johnson Y, Manktelow TC, Wesnes K.Effect of 902 MHz mobile phone transmission on cognitive function in children. Bioelectromagnetics.Suppl 7:S138-143, 2005. (AE, BE, HU)

We examine whether a standard mobile exposure at 902 MHz has a significant effect on cognitive function in 18 children 10-12 years of age. These were in a single group in which each child was given a single training session and then three test sessions in a randomized, three-way crossover design, using the cognitive drug research (CDR) cognitive assessment system. Exposures were 0, 0.025, or 0.25 W from a standard Nokia 3110 mobile phone handset mounted on a plastic headset in normal use position. The results of testing showed that the baseline (0 W) performance for the reaction time measurements was considerably slower than for the comparable measures in adult. There was a tendency for reaction time to be shorter during exposure to radiation than in the sham (baseline) condition, an effect that was most marked for simple reaction time. However, no effects reached statistical significance after Bonferroni correction. Therefore, we conclude that this study on 18 children did not replicate our earlier finding in adults that exposure to microwave radiation was associated with a reduction in reaction time. It should be noted that the present study investigated the effects of radiation from a GSM handset, whereas in our previous study the effect on reaction time was observed only with a more powerful analogue handset.

(E) Pyrpasopoulou A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras IN, Xenos TD, Tsiboukis TD, Karkavelas G. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. Bioelectromagnetics 25(3):216-227, 2004. (CE, GE, IU, VO) (Low SAR 0.0005 W/g)

Effects of nonthermal radiofrequency radiation (RFR) of the global system of mobile communication (GSM) cellular phones have been as yet mostly studied at the molecular level in the context of cellular stress and proliferation, as well as neurotransmitter production and localization. In this study, a simulation model was designed for the exposure of pregnant rats to pulsed GSM-like RFR (9.4 GHz), based on the different resonant frequencies of man and rat. The power density applied was 5 microW/cm^2, in order to avoid thermal electromagnetic effects as much as possible. Pregnant rats were exposed to RFR during days 1-3 postcoitum (p.c.) (embryogenesis, pre-implantation) and days 4-7 p.c. (early organogenesis, peri-implantation). Relative expression and localization of bone morphogenetic proteins (BMP) and their receptors (BMPR), members of a molecular family currently considered as major endocrine and autocrine morphogens and known to be involved in renal development, were investigated in newborn kidneys from RFR exposed and sham irradiated (control) rats. Semi-quantitative duplex RT-PCR for BMP-4, -7, BMPR-IA, -IB, and -II showed increased BMP-4 and BMPR-IA, and decreased BMPR-II relative expression in newborn kidneys. These changes were statistically significant for BMP-4, BMPR-IA, and -II after exposure on days 1-3 p.c. ($P < .001$ each), and for BMP-4 and BMPR-IA after exposure on days 4-7 p.c. ($P < .001$ and $P = .005$, respectively).

Immunohistochemistry and in situ hybridization (ISH) showed aberrant expression and localization of these molecules at the histological level. Our findings suggest that GSM-like RFR interferes with gene expression during early gestation and results in aberrations of BMP expression in the newborn. These molecular changes do not appear to affect renal organogenesis and may reflect a delay in the development of this organ. The differences of relative BMP expression after different time periods of exposure indicate the importance of timing for GSM-like RFR effects on embryonic development.

(E)Qin F, Zhang J, Cao H, Yi C, Li JX, Nie J, Chen LL, Wang J, Tong J.Effects of 1800-MHz radiofrequency fields on circadian rhythm of plasma melatonin and testosterone in male rats. J Toxicol Environ Health A.75(18):1120-1128, 2012. (CE, FC. M, MO, VO)

Radiofrequency fields (RF) at 1800 MHz are known to affect melatonin (MEL) and testosterone in male rats, but it remains to be determined whether RF affected circadian rhythm of these plasma hormones. Male Sprague-Dawley rats were exposed to 1800-MHz RF at 208 μw/cm² power density (SAR: 0.5762 W/kg) at different zeitgeber (ZT) periods of the day, including 0 (ZT0), 4 (ZT4), 8 (ZT8), 12 (ZT12), 16 (ZT16), and 20 (ZT20) h. RF exposure was 2 h/d for 32 d. From each rat, the concentrations of plasma MEL and testosterone were determined in plasma after RF exposure and compared with controls. The results confirmed the existence of circadian rhythms in the synthesis of MEL and testosterone, but revealed an inverse relationship in peak phase of these rhythms. These rhythms were disturbed after exposure to RF, with the effect being more pronounced on MEL than testosterone. The most pronounced effect of RF exposure on MEL and testosterone appears to be in rats exposed to RF at ZT 16 and ZT0 h, respectively. Data suggest that regulation of testosterone is controlled by MEL and that MEL is more sensitive to RF exposure.

(E) Qin F, Zhang J, Cao H, Guo W, Chen L, Shen O, Sun J, Yi C, Li J, Wang J, Tong J. Circadian alterations of reproductive functional markers in male rats exposed to 1800-MHz radiofrequency field. Chronobiol Int. 3191):123-133, 2014. (CE, FC. GE, M, MO, VO) (Low SAR)

In this study, we explored the circadian effects of daily radiofrequency field (RF) exposure on reproductive functional markers in adult male Sprague-Dawley rats. Animals in circadian rhythm (as indicated by melatonin measurements), were divided into several groups and exposed to 1800 MHz RF at 205 μw/cm^2 power density (specific absorption rate 0.0405 W/kg) for 2 h/day for 32 days at different zeitgeber time (ZT) points, namely, ZT0, ZT4, ZT8, ZT12, ZT16 and ZT20. Sham-exposed animals were used as controls in the study. From each rat, testicular and epididymis tissues were collected and assessed for testosterone levels, daily sperm production and sperm motility, testis marker enzymes γ-GT and ACP, cytochrome P450 side-chain cleavage (p450cc) mRNA expression, and steroidogenic acute regulatory protein (StAR) mRNA expression. Via these measurements, we confirmed the existence of circadian rhythms in sham-exposed animals. However, rats exposed to RF exhibited a disruption of circadian rhythms, decreased testosterone levels, lower daily sperm production and sperm motility, down-regulated activity of γ-GT and ACP, as well as altered mRNA expression of cytochrome P450 and StAR. All of these observations were more pronounced when rats were exposed to RF at ZT0. Thus, our findings indicate potential adverse effects of RF exposure on male reproductive functional markers, in terms of both the daily overall levels as well as the circadian rhythmicity.

(NE) Rağbetli MC, Aydinlioğlu A, Koyun N, Rağbetli C, Karayel M. Effect of prenatal exposure to mobile phone on pyramidal cell numbers in the mouse hippocampus: a stereological study. Int J Neurosci. 119(7):1031-1041, 2009. (CE, IU, ME, VO) (SAR 1.2 W/kg)

Because of the possible risk factor for the health, World Health Organization (WHO) recommended the study with animals on the developing nervous system concerning the exposure to radiofrequency (RF) field. A few studies related to hippocampal exposure are available, which indicate the impact of RF field in some parameters. The present study investigated the effect of exposure to mobile phone on developing hippocampus. Male and female Swiss albino mice were housed as control and mobile phone exposed groups. The pregnant animals in tested group were exposed to the effects of mobile phone in a room possessing the exposure system. The left hemispheres of the brains were processed by frozen microtome. The sections obtained were stained with Hematoxylin & Eosin. For cell counting by the optical fractionator method, a pilot study was first performed. Hippocampal areas were analyzed using Axiovision software running on a personal computer. The optical dissector, systematically and randomly spaced, was focused to the widest profile of the pyramidal cell nucleus. No significant difference in pyramidal cell number of total Cornu Ammonis (CA) sectors of hippocampus was found between the control and the mobile phone exposed groups ($p > .05$). It was concluded that further study is needed in this field due to popular use of mobile telephones and relatively high exposure to the developing brain.

(E) Rago R, Salacone P, Caponecchia L, Sebastianelli A, Marcucci I, Calogero AE, Condorelli R, Vicari E, Morgia G, Favilla V, Cimino S, Arcoria AF, La Vignera S. The semen quality of the mobile phone users. J Endocrinol Invest. 36(11):970-974, 2013. (CE, HU, M, ME)

BACKGROUND: The increased use of mobile phones, the media's attention for general health, and the increase of idiopathic male infertility suggest to investigate the possible

consequences of an excessive use of mobile phones on semen quality. AIM: To evaluate the conventional and some of the main biofunctional sperm parameters in healthy men according to the different use of the mobile phone. SUBJECTS AND METHODS: All the enrolled subjects in this study were divided into four groups according to their active cell phone use: group A= no use (no.=10 subjects); group B= <2 h/day (no.=16); group C= 2-4 h/day (no.=17); and group D= >4 h/day (no.=20). Among the subjects of the group D (>4 h/day), a further evaluation was made between the "trousers users"(no.=12) and "shirt users"(no.=8), and they underwent semen collection to evaluate conventional and biofunctional sperm parameters (density, total count, morphology, progressive motility, apoptosis, mithocondrial membrane potential, chromatin compaction, DNA fragmentation). RESULTS: None of the conventional sperm parameters examined were significantly altered. However, the group D and the trousers users showed a higher percentage of sperm DNA fragmentation compared to other groups. CONCLUSION: These results suggest that the sperm DNA fragmentation could represent the only parameter significantly altered in the subjects who use the mobile phone for more than 4 h/day and in particular for those who use the device in the pocket of the trousers.

(E)Rahban R, Senn A, Nef S, Röösli M. Association between self-reported mobile phone use and the semen quality of young men. Fertility and Sterility 120(6):1181-1192, 2023. (CE, HU, M)

Objectives. To investigate the association between mobile phone exposure and semen parameters. Design. A nationwide cross-sectional study. Setting. Andrology laboratories in close proximity to 6 army recruitment centers. Patients. In total, 2886 men from the general Swiss population, 18–22 years old, were recruited between 2005 and 2018 during military conscription. Intervention. Participants delivered a semen sample and completed a questionnaire on health and lifestyle, including the number of hours they spent using their mobile phones and where they placed them when not in use. Main Outcome Measures. Using logistic and multiple linear regression models, adjusted odds ratios and β coefficients were determined, respectively. The association between mobile phone exposure and semen parameters such as volume, sperm concentration, total sperm count (TSC), motility, and morphology was then evaluated. Results. A total of 2759 men answered the question concerning their mobile phone use, and 2764 gave details on the position of their mobile phone when not in use. In the adjusted linear model, a higher frequency of mobile phone use (>20 times per day) was associated with a lower sperm concentration (adjusted β: −0.152; 95% confidence interval: −0.316; 0.011) and a lower TSC (adjusted β: −0.271; 95% confidence interval: −0.515; −0.027). In the adjusted logistic regression model, this translates to a 30% and 21% increased risk for sperm concentration and TSC to be below the World Health Organization reference values for fertile men, respectively. This inverse association was found to be more pronounced in the first study period (2005–2007) and gradually decreased with time (2008–2011 and 2012–2018). No consistent associations were observed between mobile phone use and sperm motility or sperm morphology. Keeping a mobile phone in the pants pocket was not found to be associated with lower semen parameters. Conclusion. This large population-based study suggests that higher mobile phone use is associated with lower sperm concentration and TSC. The observed time trend of decreasing association is in line with the transition to new technologies and the corresponding decrease in

mobile phone output power. Prospective studies with improved exposure assessment are needed to confirm whether the observed associations are causal.

(E) Razavinasab M, Moazzami K, Shabani M. Maternal mobile phone exposure alters intrinsic electrophysiological properties of CA1 pyramidal neurons in rat offspring. Toxicol Ind Health. 32(6):968-979, 2016. (BE, CE, FC, IU, VO) (No dosimetry data).

Some studies have shown that exposure to electromagnetic field (EMF) may result in structural damage to neurons. In this study, we have elucidated the alteration in the hippocampal function of offspring Wistar rats (n = 8 rats in each group) that were chronically exposed to mobile phones during their gestational period by applying behavioral, histological, and electrophysiological tests. Rats in the EMF group were exposed to 900 MHz pulsed-EMF irradiation for 6 h/day. Whole cell recordings in hippocampal pyramidal cells in the mobile phone groups did show a decrease in neuronal excitability. Mobile phone exposure was mostly associated with a decrease in the number of action potentials fired in spontaneous activity and in response to current injection in both male and female groups. There was an increase in the amplitude of the afterhyperpolarization (AHP) in mobile phone rats compared with the control. The results of the passive avoidance and Morris water maze assessment of learning and memory performance showed that phone exposure significantly altered learning acquisition and memory retention in male and female rats compared with the control rats. Light microscopy study of brain sections of the control and mobile phone-exposed rats showed normal morphology. Our results suggest that exposure to mobile phones adversely affects the cognitive performance of both female and male offspring rats using behavioral and electrophysiological techniques.

(E) Rezk AY, Abdulqawi K, Mustafa RM, Abo El-Azm TM, Al-Inany H. Fetal and neonatal responses following maternal exposure to mobile phones. Saudi Med J. 29(2):218-223, 2008. (AE, FC, HU)

OBJECTIVE: To study fetal and neonatal heart rate (HR) and cardiac output (COP), following acute maternal exposure to electromagnetic fields (EMF) emitted by mobile phones. METHODS: The present study was carried out at Benha University Hospital and El-Shorouq Hospital, Cairo, Egypt, from October 2003 to March 2004. Ninety women with uncomplicated pregnancies aged 18-33 years, and 30 full term healthy newborn infants were included. The pregnant mothers were exposed to EMF emitted by mobile telephones while on telephone-dialing mode for 10 minutes during pregnancy and after birth. The main outcome were measurements of fetal and neonatal HR and COP. RESULTS: A statistical significant increase in fetal and neonatal HR, and statistical significant decrease in stroke volume and COP before and after use of mobile phone were noted. All these changes are attenuated with increase in gestational age. CONCLUSION: Exposure of pregnant women to mobile phone significantly increase fetal and neonatal HR, and significantly decreased the COP.

(NE) Ribeiro EP, Rhoden EL, Horn MM, Rhoden C, Lima LP, Toniolo L, Effects of Subchronic Exposure to Radio Frequency From a Conventional Cellular Telephone on Testicular Function in Adult Rats. J Urol 177:395-399, 2007. (CE, M, ME, VO) (0.04 mW/cm^2)

Purpose. We investigated the effects of subchronic exposure to radio frequency emitted from a conventional cellular telephone on the testicular function in adult rats. Materials and Methods. A total of 16 male Wistar rats at age 30 days were randomly divided into 2 groups, including experimental and control groups. The experimental group was exposed to radio frequency emitted from a conventional GSM (global system for mobile communications) cellular telephone (1,835 to 1,850 MHz) for 1 hour daily during 11 weeks. Rectal temperature was measured before and after the exposure period. Testicular and epididymal weight, lipid peroxidation levels in these organs, serum total testosterone and the epididymal sperm count were evaluated. Maturation phase spermatid retention at stage IX-X, interstitial infiltration, cellular vacuolation and multinucleate giant cells were among the qualitative testicular histopathological end points analyzed. Each rat had 10 consecutive round seminiferous tubules at stage VII-VIII evaluated for the mean seminiferous tubular diameter measurement, the crude histological count of round spermatids, pachytene spermatocytes and Sertoli's cells with evident nucleoli, and the true histological count (Abercrombie's correction factor) of round spermatids and pachytene spermatocytes. Results. Mean rectal temperature did not alter following exposure. There was no statistical difference between the control and experimental groups in any end points evaluated. Conclusions: The current study shows that the low intensity pulsed radio frequency emitted by a conventional cellular telephone does not impair testicular function in adult rats.

(E) Safian F, Khalili MA, Khoradmehr A, Anbari F, Soltani S, Halvaei I. Survival Assessment of Mouse Preimplantation Embryos After Exposure to Cell Phone Radiation. J Reprod Infertil. 17(3):138-143, 2016. (CE, IU, ME) (No dosimetry data).

BACKGROUND: Using cellular phone has rapidly increased all over the world. Also, the concern on the possible health hazards of electromagnetic fields (EMF) induced from cell phones to reproduction has been growing in many countries. The aim of this study was to assess the consequences and effects of exposure to the cell phone radiation on the quality and survival rates of preimplantation embryos in mice. METHODS: A total of 40 mice (20 females and 20 males), 6 weeks old and sexually mature BALB/c, were used for control and experimental groups. The ovary burses were removed and the zygotes were dissected in the morning after mating. Next, 2-cell embryos were divided into two groups of control (n=150) and experimental (n=150). EMF (900-1800 MHz) was used for four days in experimental group for 30 min/day in culture at 37°C in a CO_2 incubator. The quality of embryos was recorded daily and the fluorescent staining was used for identification of viable blastocysts. All data were compared by Student's t-test and Mann-Whitney test ($p<0.05$). RESULTS: The rate of embryo survival to the blastocysts stage was similar in both groups. However, the percentage of dead embryos at the 2-cell stage was significantly higher in EMF-exposed group compared with controls ($p=0.03$). Also, the loss of cell viability significantly increased in experimental blastocysts ($p=0.002$). CONCLUSION: The normal embryonic development up to the blastocyst stage indicates that EMF-exposure commonly did not have adverse effect on embryo development in mice. But, it caused loss of blastocysts cell viability.

(E) Sagioglou NE, Manta AK, Giannarakis IK, Skouroliakou AS, Margaritis LH. Apoptotic cell death during Drosophila oogenesis is differentially increased by electromagnetic radiation depending on modulation, intensity and duration of

exposure. Electromagn Biol Med. 35:40-53, 2016. (AE, CE, ME, VO) (Low SAR 0.00001-0.102 W/kg)

Present generations are being repeatedly exposed to different types and doses of non-ionizing radiation (NIR) from wireless technologies (FM radio, TETRA and TV stations, GSM and UMTS phones/base stations, Wi-Fi networks, DECT phones). Although there is controversy on the published data regarding the non-thermal effects of NIR, studies have convincingly demonstrated bioeffects. Their results indicate that modulation, intensity, exposure duration and model system are important factors determining the biological response to irradiation. Attempting to address the dependence of NIR bioeffectiveness on these factors, apoptosis in the model biological system Drosophila melanogaster was studied under different exposure protocols. A signal generator was used operating alternatively under Continuous Wave (CW) or Frequency Modulation (FM) emission modes, at three power output values (10 dB, 0, -10 dB), under four carrier frequencies (100, 395, 682, 900 MHz). Newly emerged flies were exposed either acutely (6 min or 60 min on the 6th day), or repeatedly (6 min or 60 min daily for the first 6 days of their life). All exposure protocols resulted in an increase of apoptotic cell death (ACD) observed in egg chambers, even at very low electric field strengths. FM waves seem to have a stronger effect in ACD than continuous waves. Regarding intensity and temporal exposure pattern, EMF-biological tissue interaction is not linear in response. Intensity threshold for the induction of biological effects depends on frequency, modulation and temporal exposure pattern with unknown so far mechanisms. Given this complexity, translating such experimental data into possible human exposure guidelines is yet arbitrary.

(E)Salameh M, ZeitounGhandour S, Sabra L, Ismail L, Daher A, Bazzi A, Khalil M, Jo umaa WH. Effects of continuous prenatal and postnatal global system for mobile communications electromagnetic waves (GSM-EMW) exposure on the oxidative stress biomarkers in female rat liver. Heliyon 8(12):e12367, 2022. (CE, GE, IU, OX, PN, VO) (Liver SAR 0.783 W/kg)

In light of the increased use of communication technologies, the harm caused by continuous exposure to emitted radiation on pregnancy and developing newborns is among the public concerns. Using Sprague-Dawley rats, our study investigates the effects of 24 h/day prenatal and postnatal 900 MHz radiofrequency electromagnetic radiation (RF-EMR) exposure of female rats on liver oxidative stress (OS) and other hepatic parameters at postnatal days (PND) 1, 9, and 21. Our results showed that RF-EMR exposure led to an increase in oxidative stress status as indicated by a significant elevation in MDA level at PND9 and PND21, a decrease in catalase (CAT) activity at all ages, a reduction (PND1 and PND9) in catalase amounts and mRNA expression, in addition to a decrease in GPx activity at PND21 in the exposed group. Current findings also showed a significant increase in cytoSOD at PND9 and 21 and a reduction in mitoSOD at PND21 in the exposed groups compared to the control groups. However, significant increases in glutathione peroxidase (GPx) level and mitoSOD activity were observed at all studied ages. Furthermore, cytoSOD activity showed a significant reduction in PND1, whereas in PND9 the value of this parameter increased compared to the non-exposed group. Moreover, while SOD1 mRNA expression increased at PND1, it decreased at PND9 and 21. However, GPx1 expression was shown to be always decreased in the exposed group. In addition, at PND1

and 9, exposed rats showed a similar response on Akt1, nuclear factor erythroïd 2-related factor 2 (Nrf-2), and intercellular adhesion molecule-1 (ICAM-1) expression. Therefore, an increased oxidative stress status produced from a continuous (24 h/day) GSM-modulated 900 MHz radiofrequency electromagnetic radiation (RF-EMR) exposure during the prenatal and postnatal periods may result in adverse health effects during future life stages.

(E) Salameh M, Zeitoun-Ghandour S, Sabra L, Daher A, Khalil M, Joumaa WH Impact of GSM-EMW exposure on the markers of oxidative stress in fetal rat liver. Sci Rep 13(1):17806, 2023. (CE, GE, IU, OX, VO)

The current study investigated the effects of 24 h/day prenatal exposure to global system for mobile communication electromagnetic fields (GSM-EMFs), 900 MHZ-induced electromagnetic radiation (EMR), on oxidative stress (OS) status, apoptotic, and inflammatory changes in liver of rats during their fetal development period. Fifty-two Sprague-Dawley pregnant rats were equally divided into control and exposed groups. Whole embryos were removed at 7.5 dpc (days post coitus), while liver tissues were extracted from embryos at 11.5, 15.5, and 19.5 dpc. For exposed animals, results showed an increased OS reflected by high levels of malondialdehyde (MDA), a decrease in cytosolic superoxide dismutase (cytoSOD) activity, in mitochondrial superoxide dismutase (mitoSOD) levels and catalase (CAT) mRNA expression but also in hepatic nuclear factor erythroïd 2-related Factor 2 (Nrf-2), protein kinase B (Akt1), and intercellular adhesion molecule-1 (ICAM-1) mRNA expression at 15.5 dpc. Moreover, GSM-EMR exposure was shown to significantly decrease mitoSOD and CAT activities at almost all studied ages. Thus, rat embryos may be protected by their mothers from OS, apoptotic, and pro-inflammatory responses till a sensitive developmental stage, during a continuous prenatal EMR exposure. This protection could be then created from the embryos themselves.

(NE) Sambucci M, Laudisi F, Nasta F, Pinto R, Lodato R, Altavista P, Lovisolo GA, Marino C, Pioli C. Prenatal exposure to non-ionizing radiation: effects of WiFi signals on pregnancy outcome, peripheral B-cell compartment and antibody production. Radiat Res. 174(6):732-740, 2010. (CE, IU, ME, VO)

During embryogenesis, the development of tissues, organs and systems, including the immune system, is particularly susceptible to the effects of noxious agents. We examined the effects of prenatal (in utero) exposure to WiFi signals on pregnancy outcome and the immune B-cell compartment, including antibody production. Sixteen mated (plug-positive) female mice were assigned to each of the following groups: cage control, sham-exposed and microwave-exposed (WiFi signals at 2.45 GHz, whole body, SAR 4 W/kg, 2 h/day, 14 consecutive days starting 5 days after mating). No effects due to exposure to WiFi signals during pregnancy on mating success, number of newborns/mother and body weight at birth were found. Newborn mice were left to grow until 5 or 26 weeks of age, when immunological analyses were performed. No differences due to exposure were found in spleen cell number, B-cell frequency or antibody serum levels. When challenged in vitro with LPS, B cells from all groups produced comparable amounts of IgM and IgG, and proliferated at a similar level. All these findings were consistently observed in the female and male offspring at both juvenile (5 weeks) and adult (26 weeks) ages. Stress-associated effects as well as age-

and/or sex-related differences were observed for several parameters. In conclusion, our results do not show any effect on pregnancy outcome or any early or late effects on B-cell differentiation and function due to prenatal exposure to WiFi signals.

(NE) Sambucci M, Laudisi F, Nasta F, Pinto R, Lodato R, Lopresto V, Altavista P, Marino C, Pioli C. Early life exposure to 2.45GHz WiFi-like signals: effects on development and maturation of the immune system. Prog Biophys Mol Biol. 107(3):393-398, 2011. (CE, DE, ME, PN, VO)

The development of the immune system begins during embryogenesis, continues throughout fetal life, and completes its maturation during infancy. Exposure to immune-toxic compounds at levels producing limited/transient effects in adults, results in long-lasting or permanent immune deficits when it occurs during perinatal life. Potentially harmful radiofrequency (RF) exposure has been investigated mainly in adult animals or with cells from adult subjects, with most of the studies showing no effects. Is the developing immune system more susceptible to the effects of RF exposure? To address this question, newborn mice were exposed to WiFi signals at constant specific absorption rates (SAR) of 0.08 or 4 W/kg, 2h/day, 5 days/week, for 5 consecutive weeks, starting the day after birth. The experiments were performed with a blind procedure using sham-exposed groups as controls. No differences in body weight and development among the groups were found in mice of both sexes. For the immunological analyses, results on female and male newborn mice exposed during early post-natal life did not show any effects on all the investigated parameters with one exception: a reduced IFN-γ production in spleen cells from microwaves (MW)-exposed (SAR 4 W/kg) male (not in female) mice compared with sham-exposed mice. Altogether our findings do not support the hypothesis that early post-natal life exposure to WiFi signals induces detrimental effects on the developing immune system.

(E) Sangun O, Dundar B, Darici H, Comlekci S, Doguc DK, Celik S. The effects of long-term exposure to a 2450 MHz electromagnetic field on growth and pubertal development in female Wistar rats. Electromagn Biol Med. 34(1):63-71, 2015. (CE, DE, F, IU, ME, MO, OX, PN, VO) (Low SAR 0.143 W/kg)

The aim of this study was to investigate the effects of a 2450 MHz electromagnetic field (EMF) (wireless internet frequency) on the growth and development of female Wistar rats. The study was conducted on three groups of rats. The prenatal and postnatal groups were exposed to EMF 1 h/day beginning from intrauterine and postnatal periods, respectively. The third group was the sham-exposed group. Growth, nutrition and vaginal opening (VO) were regularly monitored. Serum and tissue specimens were collected at puberty. Histological examinations, total antioxidant status (TAS), total oxidant status (TOS) and oxidative stress index (OSI) measurements in ovary and brain tissues and also immunohistochemical staining of the hypothalamus were performed besides the determination of serum FSH, LH, E2 and IGF-1 values. Birth masses of the groups were similar ($p > 0.05$). Mass gain per day was significantly lower and the puberty was significantly later in the prenatal group. Brain and ovary TOS and OSI

values in the prenatal group were significantly increased ($p < 0.05$) compared to the control group. Serum LH levels of the prenatal and postnatal groups were increased, although serum FSH, and E2 values did not differ among the groups ($p > 0.05$). Histological examinations of the specimens revealed no statistically significant difference between the groups ($p > 0.05$). Exposure to 2450 MHz EMF, particularly in the prenatal period, resulted in postnatal growth restriction and delayed puberty in female Wistar rats. Increased TOS and OSI values in the brain and ovary tissues can be interpreted as a sign of chronic stress induced by EMF. This is the first longitudinal study which investigates the effects of EMF induced by wireless internet on pubertal development beside growth.

Sangün Ö, Dündar B, Çömlekçi S, Büyükgebiz A. The Effects of Electromagnetic Field on the Endocrine System in Children and Adolescents. Pediatr Endocrinol Rev 13(2):531-545, 2015. (Review)

Children are exposed to various kind of non-ionizan radiation in their daily life involuntarily. The potential sensitivity of developing organism to the effects of radiofrequency (RF) signals, the higher estimated specific absorption rate (SAR) values of children and greater lifetime cumulative risk raised the scientific interest for children's vulnerability to electromagnetic fields (EMFs). In modern societies, children are being exposed to EMFs in very early ages. There are many researches in scientific literature investigating the alterations of biological parameters in living organisms after EMFs. Although the international guidelines did not report definite, convincing data about the causality, there are unignorable amount of studies indicating the increased risk of cancer, hematologic effects and cognitive impairment. Although they are less in amount; growing number of studies reveal the impacts on metabolism and endocrine function. Reproductive system and growth look like the most challenging fields. However there are also some concerns on detrimental effects of EMFs on thyroid functions, adrenal hormones, glucose homeostasis and melatonin levels. It is not easy to conduct a study investigating the effects of EMFs on a fetus or child due to ethical issues. Hence, the studies are usually performed on virtual models or animals. Although the results are conflicting and cannot be totally matched with humans; there is growing evidence to distress us about the threats of EMF on children.

Santini SJ, Cordone V, Falone S, Mijit M, Tatone C, Amicarelli F, Di Emidio G. Role of Mitochondria in the Oxidative Stress Induced by Electromagnetic Fields: Focus on Reproductive Systems. Oxid Med Cell Longev 2018:5076271, 2018. (Review)

Erratum in

- Corrigendum to "Role of Mitochondria in the Oxidative Stress Induced by Electromagnetic Fields: Focus on Reproductive Systems".

  Santini SJ, Cordone V, Falone S, Mijit M, Tatone C, Amicarelli F, Di Emidio G.Oxid Med Cell Longev. 2020:5203105, 2020.

Modern technologies relying on wireless communication systems have brought increasing levels of electromagnetic field (EMF) exposure. This increased research interest in the effects of these radiations on human health. There is compelling evidence that EMFs affect cell physiology by

altering redox-related processes. Considering the importance of redox *milieu* in the biological competence of oocyte and sperm, we reviewed the existing literature regarding the effects of EMFs on reproductive systems. Given the role of mitochondria as the main source of reactive oxygen species (ROS), we focused on the hypothesis of a mitochondrial basis of EMF-induced reproductive toxicity. MEDLINE, Web of Science, and Scopus database were examined for peer-reviewed original articles by searching for the following keywords: "extremely low frequency electromagnetic fields (ELF-EMFs)," "radiofrequency (RF)," "microwaves," "Wi-Fi," "mobile phone," "oxidative stress," "mitochondria," "fertility," "sperm," "testis," "oocyte," "ovarian follicle," and "embryo." These keywords were combined with other search phrases relevant to the topic. Although we reported contradictory data due to lack of uniformity in the experimental designs, a growing body of evidence suggests that EMF exposure during spermatogenesis induces increased ROS production associated with decreased ROS scavenging activity. Numerous studies revealed the detrimental effects of EMFs from mobile phones, laptops, and other electric devices on sperm quality and provide evidence for extensive electron leakage from the mitochondrial electron transport chain as the main cause of EMF damage. In female reproductive systems, the contribution of oxidative stress to EMF-induced damages and the evidence of mitochondrial origin of ROS overproduction are reported, as well. In conclusion, mitochondria seem to play an important role as source of ROS in both male and female reproductive systems under EMF exposure. Future and more standardized studies are required for a better understanding of molecular mechanisms underlying EMF potential challenge to our reproductive system in order to improve preventive strategies.

(E) Saygin M, Caliskan S, Karahan N, Koyu A, Gumral N, Uguz A. Testicular apoptosis and histopathological changes induced by a 2.45 GHz electromagnetic field. Toxicol Ind Health. 27(5):455-463, 2011. (CE, GE, M, ME, VO)

There is a growing public concern about the potential human health hazard caused by exposure to electromagnetic radiation (EMR). The objective of this study is to investigate the effects of 2450 mhz electromagnetic field on apoptosis and histopathological changes on rat testis tissue. Twelve-week-old male Wistar Albino rats were used in this study. Eighteen rats equally divided into three different groups which were named group I, II and III. Cage control (group I), sham control (group II) and 2.45 GHz EMR (group III) groups were formed. Group III were exposed to 2.45 GHz EMR, at 3.21 W/kg specific absorption rate for 60 minutes/ day for 28 days. There was no difference among the groups for the diameter of the seminiferous tubules, pyknotic, karyolectic and karyotic cells. However, the number of Leydig cells of testis tissue of the rats in group III was significantly reduced comparing with the group I ($p < 0.05$). Estimation of spermatogenesis using the Johnsen testicular biopsy score revealed that the difference between groups is statistically significant. The level of TNF-α, Caspase-3 and Bcl-2 were compared, and no significant difference was found between the groups. When Bax apoptosis genes and Caspase-8 apoptosis enzyme were compared, there were significant differences between the groups ($p < 0.05$). Electromagnetic field affects spermatogenesis and causes to apoptosis due to the heat and other stress-related events in testis tissue.

(E) Saygin M, Asci H, Ozmen O, Cankara FN, Dincoglu D, Ilhan I. Impact of 2.45 GHz microwave radiation on the testicular inflammatory pathway biomarkers in young

rats: The role of gallic acid. Environ Toxicol. 31(12):1771-1784, 2016. (CE, M, ME, OX, VO) (SAR 3.21 W/kg)

The aim of this study was to investigate electromagnetic radiation (EMR) transmitted by wireless devices (2.45 GHz), which may cause physiopathological or ultrastructural changes, in the testes of rats. We addressed if the supplemental gallic acid (GA) may reduce these adverse effects. Six-week-old male Sprague Dawley rats were used in this study. Forty eight rats were equally divided into four groups, which were named: Sham, EMR only (EMR, 3 h day^{-1} for 30 days), EMR + GA (30 mg/kg/daily), and GA (30 mg/kg/daily) groups. Malondialdehyde (MDA) and total oxidant status (TOS) levels increased ($p = 0.001$ for both) in EMR only group. TOS and oxidative stress index (OSI) levels decreased in GA treated group significantly ($p = 0.001$ and $p = 0.045$, respectively). Total antioxidant status (TAS) activities decreased in EMR only group and increased in GA treatment group ($p = 0.001$ and $p = 0.029$, respectively). Testosterone and vascular endothelial growth factor (VEGF) levels decreased in EMR only group, but this was not statistically significant. Testosterone and VEGF levels increased in EMR+GA group, compared with EMR only group ($p = 0.002$), and also increased in GA group compared with the control and EMR only group ($p = 0.044$ and $p = 0.032$, respectively). Prostaglandin E_2 (PGE_2) and calcitonin gene releated peptide (CGRP) staining increased in tubules of the testes in EMR only group ($p < 0.001$ for both) and decreased in tubules of the testes in EMR+GA group ($p < 0.001$ for all parameters). In EMR only group, most of the tubules contained less spermatozoa, and the spermatozoon counts decreased in tubules of the testes. All these findings and the regenerative reaction, characterized by mitotic activity, increased in seminiferous tubules cells of the testes in EMR+GA group ($p < 0.001$). Long term EMR exposure resulted in testicular physiopathology via oxidative damage and inflammation. GA may have ameliorative effects on the prepubertal rat testes physiopathology.

Schonborn F, Burkhardt M, Kuster N, Differences in energy absorption between heads of adults and children in the near field of sources. *Health Phys* **74(2):160-168, 1998. (Dosimetry)**

This paper was motivated by a recent article in which the levels of electromagnetic energy absorbed in the heads of mobile phone users were compared for children and adults at the frequencies of 835 MHz and 1,900 MHz. Significant differences were found, in particular substantially greater absorption in children's heads at 835 MHz. These findings contradict other studies in which no significant changes had been postulated. The clarification of this issue is crucial to the mobile communications industry since current SAR evaluations as required by the FCC are only performed with phantoms based on the heads of adults. In order to investigate the differences in absorption between adults and children due to their differing anatomies, simulations have been performed using head phantoms based on MRI scans of an adult (voxel size 2 x 2 x 1 mm3) and two children (voxel size 2 x 2 x 1.1 mm3) of the ages of 3 and 7 y. Ten different tissue types were distinguished. The differences in absorption were investigated for the frequencies of 900 MHz and 1,800 MHz using 0.45 lambda dipoles instead of actual mobile phones. These well-defined sources simplified the investigation and facilitated the comparison to previously published data obtained from several numerical and experimental studies on phantoms based on adults. All simulations

were performed using a commercial code based on the finite integration technique. The results revealed no significant differences in the absorption of electromagnetic radiation in the near field of sources between adults and children. The same conclusion holds when children are approximated as scaled adults.

(E) Schrader, SM, Langford, RE, Turner, TW, Breitenstein, MJ, Clark, JC, Jenkins, BL, Lundyl DO, Simonl SD, Weyandtl TBl, Reproductive function in relation to duty assignments among military personnel. Reprod Toxicol 12(4):465-468, 1998. (CE, HU, M, MO) (see Weyandt et al. (1996))

As a follow-up to the pilot study of semen quality of soldiers with various military assignments a larger, more complete study was conducted. Soldiers were recruited at Fort Hood, Texas. Thirty-three men were exposed to radar as part of their duty assignment in the Signal Corps, 57 men were involved with firing the 155 mm howitzer (potential lead exposure), and 103 soldiers had neither lead nor radar exposure and served as the comparison control group. Both serum and urinary follicle-stimulating hormone and luteinizing hormone and serum, salivary, and urine testosterone levels were determined in all men. A complete semen analysis was conducted on each soldier. For statistical analysis, the primary study variables were: sperm concentration, sperm/ejaculate, semen volume, percent normal morphology, percent motile, percent viable (both vital stain and hypoosmotic swelling), curvilinear velocity,straight-line velocity, linearity, sperm head length, width, area, and perimeter. Variables were adjusted for significant confounders (e.g., abstinence, sample age, race). No statistical differences ($P < 0.05$) were observed in any measurement. While these results are in agreement with two previous studies assessing soldiers firing the 155-mm howitzer, they contradict our previous report indicating that radar exposure caused a significant decrease in sperm numbers. A possible explanation is that the radar exposure in this study was that used in Signal Corps operations while the men in the previous study were using different radar as part of military intelligence operations. The data presented here in men firing the 155-mm howitzer combined with the results from the previous studies confirms that there are no deficits in semen quality in these men. The contradiction between the results of the radar exposure studies indicates that more data are needed to evaluate the relationship of military radar and male reproductive health.

Sciorio R, Tramontano L, Esteves SC. Effects of mobile phone radiofrequency radiation on sperm quality. Zygote 30(2):159-168, 2022. (Review)

In the last decades, the universal use of mobile phones has contributed to radiofrequency electromagnetic radiation environmental pollution. The steady growth in mobile phone usage has raised concerns about the effects of phone radiation on male reproductive health. Epidemiological studies report a sharp decline in sperm counts in developing countries, and worldwide with c. 14% of couples having difficulties to conceive, many of which are attributed to a male infertility factor. Environment and lifestyle factors are known to contribute to male infertility. Exposure to heat, radiation, or radioactivity might induce damage to biological tissue organs, including the testis. Given the ubiquitous use of mobile phones, the potential adverse effects of the resulting environmental radiation needs to be elucidated further. It seems to be an apparent relationship between the increased exposure to mobile phone radiofrequency and sperm quality decline, but the evidence is not conclusive. Our review summarizes the evidence

concerning the possible adverse effects of cell phone radiation on the male reproductive system, with a focus on sperm quality. Also, we critically analyze the effects of elevated testicular temperature and oxidative stress on male fertility and how these factors could interfere with the physiological activities of the testis.

(E)Seckin E, SurenBasar F, Atmaca S, Kaymaz FF, Suzer A, Akar A, Sunan E, Koyuncu M. The effect of radiofrequency radiation generated by a Global System for Mobile Communications source on cochlear development in a rat model. J Laryngol Otol 128(5):400-405, 2014.(CE, IU, ME, PN, VO) (pregnant and newborn rat: 900 MHz 9-25 v/m and 19-25 v/m; 1800 MHz 9-18 v/m and 10-18 v/m)

Objective: This study aimed to determine the effect of radiofrequency radiation generated by 900 and 1800 MHz Global System for Mobile Communications sources on cochlear development in the rat model. **Methods:** Eight pregnant albino Wistar rats were divided into three groups: control, 900 MHz and 1800 MHz. The latter two groups of pregnant rats were exposed to radiofrequency radiation for 1 hour per day starting on the 12th day of pregnancy until delivery. The rats in the control, 900 MHz and 1800 MHz groups gave birth to 24, 31 and 26 newborn rats respectively. Newborn rats in the 900 MHz and 1800 MHz groups were exposed to radiofrequency radiation for 1 hour per day for 21 days after delivery. Hearing evaluations of newborn rats were carried out using distortion product otoacoustic emissions testing. Eight newborn rats were randomly selected from each group for electron microscopic evaluation. **Results:** Distortion product otoacoustic emission tests revealed no significant difference among the groups, but electron microscopic evaluation revealed significant differences among the groups with regard to the number of normal, apoptotic and necrotic cells. **Conclusion:** The findings indicated cellular structural damage in the cochlea caused by radiofrequency radiation exposure during cochlear development in the rat model.

(E) Sehitoglu I, Tumkaya L, Kalkan Y, Bedir R, Cure MC, Zorba OU, Cure E, Yuce S. Biochemical and histopathological effects on the rat testis after exposure to electromagnetic field during fetal period. Arch Esp Urol. 68(6):562-568, 2015. (CE, IU, M, ME, MO, VO) (No dosimetry data)

OBJECTIVES: Electromagnetic radiation (ER) emitted from cell phones may exert a detrimental influence on human health and may affect the man reproductive system. We aimed to study the biological and morphological effects on the testes of 60-day-old male rats after ER exposure (900 MHz), which was applied continuously throughout embryogenesis. METHODS: A total of six pregnant Sprague Dawley rats were included in the study. Three pregnant rats (experimental group) were exposed to radiation from a cell phone set to talking mode for 24 hours a day for 20 days, and the other 3 pregnant rats (control group) were not to exposed to radiation. Newborn male rats were included from the experimental group (n=7) and the control group (n=7). At the end of 60 days, the rats' testes were excised, and testis length, width, depth, and weight were measured. Histopathological examinations were compared and serum testosterone (T) levels were assayed biochemically. RESULTS: While serum T level (3.51±0.21 ng/ml) of ER Exposed group was significantly lower than the control group (4.04±0.47 ng/ml, p=0.018), Caspase-3 enzyme activity (2.00±0.88) was significantly higher than the control group control (1.00±0.63,

p=0.026). Johnsen score (8.4±0.5) of ER group was fairly lower than the control group (9.4±0.5, p= 0.010). CONCLUSION: Our study demonstrated that ER exposure throughout embryogenesis may cause reductions in serum total T levels and in the size and weight of the testes of male rats, while causing modest increase in apoptosis.

(E) Sepehrimanesh M, Saeb M, Nazifi S, Kazemipour N, Jelodar G, Saeb S. Impact of 900 MHz electromagnetic field exposure on main male reproductive hormone levels: a Rattus norvegicus model. Int J Biometeorol. 58(7):1657-1663, 2014. (CE, M, MO, VO) (SAR 0.19-1.22 W/kg)

This work analyzes the effects of radiofrequency-electromagnetic field (RF-EMF) exposure on the reproductive system of male rats, assessed by measuring circulating levels of FSH, LH, inhibin B, activin B, prolactin, and testosterone. Twenty adult male Sprague-Dawley rats (180 ± 10 g) were exposed to 900 MHz RF-EMF in four equal separated groups. The duration of exposure was 1, 2, and 4 h/day over a period of 30 days and sham-exposed animals were kept under the same environmental conditions as the exposed group except with no RF-EMF exposure. Before the exposure, at 15 and 30 days of exposure, determination of the abovementioned hormone levels was performed using ELISA. At the end of the experiment, FSH and LH values of the long time exposure (LTE) group were significantly higher than the sham-exposed group ($p < 0.05$). Serum activin B and prolactin in the LTE group showed significant increase and inhibin B showed significant decrease than sham and short time exposed (STE) groups after 30 days RF-EMF exposure ($p < 0.05$). Also, a significant decrease in serum testosterone levels in the LTE group was found compared to short and moderate time exposed (MTE) groups after 30 days RF-EMF exposure ($p < 0.05$). Results suggest that reproductive hormone levels are disturbed as a result of RF-EMF exposure and it may possibly affect reproductive functions. However, testosterone and inhibin B concentrations as a fertility marker and spermatogenesis were decreased significantly.

(E) Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S. Analysis of rat testicular proteome following 30-days exposure to 900 MHz electromagnetic field radiation. Electrophoresis.35(23):3331-3338, 2014. (CE, M, MO, OX, VO) (SAR 0.19-1.22 W/kg)

The use of electromagnetic field (EMF) generating apparatuses such as cell phones is increasing, and has caused an interest in the investigations of its effects on human health. We analyzed proteome in preparations from the whole testis in adult male Sprague-Dawley rats exposed for 1, 2 or 4 h/d for 30 consecutive days to 900 MHz EMF radiation, simulating a range of possible human cell phone use. Subjects were sacrificed immediately after the end of the experiment and testes fractions were solubilized and separated via high resolution 2-dimensional electrophoresis, and gel patterns were scanned, digitized and processed. Thirteen of the proteins which found only in sham or in exposure groups were identified by MALDI-TOF/TOF-MS. Among them, heat shock proteins, superoxide dismutase, peroxiredoxin-1 and other proteins related to misfolding of proteins and/or stress were identified. These results demonstrate significant effects of radio-frequency modulated electromagnetic fields (RF-EMF) exposure on proteome, particularly in protein species in the

rodent testis, and suggest that a 30 d exposure to EMF radiation induces non-thermal stress in testicular tissue. The functional implication of the identified proteins was discussed.

(E) Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S, Davis DL. Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. Environ Sci Pollut Res Int. 24(15):13666-13673, 2017. (CE, M, MO, VO) (SAR 0.19-1.22 W/kg)

Although cell phones have been used worldwide, some adverse and toxic effects were reported for this communication technology apparatus. To analyze in vivo effects of exposure to radiofrequency-electromagnetic field (RF-EMF) on protein expression in rat testicular proteome, 20 Sprague-Dawley rats were exposed to 900 MHz RF-EMF for 0, 1, 2, or 4 h/day for 30 consecutive days. Protein content of rat testes was separated by high-resolution two-dimensional electrophoresis using immobilized pH gradient (pI 4-7, 7 cm) and 12% acrylamide and identified by MALDI-TOF/TOF-MS. Two protein spots were found differentially overexpressed ($P < 0.05$) in intensity and volume with induction factors 1.7 times greater after RF-EMF exposure. After 4 h of daily exposure for 30 consecutive days, ATP synthase beta subunit (ASBS) and hypoxia up-regulated protein 1 precursor (HYOU1) were found to be significantly up-regulated. These proteins affect signaling pathways in rat testes and spermatogenesis and play a critical role in protein folding and secretion in the endoplasmic reticulum. Our results indicate that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage. In light of the widespread practice of men carrying phones in their pockets near their gonads, where exposures can exceed as-tested guidelines, further study of these effects should be a high priority.

(E) Shahin NN, El-Nabarawy NA, Gouda AS, Mégarbane B. The protective role of spermine against male reproductive aberrations induced by exposure to electromagnetic field - An experimental investigation in the rat. Toxicol Appl Pharmacol 370:117-130, 2019. (CE, GE, IX, M, ME, MO, OX, VO) (SAR 1.075 W/kg)

The exponentially increasing use of electromagnetic field (EMF)-emitting devices imposes substantial health burden on modern societies with particular concerns of male infertility. Limited studies have addressed the modulation of this risk by protective agents. We investigated the hazardous effects of rat exposure to EMF (900 MHz, 2 h/day for 8 weeks) on male fertility and evaluated the possible protective effect of the polyamine, spermine, against EMF-induced alterations. Exposure to EMF significantly decreased sperm count, viability and motility, and increased sperm deformities. EMF-exposed rats exhibited significant reductions in serum inhibin B and testosterone along with elevated activin A, follicle-stimulating hormone, luteinizing hormone and estradiol concentrations. Testicular steroidogenic acute regulatory protein (StAR), c-kit mRNA expression and testicular activities of the key androgenic enzymes 3β- and 17β-hydroxysteroid dehydrogenases were significantly attenuated following exposure to EMF. Exposure led to testicular lipid peroxidation, decreased catalase and glutathione peroxidase activities and triggered nuclear factor-kappa B p65, inducible nitric oxide synthase, cyclooxygenase-2 and caspase-3 overexpression. EMF-exposed rats showed testicular DNA damage as indicated by elevated comet parameters. Spermine administration (2.5 mg/Kg/day

intraperitoneally for 8 weeks) prevented EMF-induced alterations in the sperm and hormone profiles, StAR and c-kit expression and androgenic enzyme activities. Spermine hampered EMF-induced oxidative, inflammatory, apoptotic and DNA perturbations. Histological and histomorphometric analysis of the testes supported all biochemical findings. In conclusion, rat exposure to EMF disrupts sperm and hormone profiles with underlying impairment of steroidogenesis and spermatogenesis. Spermine confers protection against EMF-associated testicular and reproductive aberrations, at least in part, via antioxidant, anti-inflammatory and anti-apoptotic mechanisms.

(E) Shahin S, Singh VP, Shukla RK, Dhawan A, Gangwar RK, Singh SP, Chaturvedi CM. 2.45 GHz microwave irradiation-induced oxidative stress affects implantation or pregnancy in mice, Mus musculus. Appl Biochem Biotechnol. 169(5):1727-1751, 2013. (CE, DE, F, GE, MO, OX, VO) (Low SAR)

The present experiment was designed to study the 2.45 GHz low-level microwave (MW) irradiation-induced stress response and its effect on implantation or pregnancy in female mice. Twelve-week-old mice were exposed to MW radiation (continuous wave for 2 h/day for 45 days, frequency 2.45 GHz, power density=0.033549 mW/cm(2), and specific absorption rate=0.023023 W/kg). At the end of a total of 45 days of exposure, mice were sacrificed, implantation sites were monitored, blood was processed to study stress parameters (hemoglobin, RBC and WBC count, and neutrophil/lymphocyte (N/L) ratio), the brain was processed for comet assay, and plasma was used for nitric oxide (NO), progesterone and estradiol estimation. Reactive oxygen species (ROS) and the activities of ROS-scavenging enzymes- superoxide dismutase, catalase, and glutathione peroxidase- were determined in the liver, kidney and ovary. We observed that implantation sites were affected significantly in MW-irradiated mice as compared to control. Further, in addition to a significant increase in ROS, hemoglobin ($p<0.001$), RBC and WBC counts ($p<0.001$), N/L ratio ($p<0.01$), DNA damage ($p<0.001$) in brain cells, and plasma estradiol concentration ($p<0.05$), a significant decrease was observed in NO level ($p<0.05$) and antioxidant enzyme activities of MW-exposed mice. Our findings led us to conclude that a low level of MW irradiation-induced oxidative stress not only suppresses implantation, but it may also lead to deformity of the embryo in case pregnancy continues. We also suggest that MW radiation-induced oxidative stress by increasing ROS production in the body may lead to DNA strand breakage in the brain cells and implantation failure/resorption or abnormal pregnancy in mice.

(E) Shahin S, Mishra V, Singh SP, Chaturvedi CM. 2.45-GHz microwave irradiation adversely affects reproductive function in male mouse, Mus musculus by inducing oxidative and nitrosative stress. Free Radic Res. 48(5):511-525, 2014. (CE, M, ME, MO, OX, VO) (Low SAR)

Electromagnetic radiations are reported to produce long-term and short-term biological effects, which are of great concern to human health due to increasing use of devices emitting EMR especially microwave (MW) radiation in our daily life. In view of the unavoidable use of MW emitting devices (microwaves oven, mobile phones, Wi-Fi, etc.) and their harmful effects on biological system, it was thought worthwhile to investigate the long-

term effects of low-level MW irradiation on the reproductive function of male Swiss strain mice and its mechanism of action. Twelve-week-old mice were exposed to non-thermal low-level 2.45-GHz MW radiation (CW for 2 h/day for 30 days, power density = 0.029812 mW/cm(2) and SAR = 0.018 W/Kg). Sperm count and sperm viability test were done as well as vital organs were processed to study different stress parameters. Plasma was used for testosterone and testis for 3β HSD assay. Immunohistochemistry of 3β HSD and nitric oxide synthase (i-NOS) was also performed in testis. We observed that MW irradiation induced a significant decrease in sperm count and sperm viability along with the decrease in seminiferous tubule diameter and degeneration of seminiferous tubules. Reduction in testicular 3β HSD activity and plasma testosterone levels was also noted in the exposed group of mice. Increased expression of testicular i-NOS was observed in the MW-irradiated group of mice. Further, these adverse reproductive effects suggest that chronic exposure to nonionizing MW radiation may lead to infertility via free radical species-mediated pathway.

(E) Shahin S, Singh SP, Chaturvedi CM. Mobile phone (1800 MHz) radiation impairs female reproduction in mice, Mus musculus, through stress induced inhibition of ovarian and uterine activity. Reprod Toxicol. 73:41-60, 2017. (CE, DE, F, ME, MO, OX, VO)

Present study investigated the long-term effects of mobile phone (1800 MHz) radiation in stand-by, dialing and receiving modes on the female reproductive function (ovarian and uterine histo-architecture, and steroidogenesis) and stress responses (oxidative and nitrosative stress). We observed that mobile phone radiation induces significant elevation in ROS, NO, lipid peroxidation, total carbonyl content and serum corticosterone coupled with significant decrease in antioxidant enzymes in hypothalamus, ovary and uterus of mice. Compared to control group, exposed mice exhibited reduced number of developing and mature follicles as well as corpus lutea. Significantly decreased serum levels of pituitary gonadotrophins (LH, FSH), sex steroids (E2 and P4) and expression of SF-1, StAR, P-450scc, 3β-HSD, 17β-HSD, cytochrome P-450 aromatase, ER-α and ER-β were observed in all the exposed groups of mice, compared to control. These findings suggest that mobile phone radiation induces oxidative and nitrosative stress, which affects the reproductive performance of female mice.

(E) Shahin S, Singh SP, Chaturvedi CM 2.45 GHz microwave radiation induced oxidative and nitrosative stress mediated testicular apoptosis: Involvement of a p53 dependent bax-caspase-3 mediated pathway. Environ Toxicol 33(9):931-945, 2018. (CE, M, ME, MO, OX, VO) (Low SAR)

Deleterious effects of MW radiation on the male reproduction are well studied. Previous reports although suggest that 2.45 GHz MW irradiation induced oxidative and nitrosative stress adversely affects the male reproductive function but the detailed molecular mechanism occurring behind it has yet to be elucidated. The aim of present study was to investigate the underlying detailed pathway of the testicular apoptosis induced by free radical load and redox imbalance due to 2.45 GHz MW radiation exposure and the degree of severity along with the increased exposure duration. Twelve-week old male mice were exposed to 2.45 GHz MW radiation

[continuous-wave (CW) with overall average Power density of 0.0248 mW/cm2 and overall average whole body SAR value of 0.0146 W/kg] for 2 hr/day over a period of 15, 30, and 60 days. Testicular histology, serum testosterone, ROS, NO, MDA level, activity of antioxidant enzymes, expression of pro-apoptotic proteins (p53 and Bax), anti-apoptotic proteins (Bcl-2 and Bcl-xL), cytochrome-c, inactive/active caspase-3, and uncleaved PARP-1 were evaluated. Findings suggest that 2.45 GHz MW radiation exposure induced testicular redox imbalance not only leads to enhanced testicular apoptosis via p53 dependent Bax-caspase-3 mediated pathway, but also increases the degree of apoptotic severity in a duration dependent manner.

(E) Shallom JM, Di Carlo AL, Ko D, Penafiel LM, Nakai A, Litovitz TA. Microwave exposure induces Hsp70 and confers protection against hypoxia in chick embryos. J Cell Biochem 86(3):490-496, 2002. (AE, DE, IU, MO) (SAR 1.75 or 2.5 W/kg)

To determine if microwave exposure could elicit a biological effect in the absence of thermal stress, studies were designed in which chick embryos were exposed to athermal microwave radiation (915 MHz) to look for induction of Hsp70, a protein produced during times of cellular stress that aids in the protection of cellular components. Levels of Hsp70 were found to increase within 2 h, with maximum expression (approximately 30% higher than controls) typically occurring by 3 h from the start of exposure. Other embryos were exposed to microwave radiation prior to being subjected to hypoxic stress, and were found to have significantly higher survival ($P < 0.05$) following re-oxygenation than non-exposed controls. The results of these studies indicate that not only can athermal microwave exposures activate the stress protein response pathway; they can also enhance survivability following exposure to a subsequent, potentially lethal stress. From a public health standpoint, it is important that more studies be performed to determine if repeated exposures, a condition likely to be found in cell phone use, are still beneficial.

(E) Sharma A, Kesari KK, Saxena VK, Sisodia R. Ten gigahertz microwave radiation impairs spatial memory, enzymes activity, and histopathology of developing mice brain. Mol Cell Biochem. 435(1-2):1-13, 2017. (BE, CE, DE, ME, OX, VO) (Low SAR 0.179 W/kg)

For decades, there has been an increasing concern about the potential hazards of non-ionizing electromagnetic fields that are present in the environment and alarming as a major pollutant or electro-pollutant for health risk and neuronal diseases. Therefore, the objective of the present study was to explore the effects of 10 GHz microwave radiation on developing mice brain. Two weeks old mice were selected and divided into two groups (i) sham-exposed and (ii) microwave-exposed groups. Animals were exposed for 2 h/day for 15 consecutive days. After the completion of exposure, within an hour, half of the animals were autopsied immediately and others were allowed to attain 6 weeks of age for the follow-up study. Thereafter results were recorded in terms of various biochemical, behavioral, and histopathological parameters. Body weight result showed significant changes immediately after treatment, whereas non-significant changes were observed in mice attaining 6 weeks of age. Several other endpoints like brain weight, lipid peroxidation, glutathione, protein, catalase, and superoxide dismutase were also

found significantly ($p < 0.05$) altered in mice whole brain. These significant differences were found immediately after exposure and also in follow-up on attaining 6 weeks of age in microwave exposure group. Moreover, statistically significant ($p < 0.001$) effect was investigated in spatial memory of the animals, in learning to locate the position of platform in Morris water maze test. Although in probe trial test, sham-exposed animals spent more time in searching for platform into the target quadrant than in opposite or other quadrants. Significant alteration in histopathological parameters (qualitative and quantitative) was also observed in CA1 region of the hippocampus, cerebral cortex, and ansiform lobule of cerebellum. Results from the present study concludes that the brain of 2 weeks aged mice was very sensitive to microwave exposure as observed immediately after exposure and during follow-up study at 6 weeks of age

(NE) Shirai T, Wang J, Kawabe M, Wake K, Watanabe SI, Takahashi S, Fujiwara O. No adverse effects detected for simultaneous whole-body exposure to multiple-frequency radiofrequency electromagnetic fields for rats in the intrauterine and pre- and post-weaning periods. J Radiat Res. 58(1):48-58, 2017. (BE, CE, DE, IU, VO) (SAR 0.384-0.433 W/kg)

In everyday life, people are exposed to radiofrequency (RF) electromagnetic fields (EMFs) with multiple frequencies. To evaluate the possible adverse effects of multifrequency RF EMFs, we performed an experiment in which pregnant rats and their delivered offspring were simultaneously exposed to eight different communication signal EMFs (two of 800 MHz band, two of 2 GHz band, one of 2.4 GHz band, two of 2.5 GHz band and one of 5.2 GHz band). Thirty six pregnant Sprague-Dawley (SD) 10-week-old rats were divided into three groups of 12 rats: one control (sham exposure) group and two experimental (low- and high-level RF EMF exposure) groups. The whole body of the mother rats was exposed to the RF EMFs for 20 h per day from Gestational Day 7 to weaning, and F_1 offspring rats (46-48 F1 pups per group) were then exposed up to 6 weeks of age also for 20 h per day. The parameters evaluated included the growth, gestational condition and organ weights of the dams; the survival rates, development, growth, physical and functional development, memory function, and reproductive ability of the F_1 offspring; and the embryotoxicity and teratogenicity in the F_2 rats. No abnormal findings were observed in the dams or F_1 offspring exposed to the RF EMFs or to the F_2 offspring for any of the parameters evaluated. Thus, under the conditions of the present experiment, simultaneous whole-body exposure to eight different communication signal EMFs at frequencies between 800 MHz and 5.2 GHz did not show any adverse effects on pregnancy or on the development of rats.

(E) Shokri S, Soltani A, Kazemi M, Sardari D, Mofrad FB. Effects of Wi-Fi (2.45 GHz) Exposure on Apoptosis, Sperm Parameters and Testicular Histomorphometry in Rats: A Time Course Study. Cell J. 17(2):322-331, 2015. (CE, M, ME, VO) (No dosimetry data)

OBJECTIVE: In today's world, 2.45-GHz radio-frequency radiation (RFR) from industrial, scientific, medical, military and domestic applications is the main part of indoor-outdoor electromagnetic field exposure. Long-term effects of 2.45-GHz Wi-Fi radiation on male reproductive system was not known completely. Therefore, this study aimed to investigate

the major cause of male infertility during short- and long-term exposure of Wi-Fi radiation. MATERIALS AND METHODS: This is an animal experimental study, which was conducted in the Department of Anatomical Sciences, Faculty of Medicine, Zanjan University of Medical Sciences, Zanjan, IRAN, from June to August 2014. Three-month-old male Wistar rats (n=27) were exposed to the 2.45 GHz radiation in a chamber with two Wi-Fi antennas on opposite walls. Animals were divided into the three following groups: I. control group (n=9) including healthy animals without any exposure to the antenna, II. 1-hour group (n=9) exposed to the 2.45 GHz Wi-Fi radiation for 1 hour per day during two months and III.7-hour group (n=9) exposed to the 2.45 GHz Wi-Fi radiation for 7 hours per day during 2 months. Sperm parameters, caspase-3 concentrations, histomorphometric changes of testis in addition to the apoptotic indexes were evaluated in the exposed and control animals. RESULTS: Both 1-hour and 7-hour groups showed a decrease in sperm parameters in a time dependent pattern. In parallel, the number of apoptosis-positive cells and caspase-3 activity increased in the seminiferous tubules of exposed rats. The seminal vesicle weight reduced significantly in both1-hour or 7-hour groups in comparison to the control group. CONCLUSION: Regarding the progressive privilege of 2.45 GHz wireless networks in our environment, we concluded that there should be a major concern regarding the time-dependent exposure of whole-body to the higher frequencies of Wi-Fi networks existing in the vicinity of our living places.

(E) Shokri M, Shamsaei ME, Malekshah AK, Amiri FT. The protective effect of melatonin on radiofrequency electromagnetic fields of mobile phone-induced testicular damage in an experimental mouse model. Andrologia 52(11):e13834, 2020. (CE, M, ME, MO, OX, VO) (SAR 1.3 W/kg for head, 1.43 W/kg or whole body)

Radiofrequency electromagnetic radiation (RF-EMR) from mobile devices has undesirable effects on the male reproductive organs. Melatonin with antioxidant potential can help to prevent these damages. Therefore, the aim of this study was to evaluate the protective effect of melatonin on testicular damage induced by RF-EMR of mobile phone. In this experimental study, 32 adult male BALB/c mice were divided randomly into four groups: control, melatonin (2 mg/kg, for 30 consecutive days, intraperitoneally), RF-EMR (900 MHz, 100 to 300 MT, 54 to 160 W/m) (4 hr per day, whole body) and melatonin + RF-EMR groups. One day after the last prescription were evaluated oxidative stress parameters, testosterone level and histopathological assays of the testis. EMR of mobile phone led to the induction of oxidative stress, testicular tissue damage and decreased testosterone. Treatment with melatonin improved oxidative stress parameters such as MDA and GSH, and testis injury score, increased the thickness of the germinal epithelial thickness and diameter of the seminiferous tubule, and decreased testosterone hormone in the EMR-exposed mice, and these differences were significant($p < .05$). Data showed that melatonin with its antioxidant property can decrease oxidative damage induced by RF-EMR of mobile phones on testis tissue.

(NE) Sommer, A. M., Grote, K., Reinhardt, T., Streckert, J., Hansen, V. and Lerchl, A. Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: A Multi-generation Study. Radiat. Res. 171: 89-95, 2009. (CE, DE, VO) (cf Magras and Xenos, 1997)

Male and female mice (C57BL) were chronically exposed (life-long, 24 h/day) to mobile

phone communication electromagnetic fields at approximately 1966 MHz (UMTS). Their development and fertility were monitored over four generations by investigating histological, physiological, reproductive and behavioral functions. The mean whole-body SARs, calculated for adult animals at the time of mating, were 0 (sham), 0.08, 0.4 and 1.3 W/kg. Power densities were kept constant for each group (0, 1.35, 6.8 and 22 W/m(2)), resulting in varying SARs due to the different numbers of adults and pups over the course of the experiment. The experiment was done in a blind fashion. The results show no harmful effects of exposure on the fertility and development of the animals. The number and the development of pups were not affected by exposure. Some data, albeit without a clear dose-response relationship, indicate effects of exposure on food consumption that is in accordance with some data published previously. In summary, the results of this study do not indicate harmful effects of long-term exposure of mice to UMTS over several generations.

(E) Spiers DE, Baummer SC, Thermal and metabolic responsiveness of Japanese quail embryos following periodic exposure to 2,450 MHz microwaves. Bioelectromagnetics 12(4):225-239, 1991. (CE, DE, IU)

Two studies were performed to determine if repeated exposure of the avian egg to microwaves can alter metabolism, temperature, and growth rate of embryos. Another aim was to supplement conventional heating with microwave heating and provide an optimal temperature for growth. Japanese quail (Coturnix coturnix japonica) eggs were exposed from day 1 through 15 of incubation (8 h/day) to sham or microwave (2,450 MHz) irradiation. Microwave exposures were at two power densities, 5 or 20 mW/cm2, and at three ambient temperatures (Tas), 30.0, 33.1, or 35.4 degrees C. Specific absorption rates for unincubated and 15-day-old incubated eggs were, respectively, 0.76 and 0.66 W kg-1 mW-1 cm-2 (i.e., 3.8 and 3.3 W/kg at 5 mW/cm2 and 15.2 and 13.2 W/kg at 20 mW/cm2). Eggs were concurrently sham exposed at each of five Tas, ranging from 27.9 to 37.5 degrees C. Tests were conducted during the 16th day of incubation (i.e., 1 day post-treatment), in the absence of microwaves, to determine metabolic rate of embryos and internal and external egg temperatures at different Tas. Repeated exposures to microwaves at 5 and 20 mW/cm2 at the same Ta (30 degrees C) increased wet-embryo mass on the 16th day by an average, respectively, of 9% and 61% when compared with predicted masses for embryos exposed at the same Ta in the absence of microwave radiation. There was no reliable indication, from post-treatment tests and comparisons with control embryos of similar mass, that repeated exposure to microwave radiation resulted in abnormal physiological development. Microwave radiation can be used to increase egg temperature and embryonic growth rate at Tas below normal incubation level without altering basic metabolic and thermal characteristics of the developing bird.

(E) Stasinopoulou M, Fragopoulou AF, Stamatakis A, Mantziaras G, Skouroliakou K, Papassideri IS, Stylianopoulou F, Lai H, Kostomitsopoulos N, Margaritis LH. Effects of pre- and postnatal exposure to 1880-1900MHz DECT base radiation on development in the rat. Reprod Toxicol. 65:248-262, 2016. (CE, DE, IU, ME, MO, PN) (Low SAR 0.016-0.020 W/kg)

In the present study, to evaluate the effects of wireless 1880-1900MHz Digital Enhanced Communication Telephony (DECT) base radiation on fetal and postnatal development,

Wistar rats were exposed at an average electric field intensity of 3.7V/m, 12h/day, during pregnancy. After parturition, a group of dams and offspring were similarly exposed for another 22days. Controls were sham-exposed. The data showed that DECT base radiation exposure caused heart rate increase in the embryos on the 17th day of pregnancy. Moreover, significant changes on the newborns' somatometric characteristics were noticed. Pyramidal cell loss and glia fibrilliary acidic protein (GFAP) over-expression were detected in the CA4 region of the hippocampus of the 22-day old pups that were irradiated either during prenatal life or both pre- and postnatally. Changes in the integrity of the brain in the 22-day old pups could potentially be related to developmental behavioral changes during the fetal period.

(E) Sudan M, Kheifets L, Arah O, Olsen J, Zeltzer L. Prenatal and Postnatal Cell Phone Exposures and Headaches in Children. Open Pediatr Med Journal. 6(2012):46-52, 2012. (BE, CE, HU)

OBJECTIVE: Children today are exposed to cell phones early in life, and may be at the greatest risk if exposure is harmful to health. We investigated associations between cell phone exposures and headaches in children. STUDY DESIGN: The Danish National Birth Cohort enrolled pregnant women between 1996 and 2002. When their children reached age seven years, mothers completed a questionnaire regarding the child's health, behaviors, and exposures. We used multivariable adjusted models to relate prenatal only, postnatal only, or both prenatal and postnatal cell phone exposure to whether the child had migraines and headache-related symptoms. RESULTS: Our analyses included data from 52,680 children. Children with cell phone exposure had higher odds of migraines and headache-related symptoms than children with no exposure. The odds ratio for migraines was 1.30 (95% confidence interval: 1.01-1.68) and for headache-related symptoms was 1.32 (95% confidence interval: 1.23-1.40) for children with both prenatal and postnatal exposure. CONCLUSIONS: In this study, cell phone exposures were associated with headaches in children, but the associations may not be causal given the potential for uncontrolled confounding and misclassification in observational studies such as this. However, given the widespread use of cell phones, if a causal effect exists it would have great public health impact.

(E) Sudan M, Kheifets L, Arah OA, Olsen J. Cell phone exposures and hearing loss in children in the Danish national birth cohort. Paediatr Perinat Epidemiol. 27(3):247-257, 2013. (CE, FC, HU)

BACKGROUND: Children today are exposed to cell phones early in life, and may be the most vulnerable if exposure is harmful to health. We investigated the association between cell phone use and hearing loss in children. **METHODS:** The Danish National Birth Cohort (DNBC) enrolled pregnant women between 1996 and 2002. Detailed interviews were conducted during gestation, and when the children were 6 months, 18 months and 7 years of age. We used multivariable-adjusted logistic regression, marginal structural models (MSM) with inverse-probability weighting, and doubly robust estimation (DRE) to relate hearing loss at age 18 months to cell phone use at age 7 years, and to investigate cell phone use reported at age 7 in relation to hearing loss at age 7. **RESULTS:** Our analyses included data from 52 680 children. We observed weak associations between cell phone

use and hearing loss at age 7, with odds ratios and 95% confidence intervals from the traditional logistic regression, MSM and DRE models being 1.21 [95% confidence interval [CI] 0.99, 1.46], 1.23 [95% CI 1.01, 1.49] and 1.22 [95% CI 1.00, 1.49], respectively. **CONCLUSIONS:** Our findings could have been affected by various biases and are not sufficient to conclude that cell phone exposures have an effect on hearing. This is the first large-scale epidemiologic study to investigate this potentially important association among children, and replication of these findings is needed.

(E) Sudan M, Kheifets LI, Arah OA, Divan HA, Olsen J. Complexities of sibling analysis when exposures and outcomes change with time and birth order. Expo Sci Environ Epidemiol. 24(5):482-488, 2014. (BE, CE, HU)

In this study, we demonstrate the complexities of performing a sibling analysis with a re-examination of associations between cell phone exposures and behavioral problems observed previously in the Danish National Birth Cohort. Children (52,680; including 5441 siblings) followed up to age 7 were included. We examined differences in exposures and behavioral problems between siblings and non-siblings and by birth order and birth year. We estimated associations between cell phone exposures and behavioral problems while accounting for the random family effect among siblings. The association of behavioral problems with both prenatal and postnatal exposure differed between siblings (odds ratio (OR): 1.07; 95% confidence interval (CI): 0.69-1.66) and non-siblings (OR: 1.54; 95% CI: 1.36-1.74) and within siblings by birth order; the association was strongest for first-born siblings (OR: 1.72; 95% CI: 0.86-3.42) and negative for later-born siblings (OR: 0.63; 95% CI: 0.31-1.25), which may be because of increases in cell phone use with later birth year. Sibling analysis can be a powerful tool for (partially) accounting for confounding by invariant unmeasured within-family factors, but it cannot account for uncontrolled confounding by varying family-level factors, such as those that vary with time and birth.

(NE) Suzuki S, Okutsu M, Suganuma R, Komiya H, Nakatani-Enomoto S, Kobayashi S, Ugawa YTateno H, Fujimori K. Influence of radiofrequency-electromagnetic waves from 3rd-generation cellular phones on fertilization and embryo development in mice. Bioelectromagnetics. 38(6):466-473, 2017. (AE, F, M, IV)

The purpose of this study was to evaluate the effects of 3rd-generation (3G) cellular phone radiofrequency-electromagnetic wave (RF-EMW) exposure on fertilization and embryogenesis in mice. Oocytes and spermatozoa were exposed to 3G cellular phone RF-EMWs, 1.95 GHz wideband code division multiple access, at a specific absorption rate of 2 mW/g for 60 min, or to sham exposure. After RF-EMW exposure, in vitro fertilization and intracytoplasmic sperm injection were performed. Rates of fertilization, embryogenesis (8-cell embryo, blastocyst), and chromosome aberration were compared between the combined spermatozoa and oocyte groups: both exposed, both non-exposed, one exposed, and the other non-exposed. Rates of fertilization, embryogenesis, and blastocyst formation did not change significantly across the four groups. Considering that the degree of exposure in the present study was ≥100 times greater than daily exposure of human spermatozoa and even greater than daily exposure of oocytes, the present results indicate safety of RF-EMW exposure in humans.

(NE) Takahashi S, Imai N, Nabae K, Wake K, Kawai H, Wang J, Watanabe S, Kawabe M, Fujiwara O, Ogawa K, Tamano S, Shirai T. Lack of adverse effects of whole-body exposure to a mobile telecommunication electromagnetic field on the rat fetus. Radiat Res. 173(3):362-372, 2010. (CE, DE, IU, PN, VO) (Low SAR)

The recent steep increase in the number of users of cellular phones is resulting in marked increase of exposure of humans to radiofrequency electromagnetic fields (EMFs). Children are of particular concern. Our goal was to evaluate potential adverse effects of long-term whole-body exposure to EMFs simulating those from base stations for cellular phone communication. Pregnant rats were given low, high or no exposure. At the high level, the average specific absorption rate (SAR)for the dams was 0.066-0.093 W/kg. The SAR for the fetuses and the F(1) progeny was 0.068-0.146 W/kg. At the low level, the SARs were about 43% of these. The 2.14 GHz signals were applied for 20 h per day during the gestation and lactation periods. No abnormal findings were observed in either the dams or the F(1) generation exposed to the EMF or in the F(2) offspring. Parameters evaluated included growth, gestational condition and organ weights for dams and survival rates, development, growth, physical and functional development, hormonal status, memory function and reproductive ability of the F(1) offspring (at 10 weeks of age) along with embryotoxicity and teratogenicity in the F(2) rats. Thus, under our experimental conditions, whole-body exposure to 2.14 GHz for 20 h per day during gestation and lactation did not cause any adverse effects on pregnancy or the development of rats.

(E) Tan B, Tan FC, Yalcin B, Dasdag S, Yegin K, Yay AH. Changes in the histopathology and in the proteins related to the MAPK pathway in the brains of rats exposed to pre and postnatal radiofrequency radiation over four generations. J Chem Neuroanat 126:102187, 2022. (CE, IU, ME, MO, PN, VO) (cross degeneration effect, cf Magras and Xenos, 1997 and Sommer et al., 2009)

The development of new technologies and industry increases the number and variety of electromagnetic field (EMF) sources. Researcher are increasingly interested in the effects of EMF on brain health. The brain's function is largely dependent on electrical excitability, so it would be expected to be vulnerable to EMF. We therefore investigated the effects of brain development in the fetus, histopathological changes in female rats and the hippocampal level of MAPK proteins in male rats after exposed to pre and postnatal 2450 MHz continuous wave (CW) radiofrequency radiation (RFR) over four generations. Four groups; sham, irradiated female, irradiated male, irradiated male and female, with each consisting of four rats (one male and three females) were created. Rats in the exposure groups were whole-body exposed to 2450 MHz CW-RFR for 12 h/day during the experiment. Irradiation started one month before fertilization in the experimental group. On the 18th day of the gestational period, one pregnant rat from each group was decapitated under general anesthesia and the fetuses were taken. The remaining two pregnant rats completed the normal gestation period. When the offspring were two months old, four rats, one male and three female, were allocated for the second generation study. Next generation animals were also experienced the same processes as the first generation rats. This study were evaluated development of brain in fetuses and histopathological changes in brain of female rats using haematoxylin eosin staining, and the hippocampal level of MAPK proteins in brain of male rats by Western Bloting. We observed hemorrhagic areas, irregular

cellular localization and vascular structures in the brain of fetal and adult female rat of exposed groups in the all generations. pERK, ptau, pJNK and pP38 were increased in the brain of adult male rat of exposed groups in the all generations ($p < 0.005$). Pre and postnatal 2450 MHz continuous wave radiofrequency radiation exposure may cause changes in the function of the MAPK pathway affecting cognitive processes such as learning and memory and may cause damage to both the fetus and adult brain tissue. Also, EMF may have potential to affect brain of future generations.

(E) Tan FC, Yalçin B, Yay AH, Tan B, Yeğin K, Daşdağ S. Effects of pre and postnatal 2450 MHz continuous wave (CW) radiofrequency radiation on thymus: Four generation exposure. Electromagn Biol Med 41(3):315-324, 2022. (CE, IU, ME, PN, VO) (cross degeneration effect) (Low SAR) (SAR 1 g average: adult: whole body 0.186 W/kg, thymus 0.068 W/kg; offspring: 0.287 W/kg, thymus 0.116 W/kg)

This study aims to investigate the effects of pre- and postnatal 2450 MHz continuous wave (CW) radiofrequency radiation (RFR) on the thymus of rats spanning four generations. Four groups; sham, irradiated female, irradiated male, irradiated male and female, each consisting of four rats (one male and three females), were created. During the experiment, rats in the exposure groups were whole-body exposed to 2450 MHz CW-RFR for 12 h/day. Irradiation started one month before the fertilization in the experimental group. When the offspring were two months old, four rats, one male and three female, were allocated for the second-generation study. The remaining offspring were sacrificed under general anesthesia, and their thymuses were removed. The same procedure was applied to the next generation. Two months after the second generation gave birth, third-generation rats were decapitated, and their thymuses were removed. In all groups, cortex, medulla and resident cells could be clearly distinguished in the second and third generations. No differences were observed between the control and two experimental groups, defined as irradiated female and irradiated male. In contrast, vascularization was observed in the thymus of the fourth-generation offspring of the group where both males and females were irradiated. The number of offspring and mass of all rats decreased in the third-generation group. Pre-and postnatal 2450 MHz continuous wave radiofrequency radiation exposure may potentially affect the thymus of future generations.

(E) Tas M, Dasdag S, Akdag MZ, Cirit U, Yegin K, Seker U, Ozmen MF, Eren LB. Long-term effects of 900 MHz radiofrequency radiation emitted from mobile phone on testicular tissue and epididymal semen quality. Electromagn Biol Med. 33(3):216-222, 2014. (CE, M, ME, VO) (Low SAR)

The purpose of this study is to bridge this gap by investigating effects of long term 900 MHz mobile phone exposure on reproductive organs of male rats. The study was carried out on 14 adult Wistar Albino rats by dividing them randomly into two groups (n: 7) as sham group and exposure group. Rats were exposed to 900 MHz radiofrequency (RF) radiation emitted from a GSM signal generator. Point, 1 g and 10 g specific absorption rate (SAR) levels of testis and prostate were found as 0.0623 W/kg, 0.0445 W/kg and 0.0373 W/kg, respectively. The rats in the exposure group were subject to RF radiation 3 h per day (7 d a week) for one year. For the sham group, the same procedure was applied, except the generator was turned off. At the end of the

study, epididymal sperm concentration, progressive sperm motility, abnormal sperm rate, all-genital organs weights and testis histopathology were evaluated. Any differences were not observed in sperm motility and concentration ($p > 0.05$). However, the morphologically normal spermatozoa rates were found higher in the exposure group ($p < 0.05$). Although histological examination showed similarity in the seminiferous tubules diameters in both groups, tunica albuginea thickness and the Johnsen testicular biopsy score were found lower in the exposure group ($p < 0.05$, $p < 0.0001$). In conclusion, we claim that long-term exposure of 900 MHz RF radiation alter some reproductive parameters. However, more supporting evidence and research is definitely needed on this topic.

Thomas S, Kühnlein A, Heinrich S, Praml G, von Kries R, Radon K. Exposure to mobile telecommunication networks assessed using personal dosimetry and well-being in children and adolescents: the German MobilEe-study. Environ Health. 7(1):54, 2008. (Dosimetry)

BACKGROUND: Despite the increase of mobile phone use in the last decade and the growing concern whether mobile telecommunication networks adversely affect health and well-being, only few studies have been published that focussed on children and adolescents. Especially children and adolescents are important in the discussion of adverse health effects because of their possibly higher vulnerability to radio frequency electromagnetic fields. METHODS: We investigated a possible association between exposure to mobile telecommunication networks and well-being in children and adolescents using personal dosimetry. A population-based sample of 1.498 children and 1.524 adolescents was assembled for the study (response 52%). Participants were randomly selected from the population registries of four Bavarian (South of Germany) cities and towns with different population sizes. During a Computer Assisted Personal Interview data on participants' well-being, socio-demographic characteristics and potential confounder were collected. Acute symptoms were assessed three times during the study day (morning, noon, evening).Using a dosimeter (ESM-140 Maschek Electronics), we obtained an exposure profile over 24 hours for three mobile phone frequency ranges (measurement interval 1 second, limit of determination 0.05 V/m) for each of the participants. Exposure levels over waking hours were summed up and expressed as mean percentage of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) reference level. RESULTS: In comparison to non-participants, parents and adolescents with a higher level of education who possessed a mobile phone and were interested in the topic of possible adverse health effects caused by mobile telecommunication network frequencies were more willing to participate in the study. The median exposure to radio frequency electromagnetic fields of children and adolescents was 0.18% and 0.19% of the ICNIRP reference level respectively. CONCLUSION: In comparison to previous studies this is one of the first to assess the individual level of exposure to mobile telecommunication networks using personal dosimetry, enabling objective assessment of exposure from all sources and longer measurement periods. In total, personal dosimetry was proofed to be a well accepted tool to study exposure to mobile phone frequencies in epidemiologic studies including health effects on children and adolescents.

(E) Thomas S, Heinrich S, von Kries R, Radon K. Exposure to radio-frequency

electromagnetic fields and behavioural problems in Bavarian children and adolescents. Eur J Epidemiol. 25(2):135-141, 2010. (BE, CE, HU)

Only few studies have so far investigated possible health effects of radio-frequency electromagnetic fields (RF EMF) in children and adolescents, although experts discuss a potential higher vulnerability to such fields. We aimed to investigate a possible association between measured exposure to RF EMF fields and behavioural problems in children and adolescents. 1,498 children and 1,524 adolescents were randomly selected from the population registries of four Bavarian (South of Germany) cities. During an Interview data on participants' mental health, socio-demographic characteristics and potential confounders were collected. Mental health behaviour was assessed using the German version of the Strengths and Difficulties Questionnaire (SDQ). Using a personal dosimeter, we obtained radio-frequency EMF exposure profiles over 24 h. Exposure levels over waking hours were expressed as mean percentage of the reference level. Overall, exposure to radiofrequency electromagnetic fields was far below the reference level. Seven percent of the children and 5% of the adolescents showed an abnormal mental behaviour. In the multiple logistic regression analyses measured exposure to RF fields in the highest quartile was associated to overall behavioural problems for adolescents (OR 2.2; 95% CI 1.1-4.5) but not for children (1.3; 0.7-2.6). These results are mainly driven by one subscale, as the results showed an association between exposure and conduct problems for adolescents (3.7; 1.6-8.4) and children (2.9; 1.4-5.9). As this is one of the first studies that investigated an association between exposure to mobile telecommunication networks and mental health behaviour more studies using personal dosimetry are warranted to confirm these findings.

(E) Thomée S, Härenstam A, Hagberg M. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults--a prospective cohort study. BMC Public Health. 11:66, 2011. (BE, CE, HU)

BACKGROUND: Because of the quick development and widespread use of mobile phones, and their vast effect on communication and interactions, it is important to study possible negative health effects of mobile phone exposure. The overall aim of this study was to investigate whether there are associations between psychosocial aspects of mobile phone use and mental health symptoms in a prospective cohort of young adults. METHODS: The study group consisted of young adults 20-24 years old (n = 4156), who responded to a questionnaire at baseline and 1-year follow-up. Mobile phone exposure variables included frequency of use, but also more qualitative variables: demands on availability, perceived stressfulness of accessibility, being awakened at night by the mobile phone, and personal overuse of the mobile phone. Mental health outcomes included current stress, sleep disorders, and symptoms of depression. Prevalence ratios (PRs) were calculated for cross-sectional and prospective associations between exposure variables and mental health outcomes for men and women separately. RESULTS: There were cross-sectional associations between high compared to low mobile phone use and stress, sleep disturbances, and symptoms of depression for the men and women. When excluding respondents reporting mental health symptoms at baseline, high mobile phone use was associated with sleep disturbances and symptoms of depression for the men and symptoms

of depression for the women at 1-year follow-up. All qualitative variables had cross-sectional associations with mental health outcomes. In prospective analysis, overuse was associated with stress and sleep disturbances for women, and high accessibility stress was associated with stress, sleep disturbances, and symptoms of depression for both men and women. CONCLUSIONS: High frequency of mobile phone use at baseline was a risk factor for mental health outcomes at 1-year follow-up among the young adults. The risk for reporting mental health symptoms at follow-up was greatest among those who had perceived accessibility via mobile phones to be stressful. Public health prevention strategies focusing on attitudes could include information and advice, helping young adults to set limits for their own and others' accessibility.

(E) Tomruk A, Ozgur-Buyukatalay E, Ozturk GG, Ulusu NN. Short-term exposure to radiofrequency radiation and metabolic enzymes' activities during pregnancy and prenatal development. Electromagn Biol Med 41(4):370-378, 2022. (CE, IU, MO, OX. VO) (Low SAR)

Radiofrequency radiation (RFR) as an environmental and physical pollutant may induce vulnerability to toxicity and disturb fetal development. Therefore, the potential health effects of short-term mobile phone like RFR exposure (GSM 1800 MHz; 14 V/m, 2 mW/kg specific absorption rate (SAR) during 15 min/day for a week) during pregnancy and also the development of fetuses were investigated. Hepatic glucose regulation and glutathione-dependent enzymes' capacities were biochemically analyzed in adult (female) and pregnant New Zealand White rabbits. Pregnant rabbits' two-day-old offspring were included to understand their developmental stages under short-term maternal RFR exposure. We analyzed two regulatory enzymes in the oxidative phase of phosphogluconate pathways to interpret the cytosolic NADPH's biosynthesis for maintaining mitochondrial energy metabolism. Moreover, the efficiencies of maternal glutathione-dependent enzymes on both the removal of metabolic disturbances during pregnancy and fetus development were examined. Whole-body RFR exposures were applied to pregnant animals from the 15th to the 22nd day of their gestations, i.e., the maturation periods of tissues and organs for rabbit fetuses. There were significant differences in hepatic glucose regulation and GSH-dependent enzymes' capacities with pregnancy and short-term RFR exposure. Consequently, we observed that intrauterine exposure to RFR might lead to cellular ROS-dependent disturbances in metabolic activity and any deficiency in the intracellular antioxidant (ROS-scavenging) system. This study might be a novel insight into further studies on the possible effects of short-term RF exposure and prenatal development.

(E) Topal Z, Hanci H, Mercantepe T, Erol HS, Keleş ON, Kaya H, Mungan S, Odaci E. The effects of prenatal long-duration exposure to 900-MHz **electromagnetic field on the 21-day-old newborn male rat liver. Turk J Med Sci. 45(2):291-297, 2015. (CE, IU, ME, OX, VO) (Low SAR, 0.027 W/kg)**

BACKGROUND/AIM: To determine what effect a **900-MHz** electromagnetic field (EMF) applied in the prenatal period would have on the liver in the postnatal period. MATERIALS AND METHODS: At the start of the study, adult pregnant rats were divided into two groups, control and experimental. The experimental group was exposed to a **900-MHz** EMF for 1 h daily during days 13-21 of pregnancy. After birth, no procedure was performed on either

mothers or pups. Male rat pups (n = 6) from the control group mothers (CGMR) and male rat pups (n = 6) from the experimental group mothers (EGMR) were sacrificed on postnatal day 21. RESULTS: Biochemical analyses showed that malondialdehyde and superoxide dismutase values increased and glutathione levels decreased in the EGMR pups. Marked hydropic degeneration in the parenchyma, particularly in pericentral regions, was observed in light microscopic examination of EGMR sections stained with hematoxylin and eosin. Examinations under transmission electron microscope revealed vacuolization in the mitochondria, expansion in the endoplasmic reticulum, and necrotic hepatocytes. CONCLUSION: The study results show that a **900-MHz** EMF applied in the prenatal period caused oxidative stress and pathological alterations in the liver in the postnatal period.

(E) Tomruk A, Guler G, Dincel AS. The influence of 1800 MHz GSM-like signals on hepatic oxidative DNA and lipid damage in nonpregnant, pregnant, and newly born rabbits. Cell Biochem Biophys. 56(1):39-47, 2010. (CE, IU, OX, VO) (No effect on newborn.) (14 V/m)

The aim of our study is to evaluate the possible biological effects of whole-body 1800 MHz GSM-like radiofrequency (RF) radiation exposure on liver oxidative DNA damage and lipid peroxidation levels in nonpregnant, pregnant New Zealand White rabbits, and in their newly borns. Eighteen nonpregnant and pregnant rabbits were used and randomly divided into four groups which were composed of nine rabbits: (i) Group I (nonpregnant control), (ii) Group II (nonpregnant-RF exposed), (iii) Group III (pregnant control), (iv) Group IV (pregnant-RF exposed). Newborns of the pregnant rabbits were also divided into two groups: (v) Group V (newborns of Group III) and (vi) Group VI (newborns of Group III). 1800 MHz GSM-like RF radiation whole-body exposure (15 min/day for a week) was applied to Group II and Group IV. No significant differences were found in liver 8 OHdG/10(6) dG levels of exposure groups (Group II and Group IV) compared to controls (Group I and Group III). However, in Group II and Group IV malondialdehyde (MDA) and ferrous oxidation in xylenol orange (FOX) levels were increased compared to Group I ($P < 0.05$, Mann-Whitney). No significant differences were found in liver tissue of 8 OHdG/10(6) dG and MDA levels between Group VI and Group V ($P > 0.05$, Mann-Whitney) while liver FOX levels were found significantly increased in Group VI with respect to Group V ($P < 0.05$, Mann-Whitney). Consequently, the whole-body 1800 MHz GSM-like RF radiation exposure may lead to oxidative destruction as being indicators of subsequent reactions that occur to form oxygen toxicity in tissues.

(E) Tripathi R, Banerjee SK, Nirala JP, Mathur R. Exposure to Electromagnetic Fields from Mobile Phones and Fructose consumption Coalesce to Perturb Metabolic Regulators AMPK/SIRT1-UCP2/FOXO1 in Growing Rats. Biomed Environ Sci 36(11):1045-1058, 2023. (CE, DE, I, MO, OX, VO) (whole body SAR=0.18 W/kg)

Objective: In this study, the combined effect of two stressors, namely, electromagnetic fields (EMFs) from mobile phones and fructose consumption, on hypothalamic and hepatic master metabolic regulators of the AMPK/SIRT1-UCP2/FOXO1 pathway were elucidated to delineate the underlying molecular mechanisms of insulin resistance. **Methods:** Weaned Wistar rats (28 days old) were divided into 4 groups: Normal, Exposure Only (ExpO), Fructose Only (FruO),

and Exposure and Fructose (EF). Each group was provided standard laboratory chow *ad libitum* for 8 weeks . Additionally, the control groups, namely, the Normal and FruO groups, had unrestricted access to drinking water and fructose solution (15%), respectively. Furthermore, the respective treatment groups, namely, the ExpO and EF groups, received EMF exposure (1,760 MHz, 2 h/day x 8 weeks). In early adulthood, mitochondrial function, insulin receptor signaling, and oxidative stress signals in hypothalamic and hepatic tissues were assessed using western blotting and biochemical analysis. **Result:** In the hypothalamic tissue of EF, SIRT1, FOXO 1, p-PI3K, p-AKT, Complex III, UCP2, MnSOD, and catalase expressions and OXPHOS and GSH activities were significantly decreased ($P < 0.05$) compared to the Normal, ExpO, and FruO groups. In hepatic tissue of EF, the p-AMPKα, SIRT1, FOXO1, IRS1, p-PI3K, Complex I, II, III, IV, V, UCP2, and MnSOD expressions and the activity of OXPHOS, SOD, catalase, and GSH were significantly reduced compared to the Normal group ($P < 0.05$). **Conclusion:** The findings suggest that the combination of EMF exposure and fructose consumption during childhood and adolescence in Wistar rats disrupts the closely interlinked and multi-regulated crosstalk of insulin receptor signals, mitochondrial OXPHOS, and the antioxidant defense system in the hypothalamus and liver.

(NE) **Trošić I, Mataušić-Pišl M, Pavičić I, Marjanović AM. Histological and Cytological Examination of Rat Reproductive Tissue After Short-Time Intermittent Radiofrequency Exposure. Arh Hig Rada Toksikol. 64(4):513-519, 2013. (CE, M, ME, VO)**

The unfavourable outcomes of mobile phone use on male fertility have still not been fully elaborated. To establish the potentially adverse effects of everyday exposure to radiofrequency radiation (RF) on humans, we performed a controlled animal study that aimed to investigate the influence of RF radiation on rat testis histology as well as the amount, mobility, and structure of epididymal free sperm cell population. Eighteen adult male rats were divided into two groups of nine. One group comprised sham-exposed control animals, while the other group endured total body irradiation for an hour daily during two weeks. A 915 MHz RF field, power density of 2.4 W m-2 and strength of 30 V m-1 was generated in a Gigahertz Transversal Electromagnetic chamber. The specific absorption rate (SAR) was 0.6 W kg-1. Body mass and temperature were measured before and after each exposure treatment. Immediately after the last exposure, the animals were sacrificed and testes removed and prepared for histological analysis. The free sperm cells were collected from the cauda epididymis and their quantity, quality, and morphology were microscopically determined using a haemocytometer. No statistically significant alteration in any of the endpoints was observed. This study found no evidence of an unfavourable effect of the applied RF radiation on testicular function or structure. Based on these results, we can conclude that short-time intermittent exposure to RF radiation does not represent a significant risk factor for rat reproductive functions.

(E) **Tsarna E, Reedijk M, Birks LE, Guxens M, Ballester F, Ha M, Jiménez-Zabala A, Kheifets L, Lertxundi A, Lim HR, Olsen J, Safont LG, Sudan M, Cardis L, V rijheid M, Vrijkotte T, Huss A, Vermeulen R. Associations of Maternal Cell-Phone Use During Pregnancy With Pregnancy Duration and Fetal Growth in 4 Birth Cohorts. Am J Epidemiol 188(7):1270-1280, 2019. (CE, DE, HU, IU)**

Results from studies evaluating potential effects of prenatal exposure to radio-frequency electromagnetic fields from cell phones on birth outcomes have been inconsistent. Using data on 55,507 pregnant women and their children from Denmark (1996-2002), the Netherlands (2003-2004), Spain (2003-2008), and South Korea (2006-2011), we explored whether maternal cell-phone use was associated with pregnancy duration and fetal growth. On the basis of self-reported number of cell-phone calls per day, exposure was grouped as none, low (referent), intermediate, or high. We examined pregnancy duration (gestational age at birth, preterm/postterm birth), fetal growth (birth weight ratio, small/large size for gestational age), and birth weight variables (birth weight, low/high birth weight) and meta-analyzed cohort-specific estimates. The intermediate exposure group had a higher risk of giving birth at a lower gestational age (hazard ratio = 1.04, 95% confidence interval: 1.01, 1.07), and exposure-response relationships were found for shorter pregnancy duration ($P < 0.001$) and preterm birth ($P = 0.003$). We observed no association with fetal growth or birth weight. Maternal cell-phone use during pregnancy may be associated with shorter pregnancy duration and increased risk of preterm birth, but these results should be interpreted with caution, since they may reflect stress during pregnancy or other residual confounding rather than a direct effect of cell-phone exposure.

(E) Tsybulin O, Sidorik E, Kyrylenko S, Henshel D, Yakymenko I. GSM 900 MHz microwave radiation affects embryo development of Japanese quails. Electromagn Biol Med. 31(1):75-86, 2012. (AE, CE, DE, IU, OX)

A wide range of nonthermal biological effects of microwave radiation (MW) was revealed during the last decades. A number of reports showed evident hazardous effects of MW on embryo development in chicken. In this study, we aimed at elucidating the effects of MW emitted by a commercial model of GSM 900 MHz cell phone on embryo development in quails (Coturnix coturnix japonica) during both short and prolonged exposure. For that, fresh fertilized eggs were irradiated during the first 38 h or 14 days of incubation by a cell phone in "connecting" mode activated continuously through a computer system. Maximum intensity of incident radiation on the egg's surface was 0.2 μW/cm2.The irradiation led to a significant ($p<0.001$) increase in numbers of differentiated somites in 38-hour exposed embryos and to a significant ($p<0.05$) increase in total survival of embryos from exposed eggs after 14 days exposure. We hypothesized that observed facilitating effect was due to enhancement of metabolism in exposed embryos provoked via peroxidation mechanisms. Indeed, a level of thiobarbituric acid (TBA) reactive substances was significantly ($p<0.05$-0.001) higher in brains and livers of hatchlings from exposed embryos. Thus, observed effects of radiation from commercial GSM 900 MHz cell phone on developing quail embryos signify a possibility for non-thermal impact of MW on embryogenesis. We suggest that the facilitating effect of low doses of irradiation on embryo development can be explained by a hormesis effect induced by reactive oxygen species (ROS). Future studies need to be done to clarify this assumption.

(E) Tsybulin O, Sidorik E, Brieieva O , Buchynska L, Kyrylenko S, Henshel D, Yakymenko I. GSM 900 MHz cellular phone radiation can either stimulate or depress

early embryogenesis in Japanese quails depending on the duration of exposure. Int J Rad Biol. 89(9):756-763, 2013. (AE, DE, GE, IU) (Low SAR)

Purpose: Our study was designed to assess the effects of low intensity radiation of a GSM (Global System for Mobile communication) 900 MHz cellular phone on early embryogenesis in dependence on the duration of exposure. *Materials and methods:* Embryos of Japanese Quails were exposed *in ovo* to GSM 900 MHz cellular phone radiation during initial 38 h of brooding or alternatively during 158 h (120 h before brooding plus initial 38 h of brooding) discontinuously with 48 sec ON (average power density 0.25 μW/cm^2, specific absorption rate 3 μW/kg) followed by 12 sec OFF intervals. A number of differentiated somites was assessed microscopically. Possible DNA damage evoked by irradiation was assessed by an alkaline comet assay. *Results:* Exposure to radiation from a GSM 900 MHz cellular phone led to a significantly altered number of differentiated somites. In embryos irradiated during 38 h the number of differentiated somites increased ($p<0.001$), while in embryos irradiated during 158 h this number decreased ($p<0.05$). The lower duration of exposure led to a significant ($p<0.001$) decrease in a level of DNA strand breaks in cells of 38-hour embryos, while the higher duration of exposure resulted in a significant ($p<0.001$) increase in DNA damage as compared to the control. *Conclusion:* Effects of GSM 900 MHz cellular phone radiation on early embryogenesis can be either stimulating or deleterious depending on the duration of exposure.

(E)Tüfekci KK, Kaplan AA, Kaya A, Alrafiah A, Altun G, Aktaş A, Kaplan S. The potential protective effects of melatonin and omega-3 on the male rat optic nerve exposed to 900 MHz electromagnetic radiation during the prenatal period. Int J Neurosci 133(12):1424-1436, 2023. (CE, DE, IU, ME, NU, OX. VO)

Background: Due to children and adolescents' widespread use of electronic devices, researchers have focused on pre-and early postnatal electromagnetic field (EMF) exposure. However, little is known about the effects of EMF exposure on the optic nerve. The aim of study was to investigate the changes occurring in the optic nerve and the protective effects of melatonin (mel) and omega 3 (ω-3) in rats. **Methods:** Thirty-five pregnant rats were divided into seven groups, Cont, Sham, EMF, EMF + melatonin (EMF + Mel), EMF + ω3, Mel, and ω3. The EMF groups were exposed to 900 megahertz (MHz) EMF daily for two hours during pregnancy. After the experiment, the right optic nerve of each offspring rat was removed and fixed in glutaraldehyde. Thin and semi-thin sections were taken for electron microscopic and stereological analyses. Myelinated axon numbers, myelin sheath thicknesses, and axonal areas were estimated using stereological methods. **Results:** The groups had no significant differences regarding mean numbers of axons, mean axonal areas, or mean myelin sheath thicknesses ($p > 0.05$). Histological observations revealed impaired lamellae in the myelin sheath of most axons, and vacuolization was frequently observed between the myelin sheath and axon in the EMF-exposed group. The Mel and ω-3-treated EMF groups exhibited well-preserved myelinated nerve fibers and intact astrocytes and oligodendrocytes. **Conclusions:** At the ultrastructural level, Mel and ω3 exhibits a neuroprotective effect on the optic nerve exposed to prenatal EMF. The protective effects of these antioxidants on oligodendrocytes, which play an essential role in myelin formation in the central nervous system, now require detailed investigation.

(NE) Tumkaya L, Kalkan Y, Bas O, Yilmaz A. Mobile phone radiation during pubertal development has no effect on testicular histology in rats. Toxicol Ind Health. 32(2):328-336, 2016. (CE, M, ME, MO, VO) (SAR 0.48 W/kg)

Mobile phones are extensively used throughout the world. There is a growing concern about the possible public health hazards posed by electromagnetic radiation emitted from mobile phones. Potential health risk applies particularly to the most intensive mobile phone users-typically, young people. The aim of this study was to investigate the effects of mobile phone exposure to the testes, by assessing the histopathological and biochemical changes in the testicular germ cells of rats during pubertal development. A total of 12 male Sprague Dawley rats were used. The study group (n = 6) was exposed to a mobile phone for 1 h a day for 45 days, while the control group (n = 6) remained unexposed. The testes were processed with routine paraffin histology and sectioned. They were stained with hematoxylin-eosin, caspase 3, and Ki-67 and then photographed. No changes were observed between the groups ($p > 0.05$). The interstitial connective tissue and cells of the exposed group were of normal morphology. No abnormalities in the histological appearance of the seminiferous tubules, including the spermatogenic cycle stage, were observed. Our study demonstrated that mobile phones with a low specific absorption rate have no harmful effects on pubertal rat testicles.

(E) Tumkaya L, Yilmaz A, Akyildiz K, Mercantepe T, Yazici ZA, Yilmaz H. Prenatal Effects of a 1,800-MHz Electromagnetic Field on Rat Livers. Cells Tissues Organs 207(3-4):187-196, 2019. (CE, IU, ME, MO, OX, VO)

The use of devices, including mobile phones, generating electromagnetic fields (EMF) is widespread and is progressively increasing. It has also been shown that EMF may have detrimental effects. This is the first study to investigate the postnatal biochemical and histological effects of prenatal exposure of rat livers to 1,800-MHz EMF at different time intervals in uteroplacental life. The 3 EMF groups of rats were exposed to 1,800-MHz EMF for 6, 12, or 24 h daily for 20 days. Unexposed rats served as control group. All rats were subjected to anesthesia, and on postnatal day 60, the livers were excised, and blood was collected for histological and biochemical analyses. Malondialdehyde levels were significantly higher in the exposed groups than the unexposed controls ($p < 0.05$). In contrast, EMF-exposed groups had lower liver tissue glutathione levels than controls ($p < 0.05$). Serum Ca2+, alanine transaminase, and aspartate aminotransferase levels were higher in EMF-exposed groups than controls ($p < 0.05$). In addition, liver tissue total oxidant status levels were increased ($p < 0.05$), and liver tissue total antioxidant status levels were decreased ($p < 0.05$) compared to the control group. Furthermore, in the EMF groups, extensive vacuolation and degeneration of the hepatocytes in the portal area, as well as those surrounding the sinusoids, were evident. Affected hepatocytes had polygonally shaped nuclei and vacuolic cytoplasm imparting eosinophilic staining. Loss of cellular membrane integrity and invaginations, as well as picnotic nuclei, was prominent. This study has shown that intrauterine liver damage caused by 1,800-MHz EMF exposure persists into puberty in rats.

(E) Tümkaya L, Bas O, Mercantepe T, Cınar S, Özgür A, Yazici ZA. Effect of the prenatal electromagnetic field exposure on cochlear nucleus neurons and oligodendrocytes in rats. Environ Sci Pollut Res Int 29(26):40123-40130, 2022. (CE, IU, NU, VO)

Electromagnetic radiation from elecromagnetic field (EMF) sources has been an important health concern for a long time. The vast majority of this exposure is due to the widespread use of mobile phones, an important source of the EMF. The EMF generated by mobile phones may have adverse effects on the various biological structures that regulate the body system and function. In this study, it was aimed to evaluate histopathologically the effects of 900-megahertz (MHz) EMF application in the prenatal period on the development of the ventral cochlear nucleus, which is the first place of hearing in the brainstem, at various time points of the postnatal period in rats. In the study, Sprague-Dawley pregnant rats were divided randomly into two groups as the control group and the EMF group. The rats in the EMF group were exposed to a 900-MHz EMF every day until birth, while no EMF was applied to the rats in the control group. Auditory brainstem responses of both groups were recorded on the postnatal 13th day, the day the hearing starts. Newborn rats were sacrificed by anesthesia on days 7, 10, 15, and 30. Contrary to the control group, structural damage in cochlear nuclear neurons and oligodendrocyte cell structures and increased caspase-3 activity were observed in the postnatal period in the EMF groups. However, no significant difference was observed between the groups in terms of structural damage and caspase-3 activity at different stages of the postnatal period when cochlear nucleus development was observed. According to ABS, there was no significant difference between the average latency of waves in both groups. In conclusion, this study shows that 900-MHz electromagnetic waves propagated from mobile phones during the prenatal period have no harmful effects on the development of the ventral cochlear nucleus of rats.

(E) Türedi S, Hancı H, Topal Z, Ünal D, Mercantepe T, Bozkurt I, Kaya H, Odacı E. The effects of prenatal exposure to a 900-MHz electromagnetic field on the 21-day-old male rat heart. Electromagn Biol Med 34(4):390-397, 2015. (CE, IU, ME, OX, VO) (Low SAR 0.025 W/kg)

The growing spread of mobile phone use is raising concerns about the effect on human health of the electromagnetic field (EMF) these devices emit. The purpose of this study was to investigate the effects on rat pup heart tissue of prenatal exposure to a 900 megahertz (MHz) EMF. For this purpose, pregnant rats were divided into experimental and control groups. Experimental group rats were exposed to a 900 MHz EMF (1 h/d) on days 13-21 of pregnancy. Measurements were performed with rats inside the exposure box in order to determine the distribution of EMF intensity. Our measurements showed that pregnant experimental group rats were exposed to a mean electrical field intensity of 13.77 V/m inside the box (0.50 W/m(2)). This study continued with male rat pups obtained from both groups. Pups were sacrificed on postnatal day 21, and the heart tissues were extracted. Malondialdehyde, superoxide dismutase and catalase values were significantly higher in the experimental group rats, while glutathione values were lower. Light microscopy revealed irregularities in heart muscle fibers and apoptotic changes in the experimental group. Electron microscopy revealed crista loss and swelling in the mitochondria, degeneration in myofibrils and structural impairments in Z bands. Our study results suggest that exposure to EMF in the prenatal period causes oxidative stress and histopathological changes in male rat pup heart tissue.

(E) Türedi S, Hancı H, Çolakoğlu S, Kaya H, Odacı E. Disruption of the ovarian follicle reservoir of prepubertal rats following prenatal exposure to a continuous 900-MHz electromagnetic field. Int J Radiat Biol. 92(6):329-337, 2016. (CE, F, ME, IU) (Low SAR 0.01 W/kg)

The effects on human health of electromagnetic field (EMF) have begun to be seriously questioned with the entry into daily life of devices establishing EMF, such as cell phones, wireless fidelity, and masts. Recent studies have reported that exposure to EMF, particularly during pregnancy, affects the developing embryo/fetus. The aim of this study was therefore to examine the effects of exposure to continuous 900-Megahertz (MHz) EMF applied in the prenatal period on ovarian follicle development and oocyte differentiation. Six pregnant Sprague Dawley rats were divided equally into a non-exposed control group (CNGr) and a group (EMFGr) exposed to continuous 900-MHz EMF for 1 h daily, at the same time every day, on days 13-21 of pregnancy. New groups were established from pups obtained from both groups after birth. One group consisting of female pups from CNGr rats was adopted as newborn CNGr (New-CNGr, n = 6), and another group consisting of female pups from EMFGr rats was adopted as newborn EMFGr (New-EMFGr, n = 6). No procedure was performed on New-CNGr or New-EMFGr rats. All rat pups were sacrificed on the postnatal 34th day, and their ovarian tissues were removed. Follicle count, histological injury scoring and morphological assessment with apoptotic index criteria were performed with sections obtained following routine histological tissue preparation. Follicle count results revealed a statistically significant decrease in primordial and tertiary follicle numbers in New-EMFGr compared to New-CNGr ($p < 0.05$), while atretic follicle numbers and apoptotic index levels increased significantly ($p < 0.05$). Histopathological examination revealed severe follicle degeneration, vasocongestion, a low level of increased stromal fibrotic tissue and cytoplasmic vacuolization in granulosa cell in New-EMFGr. Prenatal exposure to continuous 900-MHz EMF for 1 hour each day from days 13-21 led to a decrease in ovarian follicle reservoirs in female rat pups at the beginning of the prepubertal period.

(E) Ulubay M, Yahyazadeh A, Deniz ÖG, Kıvrak EG, Altunkaynak BZ, Erdem G, Kaplan S. Effects of prenatal 900 MHz electromagnetic field exposures on the histology of rat kidney. Int J Radiat Biol 91(1):35-41, 2015. (CE, IU, ME, VO) (SAR 2 W/kg)

Purpose: To research the harmful effects of prenatal exposure of 900 megahertz (MHz) electromagnetic field (EMF) on kidneys of four-week-old male rats and to determine protective effects of melatonin (MEL) and omega-3 (ω-3). **Materials and methods:** Twenty-one Wistar albino rats were randomly placed into seven groups as follows: Control (Cont), Sham, MEL, ω-3, EMF, EMF+ MEL and EMF+ω-3. After mating, three groups (EMF, EMF+ MEL, EMF+ ω-3) were exposed to an EMF. In the fourth week subsequent to parturition, six rats were randomly chosen from each group. Mean volume of kidneys and renal cortices, the total number of glomeruli and basic histological structure of kidney were evaluated by stereological and light microscopical methods, respectively. **Results:** Stereological results determined the mean volume of the kidneys and cortices were significantly increased in EMF-exposed groups compared to the Cont group. However, EMF-unexposed groups were not significantly modified compared to the Cont group. Additionally, the total number of glomeruli was significantly higher in EMF-

unexposed groups compared to the Cont group. Alternatively, the number of glomeruli in EMF-exposed groups was decreased compared to the Cont group. **Conclusions:** Prenatal exposure of rat kidneys to 900 MHz EMF resulted in increased total kidney volume and decreased the numbers of glomeruli. Moreover, MEL and ω-3 prevented adverse effects of EMF on the kidneys.

(E) Umur AS, Yaldiz C, Bursali A, Umur N, Kara B, Barutcuoglu M, Vatansever S, Selcuki D, Selcuki M. Evaluation of the effects of mobile phones on the neural tube development of chick embryos. Turk Neurosurg 23(6):742-752, 2013. (CE, IU, ME, MO) (NO SAR calculated)

Aim: The objective of this study is to examine the effects of radiation of mobile phones on developing neural tissue of chick embryos. **Material and methods:** There were 4 study groups. All Groups were placed in equal distance, from the mobile phones. Serial sections were taken from each Group to study the neural tube segments. **Results:** The TUNEL results were statistically significant ($p < 0.001$) at 30 and 48 hours in the third Group. We found low Bcl-2 levels partly in Group 4 and increased activity in Group 3. Caspase-3 was negative in the 48 and 72 hours in the Control Group, had moderate activity in the third Group 3, weak activity in the 48 hour, and was negative in the 72 hour in other groups. Caspase-9 immunoreactivity was weak in Group 1, 2 and 3 at 30 hours and was negative in Group 1 and 4 at 48 and 72 hours. Caspase-9 activity in the third Group was weak in all three stages. **Conclusion:** Electromagnetic radiation emitted by mobile phones caused developmental delay in chick embryos in early period. This finding suggests that the use of mobile phones by pregnant women may pose risks.

(E)Üstündağ ÜV, Özen MS, Ünal İ, Ateş PS, Alturfan AA, Akalın M, Sancak E, Emekli-Alturfan E. Oxidative stress and apoptosis in electromagnetic waves exposed Zebrafish embryos and protective effects of conductive nonwoven fabric. Cell Mol Biol (Noisy-le-grand) 66(1):70-75, 2020. (CE, GE, IU, OX) (no dosimetry data)

The amount of technological products including television, radio transmitters, and mobile phone that have entered our daily life has increased in recent years. But these devices may cause adverse effects on human health. Electromagnetic shielding fabrics may limit and inhibit electromagnetic waves. Aim of our study was to evaluate electromagnetic wave blocking performance of nonwoven textile surfaces on zebrafish embryos that were exposed to electromagnetic waves at specific frequencies. Oxidant-antioxidant system parameters were evaluated spectrophotometrically. The expressions of tp53 and casp3a were evaluated by RT-PCR. Results showed that electromagnetic shielding fabrics produced as conductive nonwoven textile surfaces improved oxidant-antioxidant status and tp53 expression that were impaired in electromagnetic waves exposed zebrafish embryos. Also, electromagnetic shielding fabrics decreased casp3a expression responsible for the execution phase of apoptosis that increased in electromagnetic waves exposed zebrafish embryos.

(E) Vafaei S, Motejaded F, Ebrahimzadeh-Bideskan A. Protective effect of crocin on electromagnetic field-induced testicular damage and heat shock protein A2 expression in male BALB/c mice. Iran J Basic Med Sci 23(1):102-110, 2020. (CE, M, ME, MO, VO) (No SAR provided.)

Objectives: Exposure to electromagnetic fields (EMF) emitted from mobile phones may cause a deleterious effect on human health and may affect the male reproductive system. *Crocin*, a carotenoid isolated from *Crocus Sativus L. (Saffron)*, is a pharmacologically active component of saffron. So, this study was conducted to investigate the protective effect of *crocin* on the male reproductive system of 60 day old mice after EMF exposure. **Materials and methods:** Twenty-four male BALB/c mice were randomly divided into 4 groups: 1. Em group (2100 MHZ); 2. Cr group (50 mg/kg); 3. Em+Cr group (2100 MHZ+50 mg/kg), and 4. Control group. Sperm parameters (count, and abnormal percent), testis weight index, testis volume, seminiferous tubule diam¬eter, germinal epithelium thickness, LH, FSH and testosterone serum level, testicular Heat shock protein A2 (HspA2) immunoreactivity, and apoptosis were evaluated. **Results:** HspA2 immunoreactivity, apoptosis in the germinal epithelium and abnormal sperm were increased in Em group compared with the control group (P<0.05). Sperm count, LH, and testosterone serum level were decreased in the Em group compared with the control group (P<0.05). These parameters were improved in the Em+Cr group compared with Em group significantly (P<0.05). **Conclusion:** our findings revealed that EMF exposure leads to harmful impressions on the male reproductive system, while crocin can attenuate EMF-induced destructive effects.

Valič B, Kos B, Gajšek P. TYPICAL EXPOSURE OF CHILDREN TO EMF: EXPOSIMETRY AND DOSIMETRY. Radiat Prot Dosimetry. 163(1):70-80, 2015. (Dosimetry)

A survey study with portable exposimeters, worn by 21 children under the age of 17, and detailed measurements in an apartment above a transformer substation were carried out to determine the typical individual exposure of children to extremely low- and radio-frequency (RF) electromagnetic field. In total, portable exposimeters were worn for >2400 h. Based on the typical individual exposure the in situ electric field and specific absorption rate (SAR) values were calculated for an 11-y-old female human model. The average exposure was determined to be low compared with ICNIRP reference levels: 0.29 μT for an extremely low-frequency (ELF) magnetic field and 0.09 V m^{-1} for GSM base stations, 0.11 V m^{-1} for DECT and 0.10 V m^{-1} for WiFi; other contributions could be neglected. However, some of the volunteers were more exposed: the highest realistic exposure, to which children could be exposed for a prolonged period of time, was 1.35 μT for ELF magnetic field and 0.38 V m^{-1} for DECT, 0.13 V m^{-1} for WiFi and 0.26 V m^{-1} for GSM base stations. Numerical calculations of the in situ electric field and SAR values for the typical and the worst-case situation show that, compared with ICNIRP basic restrictions, the average exposure is low. In the typical exposure scenario, the extremely low frequency exposure is <0.03 % and the RF exposure <0.001 % of the corresponding basic restriction. In the worst-case situation, the extremely low frequency exposure is <0.11 % and the RF exposure <0.007 % of the corresponding basic restrictions. Analysis of the exposures and the individual's perception of being exposed/unexposed to an ELF magnetic field showed that it is impossible to estimate the individual exposure to an ELF magnetic field based only on the information provided by the individuals, as they do not have enough knowledge and information to properly identify the sources in their vicinity.

(E)Vargová B, Majlath I, Kurimský J, Cimbala R, Pipova N, Živčák J, Tryjanowski P, Peťko B, Džmura J, Ižariková G, Majláthová V. Morphometric analysis - effect of the

radiofrequency interface of electromagnetic field on the size of hatched Dermacentor reticulatus larvae. Ann Agric Environ Med 28(3):419-425, 2021. (AE, DE, IU, VO) (1 mV/m^2)

Introduction and objective: Electromagnetic radiation interactions with living systems have been one of determining factors in biological evolution. This study investigates the effect of 900 MHz radiofrequency (RF) electromagnetics field (EMF) exposure of eggs on the development of Dermacentor reticulatus larvae. The basic objective was to determine whether the 900 MHz RF-EMF has the potential to influence the size of the body of the hatched larvae of D. reticulatus ticks. **Material and methods:** To this aim, eggs from 3 fully engorged females of D. reticulatus were included in the test procedure. Altogether four groups of eggs were designated which included eggs from each female. We used RF-EMF frequency of 900 MHz. Eggs were exposed to EMF for different time periods (30, 60 and 90 minutes) in dark, electromagnetically shielded anechoic chamber. After the irradiation eggs were allowed to hatch in climatic chamber. Randomly selected 200 larval individuals were measured to get basic morphological records. Four body traits including the total body length (TBL), length of gnathosoma with scutum (GSL), the total body width (TBW), and the width of basis capituli (BCW) were measured. **Results:** The D. reticulatus larvae hatched from eggs exposed for 60 minutes, had demonstrably larger dimensions of all measured body traits not only as a control unexposed group but also as other experimental groups. **Conclusions:** The study shows, particularly, that artificial EMF that is used in smartphone technology impacts seriously D. reticulatus larvae development.

Varsier N, Dahdouh S, Serrurier A, De la Plata JP, Anquez J, Angelini ED, Bloch I, Wiart J. Influence of pregnancy stage and fetus position on the whole-body and local exposure of the fetus to RF-EMF. Phys Med Biol. 59(17):4913-4926 2014. (Dosimetry)

This paper analyzes the influence of pregnancy stage and fetus position on the whole-body and brain exposure of the fetus to radiofrequency electromagnetic fields. Our analysis is performed using semi-homogeneous pregnant woman models between 8 and 32 weeks of amenorrhea. By analyzing the influence of the pregnancy stage on the environmental whole-body and local exposure of a fetus in vertical position, head down or head up, in the 2100 MHz frequency band, we concluded that both whole-body and average brain exposures of the fetus decrease during the first pregnancy trimester, while they advance during the pregnancy due to the rapid weight gain of the fetus in these first stages. From the beginning of the second trimester, the whole-body and the average brain exposures are quite stable because the weight gains are quasi proportional to the absorbed power increases.The behavior of the fetus whole-body and local exposures during pregnancy for a fetus in the vertical position with the head up were found to be of a similar level, when compared to the position with the head down they were slightly higher, especially in the brain.

(E)Vecchio F, Babiloni C, Ferreri F, Buffo P, Cibelli G, Curcio G, Dijkman SV, Melgari JM, Giambattistelli F, Rossini PM. Mobile phone emission modulates inter-hemispheric functional coupling of EEG alpha rhythms in elderly compared to young subjects. Clin Neurophysiol. 121(2):163-171, 2010. (AE, DE, HU, NU)

OBJECTIVE: It has been reported that GSM electromagnetic fields (GSM-EMFs) of mobile phones modulate - after a prolonged exposure - inter-hemispheric synchronization of temporal and frontal resting electroencephalographic (EEG) rhythms in normal young subjects [Vecchio et al., 2007]. Here we tested the hypothesis that this effect can vary on physiological aging as a sign of changes in the functional organization of cortical neural synchronization. METHODS: Eyes-closed resting EEG data were recorded in 16 healthy elderly subjects and 5 young subjects in the two conditions of the previous reference study. The GSM device was turned on (45min) in one condition and was turned off (45min) in the other condition. Spectral coherence evaluated the inter-hemispheric synchronization of EEG rhythms at the following bands: delta (about 2-4Hz), theta (about 4-6Hz), alpha 1 (about 6-8Hz), alpha 2 (about 8-10Hz), and alpha 3 (about 10-12Hz). The aging effects were investigated comparing the inter-hemispheric EEG coherence in the elderly subjects vs. a young group formed by 15 young subjects (10 young subjects of the reference study; Vecchio et al., 2007). RESULTS: Compared with the young subjects, the elderly subjects showed a statistically significant ($p<0.001$) increment of the inter-hemispheric coherence of frontal and temporal alpha rhythms (about 8-12Hz) during the GSM condition. CONCLUSIONS: These results suggest that GSM-EMFs of a mobile phone affect inter-hemispheric synchronization of the dominant (alpha) EEG rhythms as a function of the physiological aging. SIGNIFICANCE: This study provides further evidence that physiological aging is related to changes in the functional organization of cortical neural synchronization.

(E)Vereshchako GG, Chueshova NV, Gorokh GA, Naumov AD. State of the reproductive system in male rats of 1st generation obtained from irradiated parents and exposed to electromagnetic radiation (897 MHz) during embryogenesis and postnatal development. Radiats Biol Radioecol. 54(2):186-192, 2014.(Article in Russian) (CE, IU, M, ME, PN, VO)

The consequences of prolonged exposure to electromagnetic radiation from cellular phone (897 MHz, daily 8 h/day) in male rats of the 1st generation obtained from irradiated parents and subjected to prolonged exposure to electromagnetic radiation of the range of mobile communications during ontogeny and postnatal development were studied. It has been found that irradiation causes a decrease in the number of births of animals, changing the sex ratio towards the increase in the number of males. It had a significant impact on the reproductive system of males, accelerating their sexual development, revealed at the age of two months. Radiation from cell phones led to significant disproportions in the cell number at different stages of spermatogenesis. It increased the number of mature spermatozoa which decreased viability.

(E) Vereschako GG, Chueshova NV.Reaction of Reproductive System and Epididymal Spermatozoa .of Rats to Electromagnetic Radiation from Mobile Phone (1745 MHz) of Various Duration. Radiats Biol Radioecol 57(1):71-76, 2017. [Article in English, Russian] (CE, M, ME, VO)

Changes in the weight of reproductive system organs, quantitative and qualitative indicators of the epididymal spermatozoa of rats on the Ist and 30th days after the end of an electromagnetic exposition from the mobile phone (1745 MHz, the 8 hour/day, power density 0.2-20 μW/cm²) of various duration (from 1 to 90 days) have been researched. A significant increase in the absolute and relative weight of the epididymis and seminal vesicles and the number of epididymal spermatozoa was revealed on the 1st day after electromagnetic expo- sure during 7 days. The increase in the exposure duration up to 14 days is accompanied by a fall of the above indicators, and after a longer exposure (30, 60 days) there is an increase of the absolute weight of the testes; in all other cases, significant deviations in terms of the weight of reproductive organs are not observed. Expo- sition of various duration at 1745 MHz, except for 7-day radiation exposure, had no significant effect on the amount of epididymal spermatozoa and DNA fragmentation in them; however, viability of mature male germ cells in irradiated animals decreases independently of the duration of exposure. The revealed disturbances of the researched indicators are mainly normalized in the remote period (on the 30th day) after electromagnetic radiation.

(NE)Vijver MG, Bolte JF, Evans TR, Tamis WL, Peijnenburg WJ, Musters CJ, de Snoo GR. Investigating short-term exposure to electromagnetic fields on reproductive capacity of invertebrates in the field situation. Electromagn Biol Med. 33(1):21-28, 2014. (AE, no reproductive effect) (0.295-4.344 x 10(-4) mW/cm²)

Organisms are exposed to electromagnetic fields from the introduction of wireless networks that send information all over the world. In this study we examined the impact of exposure to the fields from mobile phone base stations (GSM 900 MHz) on the reproductive capacity of small, virgin, invertebrates. A field experiment was performed exposing four different invertebrate species at different distances from a radiofrequency electromagnetic fields (RF EMF) transmitter for a 48-h period. The control groups were isolated from EMF exposure by use of Faraday cages. The response variables as measured in the laboratory were fecundity and number of offspring. Results showed that distance was not an adequate proxy to explain dose-response regressions. No significant impact of the exposure matrices, measures of central tendency and temporal variability of EMF, on reproductive endpoints was found. Finding no impact on reproductive capacity does not fully exclude the existence of EMF impact, since mechanistically models hypothesizing non-thermal-induced biological effects from RF exposure are still to be developed. The exposure to RF EMF is ubiquitous and is still increasing rapidly over large areas. We plea for more attention toward the possible impacts of EMF on biodiversity.

(NE)Vrijheid M, Martinez D, Forns J, Guxens M, Julvez J, Ferrer M, Sunyer J. Prenatal Exposure to Cell Phone Use and Neurodevelopment at 14 Months. Epidemiology. 21: 259-262, 2010. (CE, DE, HU, IU, NU)

BACKGROUND: Recently, an association was reported between prenatal and postnatal exposure to cell phones and neurobehavioral problems in children at the age of 7 years. METHODS: A birth cohort was established in Sabadell, Spain between 2004 and 2006. Mothers completed questions about cell phone use in week 32 of the pregnancy (n =

587). Neurodevelopment of their children was tested at age 14 months using the Bayley Scales of Infant Development (n = 530). RESULTS: We observed only small differences in neurodevelopment scores between the offspring of cell phone users and nonusers. Those of users had higher mental development scores and lower psychomotor development scores, which may be due to unmeasured confounding. There was no trend with amount of cell phone use within users. CONCLUSION: This study gives little evidence for an adverse effect of maternal cell phone use during pregnancy on the early neurodevelopment of offspring.

(E)Wang XW, Ding GR, Shi CH, Zeng LH, Liu JY, Li J, Zhao T, Chen YB, Guo GZ. Mechanisms involved in the blood-testis barrier increased permeability induced by EMP. Toxicology. 276(1):58-63, 2010. (AE, FC, M, MO, VO) (200 10 ns EMP, average SAR 0.00004 W/kg)

d-testis barrier (BTB) plays an important role in male reproductive system. Lots of environmental stimulations can increase the permeability of BTB and then result in antisperm antibody (AsAb) generation, which is a key step in male immune infertility. Here we reported the results of male mice exposed to electromagneticpulse (EMP) by measuring the expression of tight-junction-associated proteins (ZO-1 and Occludin), vimentin microfilaments, and transforming growth factor-beta (TGF-beta3) as well as AsAb level in serum. Male BALB/c mice were sham exposed or exposed to EMP at two different intensities (200kV/m and 400kV/m) for 200 pulses. The testes were collected at different time points after EMP exposure. Immunofluorescence histocytochemistry, western blotting, laser confocal microscopy and RT-PCR were used in this study. Compared with sham group, the expression of ZO-1 and TGF-beta3 significantly decreased accompanied with unevenly stained vimentin microfilaments and increased serum AsAb levels in EMP-exposed mice. These results suggest a potential BTB injury and immune infertility in male mice exposed to a certain intensity of EMP.

Warille AA, Onger ME, Turkmen AP, Deniz ÖG, Altun G, Yurt KK, Altunkaynak BZ, Kaplan S. Controversies on electromagnetic field exposure and the nervous systems of children. Histol Histopathol 31(5):461-468, 2016. (Review)

This paper reviewed possible health effects from exposure to low levels of electromagnetic field (EMF) in children, arising from electrical power sources and mobile phones. Overall, the information about effects on developmental processes and cognitive functions is insufficient and further research on children and adolescents is critically needed. New research approaches are required focused on the effects on the developmental processes of children exposed to electromagnetic fields, using consistent protocols. When the current data were considered in detail, it was noted that children's unique vulnerabilities make them more sensitive to EMFs emitted by electronics and wireless devices, as compared to adults. Some experimental research shows a neurological impact and exposure in humans may lead to the cognitive and behavioral impairments. Because of the proliferation of wireless devices, public awareness of these dangers now is important to safeguard children's future healthy brain development.

(E)Wdowiak A, Wdowiak L, Wiktor H. Evaluation of the effect of using mobile phones

on male fertility. Ann Agric Environ Med. 14(1):169-172, 2007. (CE, HU, M, ME)

The problem of the lack of offspring is a phenomenon concerning approximately 15% of married couples in Poland. Infertility is defined as inability to conceive after a year of sexual intercourses without the use of contraceptives. In half of the cases the causative factor is the male. Males are exposed to the effect of various environmental factors, which may decrease their reproductive capabilities. A decrease in male fertility is a phenomenon which occurs within years, which may suggest that one of the reasons for the decrease in semen parameters is the effect of the development of techniques in the surrounding environment. A hazardous effect on male fertility may be manifested by a decrease in the amount of sperm cells, disorders in their mobility, as well as structure. The causative agents may be chemical substances, ionizing radiation, stress, as well as electromagnetic waves. The objective of the study was the determination of the effect of the usage of cellular phones on the fertility of males subjected to marital infertility therapy. The following groups were selected from among 304 males covered by the study: Group A: 99 patients who did not use mobile phones, Group B: 157 males who have used GSM equipment sporadically for the period of 1-2 years, and Group C: 48 people who have been regularly using mobile phone for more than 2 years. In the analysis of the effect of GSM equipment on the semen it was noted that an increase in the percentage of sperm cells of abnormal morphology is associated with the duration of exposure to the waves emitted by the GSM phone. It was also confirmed that a decrease in the percentage of sperm cells in vital progressing motility in the semen is correlated with the frequency of using mobile phones.

(E)Weisbrot D, Lin H, Ye L, Blank M, Goodman R. Effects of mobile phone radiation on reproduction and development in Drosophila melanogaster. J Cell Biochem 89(1):48-55, 2003. (CE, IU, MO, VO)

In this report we examined the effects of a discontinuous radio frequency (RF) signal produced by a GSM multiband mobile phone (900/1,900 MHz; SAR approximately 1.4 W/kg) on Drosophila melanogaster, during the 10-day developmental period from egg laying through pupation. As found earlier with low frequency exposures, the non-thermal radiation from the GSM mobile phone increased numbers of offspring, elevated hsp70 levels, increased serum response element (SRE) DNA-binding and induced the phosphorylation of the nuclear transcription factor, ELK-1. The rapid induction of hsp70 within minutes, by a non-thermal stress, together with identified components of signal transduction pathways, provide sensitive and reliable biomarkers that could serve as the basis for realistic mobile phone safety guidelines.

(E)Weyandt, TB, Schrader, SM, Turner, TW, Simon, SD, Semen analysis of military personnel associated with military duty assignments. Reprod Toxicol 10(6):521-528, 1996. (CE, FC, HU, M, ME)

A collaborative study between the U.S. Army Biomedical Research and DevelopmentLaboratory (USABRDL) and the National Institute for Occupational Safety and Health (NIOSH) was designed to assess fecundity of male artillery soldiers with potential exposures to airborne lead aerosols. Potential exposure assessment was based upon information provided in an interactive questionnaire. It became apparent from extensive questionnaire data that many soldiers in the initial control population had potentially

experienced microwave exposure as radar equipment operators. As a result, a third group of soldiers without potential for lead or microwave exposures, but with similar environmental conditions, was selected as a comparison population. Blood hormone levels and semen analyses were conducted on artillerymen (n = 30), radar equipment operators (n = 20), and the comparison group (n = 31). Analysis of the questionnaire information revealed that concern about fertility problems motivated participation of some soldiers with potential artillery or microwave exposures. Although small study population size and the confounding variable of perceived infertility limit the reliability of the study, several statistically significant findings wereidentified. Artillerymen who perceived a possible fertility concern demonstrated lower sperm counts/ejaculate (P = 0.067) and lower sperm/mL (P = 0.014) than the comparison group. The group of men with potential microwave exposures demonstrated lower sperm counts/mL (P = 0.009) and sperm/ejaculate (P = 0.027) than the comparison group. Variables used to assess endocrine, accessory sex gland, and sperm cell function were not different than the comparison group. Additional studies, incorporating larger numbers of individuals, should be performed in order to more optimally characterize potential lead and microwave exposure effects on male fecundity.

(E)Wu H, Wang D, Shu Z, Zhou H, Zuo H, Wang S, Li Y, Xu X, Li N, Peng R. Cytokines produced by microwave-radiated Sertoli cells interfere with spermatogenesis in rat testis. Andrologia 44 (Suppl 1):590-599, 2012. (AE, GE, IV, OX, MO) (100 mW/cm^2)

Microwave radiation resulted in degeneration, apoptosis or necrosis in germ cells at different stages. The molecular mechanisms by which microwaves induce spermatogenesis disorder have not been completely understood. Sertoli cells play crucial roles in mammalian spermatogenesis. Cytokines produced by Sertoli cells play pleiotropic roles in different conditions. At physiologically low concentration, TNFα, IL-1β and IL-6 behave as survival factors; while under pathological condition, these cytokines can induce apoptosis in testis. The effects of cytokines produced by microwave-radiated Sertoli cells on spermatogenesis are poorly understood. The purpose of this study was to determine the effect of cytokines produced by microwave-radiated Sertoli cells on the germ cells. We focused the effect of TNFα, IL-1β and IL-6 on the germ cells. The results showed that TNFα, IL-1β and IL-6 were increased in Sertoli cells after exposure to microwave radiation. These up-regulated cytokines can induce apoptosis and lipid peroxidation in the membrane of germ cells. In addition, germ cell apoptosis was associated with the up-regulation of Bax/Bcl-2 and caspase-3. These results suggest that cytokines produced by microwave-radiated Sertoli cells may disrupt spermatogenesis. Our data provided novel insight into the injury mechanism of germ cells induced by microwave radiation.

(E) Wu H, Min D, Sun B, Ma Y, Chen H, Wu J, Ren P, Wu J, Cao Y, Zhao B, Wang P. Effect of WiFi signal exposure in utero and early life on neurodevelopment and behaviors of rats. Environ Sci Pollut Res Int. 30(42):95892-95900, 2023. (BE, CE, DE, IU, MO, PN, VO) (average E field 2.1 V/m, B field 14.31 mA/m)

The aim of this study is to examine the long-term effects of prenatal and early-life WIFI signal exposure on neurodevelopment and behaviors as well as biochemical alterations of Wistar rats. On the first day of pregnancy (E0), expectant rats were allocated into two groups: the control group (n = 12) and the WiFi-exposed group (WiFi group, n = 12). WiFi group was exposed to turn on WiFi for 24 h/day from E0 to postnatal day (PND) 42. The control group was exposed to

turn-off WiFi at the same time. On PND7-42, we evaluated the development and behavior of the offspring, including body weight, pain threshold, and swimming ability, spatial learning, and memory among others. Also, levels of proteins involved in apoptosis were analyzed histologically in the hippocampus in response to oxidative stress. The results showed that WiFi signal exposure in utero and early life (1) increased the body weight of WiFi + M (WiFi + male) group; (2) no change in neuro-behavioral development was observed in WiFi group; (3) increased learning and memory function in WiFi + M group; (4) enhanced comparative levels of BDNF and p-CREB proteins in the hippocampus of WiFi + M group; (5) no neuronal loss or degeneration was detected, and neuronal numbers in hippocampal CA1 were no evidently differences in each group; (6) no change in the apoptosis-related proteins (caspase-3 and Bax) levels; and (7) no difference in GSH-PX and SOD activities in the hippocampus. Prenatal WiFi exposure has no effects on hippocampal CA1 neurons, oxidative equilibrium in brain, and neurodevelopment of rats. Some effects of prenatal WiFi exposure are sex dependent. Prenatal WiFi exposure increased the body weight, improved the spatial memory and learning function, and induced behavioral hyperactivity of male rats.

(E) Xu Y, Zheng ZA, Zhu T, Zhu B, Feng C, Chen Y, Qin F. [Joint effects of nano-selenium and nano-cerium on the male reproductive function of mice exposed to microwave radiation] Wei Sheng Yan Jiu 49(5):795-801, 2020. [Article in Chinese] (CE, IX, M, ME, MO, OX, VO) (Low SAR)

Objective: To study effect of nano-selenium and nano-cerium(nano cerium oxide) on the spermatogenic ability of mice irradiated by 1800 MHz microwave radiation(MR).
Methods: Forty-two ICR mice were randomly divided into groups: blank control group, solvent control group, microwave radiation model group, low, medium and high dose groups of nano-selenium+nano-cerium. In joint effects groups of nano-selenium and nano-cerium, the nano-selenium solution(60, 120 and 240 μg/kg) and the nano-cerium oxide solution(15, 30, 60 μg/kg) were administered to the stomach at 7:30 in the morning and 18:30 in the evening, respectively. The blank control group was orally administered with an equal volume of distilled water, and the solvent control group and the MR group were orally administered with an equal volume of carboxymethylcellulose sodium solution. During the second week of gastric administration, the mice were exposed to microwave radiation(1800 MHz) for 2 h every day(specific absorption ratio: 0. 2986 W/kg). After MR treatment, the daily sperm production of testis, sperm motility and sperm deformity rate in epididymis were measured, and the testicular marker enzymes [G6 PDH(6-phosphatedehydrogenase), ACP(acid phosphatase), LDH(lactate dehydrogenase)], antioxidant indexes [CAT(catalase), MDA(malondialdehyde) and T-AOC(total antioxidant capacity)] in testicular tissue were analyzed. **Results:** Compared with the solvent control group, MR led to the decrease of sperm motility and the increase of sperm deformity rate, decreased the enzymes activities of G6 PDH, ACP and CAT, increased LDH activity and MDA content, and decreased the T-AOC level in testicular tissue, and the differences were statistically significant(P< 0. 05). Compared with the MR group, the joint action of nano-selenium and nano-cerium with medium dose increased the daily sperm production of testis((18. 98±1. 27) ×10~6/g) vs. (15. 53±1. 24) ×10~6/g), decreased the sperm deformity rate(11. 74%±0. 91% vs. 16. 84%±2. 05%), and the joint action of nano-selenium and nano-cerium with medium and high dose increased the sperm motility in epididymis(61. 98%±6. 33%, 54. 17±4. 38 vs. 45. 16%±5. 01%),

and the differences were statistically significant(P<0. 05). Compared with the MR group, the joint action of nano-selenium and nano-cerium with low and medium dose increased the activity of ACP(11. 07±0. 98, 14. 85±1. 39 vs. 8. 72±0. 91 nmol/(min·mg prot), P<0. 05). The joint action of nano-selenium and nano-cerium with medium and high dose increased the activity of G6 PDH(24. 12±2. 06, 21. 36±3. 65 vs. 15. 11±1. 73 nmol/(min·mg prot), P<0. 05) and decreased the activity of LDH(15. 52±1. 17, 13. 51±1. 68 vs. 22. 46±2. 01 nmol/(min·mg prot), P<0. 05). The joint action of nano-selenium and nano-cerium with medium dose increased the activity of CAT(17. 92±2. 03 vs. 11. 69±0. 87 nmol/(min·mg prot), P<0. 05) and decreased the content of MDA(5. 17 ±0. 62 vs. 9. 03 ±0. 63 nmol/mg prot, P<0. 05). The joint action of nano-selenium and nano-cerium with low, medium and high dose increased the level of T-AOC(22. 06±1. 54, 29. 36±2. 39, 21. 01±2. 47 vs. 12. 88±1. 82 U/mg prot, P<0. 05). **Conclusion:** The joint addition of nano-selenium and nano-cerium can improve the reproductive function of male mice exposed to MR, and can effectively alleviate the changes of mouse testicular marker enzyme activity and the decline of antioxidant capacity caused by MR.

(E) Yahyazadeh A, Altunkaynak BZ. Protective effects of luteolin on rat testis following exposure to 900 MHz electromagnetic field. Biotech Histochem 94(4):298-307, 2019. (CE, M, ME, MO, OX, VO) (SAR 2 W/kg)

Increasing cell phone use calls for clarification of the consequences of long term exposure to electromagnetic fields (EMF). We investigated the effects of EMF on the testes of 12-week-old rats as well as possible protective effects of luteolin on testis tissue. Twenty-four Wistar albino rats were randomly divided into four groups: control, EMF, luteolin, and EMF + luteolin. The number of Leydig cells, primary spermatocytes and spermatids were reduced in the EMF group compared to the control group. In the EMF + luteolin group, the number of Leydig cells, primary spermatocytes and spermatids was significantly greater than the EMF group. We found an increase in superoxide dismutase (SOD) activity in the EMF group compared to the control group. In the EMF group, we found decreased wet weight of testes and serum testosterone levels compared to the control group. Decreased SOD enzyme activity, and increased serum testosterone levels and weight of the testes were observed in the EMF + luteolin group compared to the EMF group. EMF also affected sperm morphology. We found that in rat testis repeated exposure to 900 MHz EMF caused changes in testicular tissue and that the antioxidant, luteolin, substantially reduced the deleterious effects of EMF.

(E) Yahyazadeh A, Altunkaynak BZ, Kaplan S Biochemical, immunohistochemical and morphometrical investigation of the effect of thymoquinone on the rat testis following exposure to a 900-MHz electromagnetic field. Acta Histochem 122(1):151467, 2020. (CE, M, ME, VO) (No dosimetry data)

Long-term use of cell phones emitting electromagnetic fields (EMFs) have raised concerns regarding public health in recent year. We aimed to investigate the possible effects of 900 MHz EMF exposure (60 min/day for 28 days) on the rat testis. Another objective was to determine whether the deleterious effect of EMF radiation would be reduced by the administration of thymoquinone (TQ) (10 mg/kg/day). Twenty-four male adult Wistar albino rats were randomly selected, then assigned into four groups as follow Control, EMF, TQ and EMF + TQ. Testicular samples were analyzed using histological, stereological, biochemical and immunohistochemical

techniques. Total numbers of primary spermatocytes and spermatids as well as Leydig cells were significantly decreased in the EMF group compared to the Control group ($p < 0.05$). In the EMF + TQ group, the total number of primary spermatocytes was significantly increased compared to the EMF group ($p < 0.05$). Superoxide dismutase (SOD) activity was significantly increased in the EMF group compared to the Control group ($p < 0.05$). Also, serum testosterone levels and wet weight of testes were significantly decreased in the EMF group compared to the Control group ($p < 0.05$). Our findings suggested that exposure to a 900 MHz EMF had adverse effects on rat testicular tissue and that the administration of TQ partially mitigated testicular oxidative damages caused by EMF radiation.

(E)Yakymenko I, Burlaka A, Tsybulin I, Brieieva I, Buchynska L, Tsehmistrenko I, Che khun F. Oxidative and mutagenic effects of low intensity GSM 1800 MHz microwave radiation. Exp Oncol 40(4):282-287, 2018. (CE, GE, IU, OX)

Aim: Despite a significant number of epidemiological studies on potential carcinogenicity of microwave radiation (MWR) from wireless devices and a bulk of experimental studies on oxidative and mutagenic effects of low intensity MWR, the discussion on potential carcinogenicity of low intensity MWR is going on. This study aims to assess oxidative and mutagenic effects of low intensity MWR from a typical commercial model of a modern smartphone. **Materials and methods:** The model of developing quail embryos has been used for the assessment of oxidative and mutagenic effects of Global System for Mobile communication (GSM) 1800 MHz MWR from a commercial model of smartphone. The embryos were exposed in ovo to 0.32 μW/cm2, discontinuously - 48 s - On, 12 s - Off, during 5 days before and 14 days through the incubation period. **Results:** The exposure of quail embryos before and during the incubation period to low intensity GSM 1800 MHz has resulted in expressive statistically significant oxidative effects in embryonic cells, including a 2-fold increase in superoxide generation rate and 85% increase in nitrogen oxide generation rate, damages of DNA integrity and oxidative damages of DNA (up to twice increased levels of 8-oxo-dG in cells of 1-day old chicks from the exposed embryos). Finally, the exposure resulted in a significant, almost twice, increase of embryo mortality. **Conclusion:** The exposure of model biological system to low intensity GSM 1800 MHz MWR resulted in significant oxidative and mutagenic effects in exposed cells, and thus should be recognized as a significant risk factor for living cells.

(E)Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS. Effects of cellular phone emissions on sperm motility in rats. Fertil Steril. 88(4):957-964, 2007. (CE, M, ME, VO) (NO dosimetry data)

OBJECTIVE: To evaluate the effects of cellular phone emissions on rat sperm cells. DESIGN: Classic experimental. SETTING: Animal research laboratory. SUBJECTS: Sixteen 3-month-old male Sprague-Dawley rats, weighing 250-300 g. INTERVENTION(S): Rats in the experimental group were exposed to two 3-hour periods of daily cellular phone emissions for 18 weeks; sperm samples were then collected for evaluation. MAIN OUTCOME MEASURE(S): Evaluation of sperm motility, sperm cell morphology, total sperm cell number, and mRNA levels for two cell surface adhesion proteins. RESULT(S): Rats exposed to 6 hours of daily cellular phone emissions for 18 weeks exhibited a significantly higher incidence of sperm cell death than control group rats through chi-squared analysis. In addition, abnormal clumping of

sperm cells was present in rats exposed to cellular phone emissions and was not present in control group rats. CONCLUSION(S): These results suggest that carrying cell phones near reproductive organs could negatively affect male fertility.

(E)Yang M-L, Hong S-Y, Huang H-H, Lyu G-R, Wang L-X. [The effects of prenatal radiation of mobile phones on white matter in cerebellum of rat offspring] Zhongguo Ying Yong Sheng Li Xue Za Zhi 36(1):77-81, 2020. [Article in Chinese] (CE, IU, ME, MO, VO)

Objective: To evaluate the effects of prenatal radiation of 850～1 900 MHz mobile phone on white matter in cerebellum of adult rat offspring. **Methods:** Pregnant rats were randomly divided into short term maternal radiation group, long term maternal radiation group and control group. Rats in short term and long term maternal radiation group were exposed to 6 h/d and 24 h/d mobile phone radiation during 1-17 days of pregnancy, respectively. The cerebellums of offspring rats at the age of 3 month(n＝8) were taken. Cell morphology in cerebellum was studied by hematoxylin-eosin (HE) staining. The expressions of myelin basic protein (MBP), neurofilament-L (NF-L) and glial fibrillary acidic protein (GFAP) in cerebellum of rat offspring were detected by immunohistochemistry and Western blot. **Results:** Compared to control group, the morphological changes of purkinje cells in cerebellum were obvious in rat offspring of short term and long term maternal radiation group. Compared to control group, decreased MBP and NF-L expressions and increased GFAP expression were observed in long term maternal radiation group(all P＜0.05). Compared to short term radiation group, the expressions of MBP and NF-L were down-regulated (all P＜0.05) and the expression of GFAP was up- regulated(P＜0.05) in long term radiation group. **Conclusion:** Prenatal mobile phone radiation might lead to the damage of myelin and axon with activity of astrocytes in cerebellum of male rat offspring, which is related to the extent of radiation.

(E) Yao B, Men J, Liu S, Bai Y, Yu C, Gao Y, Xu X, Zhao L, Zhang J, Wang H, Li Y, Peng R. Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress. Electromagn Biol Med 42(4):150-162, 2023. (AE, M, ME, MO, OX, VO)

Shortwave radiation has been reported to have harmful effects on several organs in humans and animals. However, the biological effects of 27 MHz shortwave on the reproductive system are not clear. In this study, we investigated the effects of shortwave whole-body exposure at a frequency of 27 MHz on structural and functional changes in the testis. Male Wistar rats were exposed to 27 MHz continuous shortwaves at average power densities of 0, 5, 10, or 30 mW/cm2 for 6 min. The levels of insulin-like factor 3 (INSL3) and anti-sperm antibodies (AsAb) in the peripheral serum, sperm motility, sperm malformation rate, and testicular tissue structure of rats were analyzed. Furthermore, the activity of superoxide dismutase (SOD), catalase (CAT), malondialdehyde (MDA) content, calpain, and Cdk5 expression were analyzed at 1, 7, 14, and 28 days after exposure. We observed that the rats after radiation had decreased serum INSL3 levels ($p < 0.01$), increased AsAb levels ($p < 0.05$), decreased percentage of class A+B sperm ($p < 0.01$ or $p < 0.05$), increased sperm malformation ($p < 0.01$ or $p < 0.05$), injured testicular tissue structure, decreased SOD and CAT activities ($p < 0.01$ or $p < 0.05$), increased MDA content ($p < 0.01$), and testicular tissue expressions of calpain1, calpain2, and Cdk5 were increased ($p < 0.01$ or $p < 0.05$). In conclusion, Shortwave radiation caused

functional and structural damage to the reproductive organs of male rats. Furthermore, oxidative stress and key molecules in the calpain/Cdk5 pathway are likely involved in this process.

Plain language summary

Shortwave radiation has been used in communications, medical and military applications, and its damaging effects on several organs of the human body have been reported in the literature. However, the biological effects of shortwave radiation on the male reproductive system are unknown. The present study, by constructing an animal model of short-wave radiation and analyzing the experimental results, revealed that shortwave radiation could cause functional and structural damage to the reproductive organs of male rats, and that oxidative stress and key molecules in the calpain/Cdk5 pathway might be involved in this process. It will provide organizational data for further studies on the mechanisms of male reproductive damage by shortwave radiation.

(E) Ye W, Wang F, Zhang W, Fang N, Zhao W, Wang J. Effect of Mobile Phone Radiation on Cardiovascular Development of Chick Embryo. Anat Histol Embryol. 45(3):197-208, 2016. (CE, GE, IU, ME)

The biological effects on cardiovascular development of chicken embryos were examined after radiation exposure using mobile phone (900 MHz; specific absorption rate˜1.07 W/kg) intermittently 3 h per day during incubation. Samples were selected by morphological and histological methods. The results showed the rate of embryonic mortality and cardiac deformity increased significantly in exposed group ($P < 0.05$). No any histological pathological changes were observed on Day 5-7 (D5-D7) of incubation. A higher distribution of lipid droplets was unexpectedly present in myocardial tissue from the exposure groups on D10-D13. Soon afterwards, myofilament disruption, atrioventricular valve focal necrosis, mitochondria vacuolization and atrial natriuretic peptide (ANP) decrease appeared on D15-D21 of incubation. Comet assay data showed the haemocyte mean tail in the exposed group was significantly larger than that of the control ($P < 0.01$). The arterial vascular wall of exposed group was thicker ($P < 0.05$) than that of the control on D13, which was reversed to normal in later stages. Our findings suggest that long-term exposure of MPR may induce myocardium pathological changes, DNA damage and increased mortality; however, there was little effect on vascular development.

(E)Yilmaz A, Tumkaya L, Akyildiz K, Kalkan Y, Bodur AF, Sargin F, Efe F, Uydu HA, Yazici ZA. Lasting hepatotoxic effects of prenatal mobile phone exposure. J Matern Fetal Neonatal Med 30(11):1355-1359, 2017. (CE, IU, MO, OX, VO) (Low SAR 0.087 W/kg)

Objective: In this study, the livers of rats born to mothers exposed to electromagnetic field (EMF) were examined 60 days postpartum for biochemical and histopathological changes. **Methods:** Pregnant rats were exposed to radiation (900 MHz EMF, 24 h/day for 20 days) using a digital signal generator by placing the device centrally under the cage, which formed the study (EMF) group, while untreated matching rats served as controls. Livers and blood were obtained from litters (seven males and seven females) of both groups 60 days after birth, which were used for biochemical and histopathological analyses. **Results:** There was a significant increase in the levels of malondialdehyde (MDA) ($p < 0.05$) that was accompanied by a significant fall in

glutathione (GSH) ($p < 0.01$) in the liver. The serum levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were significantly increased ($p < 0.05$). Histopathologically, the liver sections of the EMF group showed intense degeneration in hepatocytes with cytoplasmic eosinophilic structures, pyknotic nuclei and fibrosis. **Conclusion:** We demonstrate that the intrauterin harmful effects of EMF on the livers of rats persist into adulthood.

(E) Yoshida Y, Seto T, Ohsu W, Hayashi S, Okazawa T, Nagase H, Yoshida M, Nakamura H, [Endocrine mechanism of placental circulatory disturbances induced by microwave in pregnant rats]. Nippon Sanka Fujinka Gakkai Zasshi 47(2):101-108, 1995. [Article in Japanese] (AE, F, FC, MO, VO)

Effects of microwaves on fetus and female genital organs remain to be elucidated. To demonstrate the placental circulatory disturbances induced by microwaves and to clarify the endocrine pathogenesis, placental blood flow and five endocrine indicators, i.e., corticosterone (CS), estradiol (E2), progesterone (P), prostaglandin E2 (PGE2) and prostaglandin F2 alpha (PGF2 alpha) were measured in rats exposed to whole-body microwaves with an intensity of 10 mW/cm2 at a frequency of 2,450 MHz. The placental blood flow at 45-90 min after exposure was significantly decreased in the rats exposed to the microwaves. Placental blood flow at 15 and 30 min was increased by pretreatment with intraperitoneal administration of angiotensin II (AII). In contrast, no significant change in placental blood flow was recognized in the AII pretreated rats exposed to the microwaves. An increase in CS and a decrease in E2 were induced by the microwave exposure independent of pretreatment with AII. P was increased by microwave exposure in the rats without pretreatment with AII. PGE2 was not changed by the microwave exposure in the case of either nonpretreatment or pretreatment with AII. PGF2 alpha was increased by the microwave exposure in the rats without pretreatment with AII. The present results indicate that excessive exposure to whole-body microwave disorders pregnancy in terms of placental circulatory dysfunction. The data suggest the involvement of endocrine mechanisms in the decrease in placental blood flow which is induced via a detrimental effect of microwaves on PGF2 alpha and on pituitary functions such as general emotional stress.

(E)Yu G, Tang Z, Chen H, Chen Z, Wang L, Cao H, Wang G, Xing J, Shen H, Cheng Q, ui Li D, Wang G, Xiang Y, Guan Y, Zhu Y, Liu Z, Bai Z. Long-term exposure to 4G smartphone radiofrequency electromagnetic radiation diminished male reproductive potential by directly disrupting Spock3-MMP2-BTB axis in the testes of adult rats. Sci Total Environ 698:133860, 2020. (CE, M, ME, MO, VO) (No dosimetry data)

The correlation between long-term exposure to SRF-EMR and the decline in male fertility is gradually receiving increasing attention from the medical society. While male reproductive organs are often exposed to SRF-EMR, little is currently known about the direct effects of long-term SRF-EMR exposure on the testes and its involvement in the suppression of male reproductive potential. The present study was designed to investigate this issue by using 4G SRF-EMR in rats. A unique exposure model using a 4G smartphone achieved localized exposure to the scrotum of the rats for 6 h each day (the smartphone was kept on active talk mode and received an external call for 1 min over 10 min intervals). Results showed that SRF-EMR

exposure for 150 days decreased sperm quality and pup weight, accompanied by testicular injury. However, these adverse effects were not evident in rats exposed to SRF-EMR for 50 days or 100 days. Sequencing analysis and western blotting suggested Spock3 overexpression in the testes of rats exposed to SRF-EMR for 150 days. Inhibition of Spock3 overexpression improved sperm quality decline and alleviated testicular injury and BTB disorder in the exposed rats. Additionally, SRF-EMR exposure suppressed MMP2 activity, while increasing the activity of the MMP14-Spock3 complexes and decreasing MMP14-MMP2 complexes; these results were reversed by Spock3 inhibition. Thus, long-term exposure to 4G SRF-EMR diminished male fertility by directly disrupting the Spock3-MMP2-BTB axis in the testes of adult rats. To our knowledge, this is the first study to show direct toxicity of SRF-EMR on the testes emerging after long-term exposure.

Yu G, Bai Z, Song C, Cheng Q, Wang G, Tang Z, Yang S. Current progress on the effect of mobile phone radiation on sperm quality: An updated systematic review and meta-analysis of human and animal studies. Environ Pollut 282:116952, 2021. (Review)

Potential suppression of fertility due to mobile phone radiation remains a focus of researchers. We conducted meta-analyses on the effects of mobile phone radiation on sperm quality using recent evidence and propose some perspectives on this issue. Using the MEDLINE/PubMed, Embase, WOS, CENTRAL, and ClinicalTrials.gov databases, we retrieved and screened studies published before December 2020 on the effects of mobile phone use/mobile phone RF-EMR on sperm quality. Thirty-nine studies were included. Data quality and general information of the studies were evaluated and recorded. Sperm quality data (density, motility, viability, morphology, and DFI) were compiled for further analyses, and we conducted subgroup, sensitivity, and publication bias analyses. The pooled results of human cross-sectional studies did not support an association of mobile phone use and a decline in sperm quality. Different study areas contributed to the heterogeneity of the studies. In East Europe and West Asia, mobile phone use was correlated with a decline in sperm density and motility. Mobile phone RF-EMR exposure could decrease the motility and viability of mature human sperm in vitro. The pooled results of animal studies showed that mobile phone RF-EMR exposure could suppress sperm motility and viability. Furthermore, it reduced sperm density in mice, in rats older than 10 weeks, and in rats restrained during exposure. Differences regarding age, modeling method, exposure device, and exposure time contributed to the heterogeneity of animal studies. Previous studies have extensively investigated and demonstrated the adverse effects of mobile phone radiation on sperm. In the future, new standardized criteria should be applied to evaluate potential effects of mobile phone RF-EMR dosages. Further sperm-related parameters at the functional and molecular levels as well as changes in biological characteristics of germ cells should be evaluated. Moreover, the impact of mobile phone RF-EMR on individual organs should also be examined.

(E) Yu G, Zhu Y, Song C, Chen L, Tang Z, Wu T. The ZIP9-centered androgen pathway compensates for the 2605 MHz radiofrequency electromagnetic radiation-mediated reduction in resistance to H_2O_2 damage in Sertoli cells of adult rats. Ecotoxicol Environ Saf 254:114733, 2023. (CE, M, ME, MO, OX, VO)

The direct biological effects of radiofrequency electromagnetic radiation (RF-EMR) from wireless communication equipment on the testes are still unclear. Our previous study proved that long-term exposure to 2605 MHz RF-EMR gradually damage spermatogenesis and resulted in time-dependent reproductive toxicity by directly disrupting blood-testis barrier circulation. Although short-term exposure did not cause readily observable damage to fertility, whether it caused specific biological effects and how these effects contributed to the time-dependent reproductive toxicity of RF-EMR were currently unknown. Studies on this issue are important for elucidating the time-dependent reproductive toxicity of RF-EMR. The present study established a 2605 MHz RF-EMR (SAR=1.05 W/Kg) scrotal exposure model with rats and extracted primary Sertoli cells for exposure to investigate the direct biological effects of short-term RF-EMR exposure on the testis. The results showed that short-term RF-EMR exposure did not decrease sperm quality and spermatogenesis, but it increased the levels of testicular testosterone (T) and zinc transporter 9 (ZIP9) in Sertoli cells of rats. In vitro, 2605 MHz RF-EMR exposure did not increase the apoptosis rate of Sertoli cells, but it increased the apoptosis rate and MDA of Sertoli cells exposed to H_2O_2. T reversed these changes and increased ZIP9 level in Sertoli cells, whereas inhibiting ZIP9 expression significantly suppressed these T-mediated protective effects. Moreover, T increased the levels of phosphorylated inositol-requiring enzyme 1 (P-IRE1), phosphorylated protein kinase R (PKR)-like endoplasmic reticulum kinase (P-PERK), phosphorylated eukaryotic initiation factor 2a (P-eIF2a) and phosphorylated activating transcription factor 6 (P-ATF6) in Sertoli cells, and these effects were reversed by ZIP9 inhibition. With prolonged exposure time, testicular ZIP9 was gradually downregulated, and testicular MDA increased. ZIP9 level was negatively correlated with MDA level in the testes of exposed rats. Thus, although short-term exposure to 2605 MHz RF-EMR (SAR=1.05 W/kg) did not significantly disturb spermatogenesis, it suppressed the ability of Sertoli cells to resist external insults, which was rescued by enhancing the ZIP9-centered androgen pathway in the short term. Increasing the unfolded protein response might be an important downstream mechanism involved. These results promote a better understanding of the time-dependent reproductive toxicity of 2605 MHz RF-EMR.

(E)Yüksel M, Nazıroğlu M, Özkaya MO. Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring. Endocrine. 52(2):352-362, 2016. (CE, F, IU, ME, MO, OX, VO) (Low SAR 0.1 W/kg)

We investigated the effects of mobile phone (900 and 1800 MHz)- and Wi-Fi (2450 MHz)-induced electromagnetic radiation (EMR) exposure on uterine oxidative stress and plasma hormone levels in pregnant rats and their offspring. Thirty-two rats and their forty newborn offspring were divided into the following four groups according to the type of EMR exposure they were subjected to: the control, 900, 1800, and 2450 MHz groups. Each experimental group was exposed to EMR for 60 min/day during the pregnancy and growth periods. The pregnant rats were allowed to stand for four generations (total 52 weeks) before, plasma and uterine samples were obtained. During the 4th, 5th, and 6th weeks of the experiment, plasma and uterine samples were also obtained from the developing rats. Although uterine lipid peroxidation increased in the EMR groups, uterine glutathione peroxidase activity (4th and 5th weeks) and plasma prolactin levels (6th week) in developing rats decreased in

these groups. In the maternal rats, the plasma prolactin, estrogen, and progesterone levels decreased in the EMR groups, while the plasma total oxidant status, and body temperatures increased. There were no changes in the levels of reduced glutathione, total antioxidants, or vitamins A, C, and E in the uterine and plasma samples of maternal rats. In conclusion, although EMR exposure decreased the prolactin, estrogen, and progesterone levels in the plasma of maternal rats and their offspring, EMR-induced oxidative stress in the uteri of maternal rats increased during the development of offspring. Mobile phone- and Wi-Fi-induced EMR may be one cause of increased oxidative uterine injury in growing rats and decreased hormone levels in maternal rats. TRPV1 cation channels are the possible molecular pathways responsible for changes in the hormone, oxidative stress, and body temperature levels in the uterus of maternal rats following a year-long exposure to electromagnetic radiation exposure from mobile phones and Wi-Fi devices. It is likely that TRPV1-mediated Ca^{2+} entry in the uterus of pregnant rats involves accumulation of oxidative stress and opening of mitochondrial membrane pores that consequently leads to mitochondrial dysfunction, substantial swelling of the mitochondria with rupture of the outer membrane and release of oxidants such as superoxide (O_2^-) and hydrogen peroxide (H_2O_2). The superoxide radical is converted to H_2O_2 by superoxide dismutase (SOD) enzyme. Glutathione peroxidase (GSH-Px) is an important antioxidant enzyme for removing lipid hydroperoxides and hydrogen peroxide and it catalyzes the reduction of H_2O_2 to water.

(E)Zareen N, Khan MY, Minhas LA. Derangement of chick embryo retinal differentiation caused by radiofrequency electromagnetic fields. Congenit Anom (Kyoto). 49(1):15-19, 2009. (CE, IU, ME) (No dosimetry data) (Exposure-duration dependent biphasic effect)

The possible adverse effects of radiofrequency electromagnetic fields (EMF) emitted from mobile phones present a major public concern. Biological electrical activities of the human body are vulnerable to interference from oscillatory aspects of EMF, which affect fundamental cellular activities, in particular, the highly active development process of embryos. Some studies highlight the possible health hazards of EMF, while others contest the hypothesis of biological impact of EMF. The present study was designed to observe the histomorphological effects of EMF emitted by a mobile phone on the retinae of developing chicken embryos. Fertilized chicken eggs were exposed to a ringing mobile set on silent tone placed in the incubator at different ages of development. After exposure for the scheduled duration the retinae of the embryos were dissected out and processed for histological examination. The control and experimental embryos were statistically compared for retinal thickness and epithelial pigmentation grades. Contrasting effects of EMF on the retinal histomorphology were noticed, depending on the duration of exposure. The embryos exposed for 10 post-incubation days exhibited decreased retinal growth and mild pigmentation of the epithelium. Growth retardation reallocated to growth enhancement on increasing EMF exposure for 15 post-incubation days, with a shift of pigmentation grade from mild to intense. We conclude that EMF emitted by a mobile phone cause derangement of chicken embryo retinal differentiation.

(E)Zareen N, Khan MY, Minhas LA. Dose related shifts in the developmental progress of chick embryos exposed to mobile phone induced electromagnetic fields. J Ayub Med Coll Abbottabad.21(1):130-134, 2009. (CE, DE, IU) (Dose dependent biphasic

effect) (No dosimetry data)

BACKGROUND: The possible adverse effects of Electromagnetic Fields (EMFs) emitted from mobile phones present a major public concern today. Some studies indicate EMFs effects on genes, free radical production, immunological and carcinogenic effects. On the other hand there are studies which do not support the hypothesis of any biological impacts of EMFs. This study was designed to observe the effects of mobile phone induced EMFs on survival and general growth and development of chick embryo, investigating dose-response relationship if any. METHODS: This was an experimental study in which developing chick embryos were exposed to different doses of mobile phone induced EMFs. For this purpose a mobile phone was placed in the incubator in the centre of fertilised eggs in silent ringing mode and was 'rung' upon from any other line or cell phone. After incubation for 10 or 15 days the eggs were opened and the developmental mile-stones of the surviving embryos were compared with the non exposed subgroup. RESULTS: EMFs exposure significantly decreased the survivability of the chick embryos. The lower doses of EMFs caused growth retardation. However, this effect of growth retardation reallocated to partial growth enhancement on increasing the dose of EMFs and shifted over to definite growth enhancement on further raising the dose. CONCLUSION: There is an adverse effect of EMFs exposure on embryo survivability. Chick embryos developmental process is influenced by EMFs. However, these effects are variable depending upon the dose of EMFs exposure.

(E)Zarei S, Mortazavi SMJ, Mehdizadeh AR, Jalalipour M, Borzou S, Taeb S, Haghani M, Mortazavi SAR, Shojaei-Fard MB, Nematollahi S, Alighanbari N, Jarideh S. A Challenging Issue in the Etiology of Speech Problems: The Effect of Maternal Exposure to Electromagnetic Fields on Speech Problems in the Offspring. J Biomed Phys Eng 5(3):151-154. 2015. (maternal exposure, FC, HU)

Background: Nowadays, mothers are continuously exposed to different sources of electromagnetic fields before and even during pregnancy. It has recently been shown that exposure to mobile phone radiation during pregnancy may lead to adverse effects on the brain development in offspring and cause hyperactivity. Researchers have shown that behavioral problems in laboratory animals which have a similar appearance to ADHD are caused by intrauterine exposure to mobile phones. **Objective:** The purpose of this study was to investigate whether the maternal exposure to different sources of electromagnetic fields affect on the rate and severity of speech problems in their offspring. **Methods:** In this study, mothers of 35 healthy 3-5 year old children (control group) and 77 children and diagnosed with speech problems who had been referred to a speech treatment center in Shiraz, Iran were interviewed. These mothers were asked whether they had exposure to different sources of electromagnetic fields such as mobile phones, mobile base stations, Wi-Fi, cordless phones, laptops and power lines. **Results:** We found a significant association between either the call time (P=0.002) or history of mobile phone use (months used) and speech problems in the offspring (P=0.003). However, other exposures had no effect on the occurrence of speech problems. To the best of our knowledge, this is the first study to investigate a possible association between maternal exposure to electromagnetic field and speech problems in the offspring. Although a major limitation in our study is the relatively small sample size, this study indicates that the maternal exposure to

common sources of electromagnetic fields such as mobile phones can affect the occurrence of speech problems in the offspring.

Zhang C, Li C, Yang L, Hou W, Du M, Wu T, Chen W. Assessment of Twin Fetal Exposure to Environmental Magnetic and Electromagnetic Fields. Bioelectromagnetics 43(3):160-173, 2022. (Dosimetry)

Fetal development is vital in the human lifespan. Therefore, it is essential to characterize exposure by a series of typical environmental magnetic and electromagnetic fields. In particular, there has recently been a sharp increase in the twin birth rate. However, lack of appropriate models has prohibited dosimetric evaluation, restricting characterization of the impact of these environmental factors on twins. The present study developed two whole-body pregnant models of 31 and 32 weeks of gestation with twin fetuses and explored several typical exposure scenarios, including 50-Hz uniform magnetic field exposure, local 125-kHz magnetic field (MF), and 13.56-MHz electromagnetic field exposure, as well as wideband planewave radiofrequency (RF) exposure from 20 to 6000 MHz. Finally, dosimetric results were derived. Compared to the singleton pregnancy with similar weeks of gestation, twin fetuses were overexposed at 50-Hz uniform MF, but they were probably underexposed in the RF scenarios with frequencies for wireless communications. Furthermore, the twin fetuses manifested large dosimetric variability compared to the singleton, which was attributed to the incident direction and fetal position. Based on the analysis, the dosimetric results over the entire gestation period were estimated. The results can be helpful to estimate the risk of twin-fetal exposure to electromagnetic fields and examine the conservativeness of the international guidelines.

(E)Zhang G, Yan H, Chen Q, Liu K, Ling X, Sun L, Zhou N, Wang Z, Zou P, Wang X, Tan L, Cui Z, Zhou Z, Liu J, Ao L, Cao J. Effects of cell phone use on semen parameters: Results from the MARHCS cohort study in Chongqing, China. Environ Int. 91:116-121, 2016. (CE, HU, M, ME)

Epidemiological and experimental evidence for detrimental effects of cell phone use on semen quality is still equivocal. And that recruiting participants from infertility clinic not from general population may raise the possibility of a selection bias. To investigate effects of cell phone use on semen parameters in a general population, we screened and documented the cell phone use information of 794 young men from the Male Reproductive Health in Chongqing College students (MARHCS) cohort study in 2013, followed by 666 and 568 in 2014 and 2015, respectively. In the univariate regression analyses, we found that the daily duration of talking on the cell phone was significantly associated with decreased semen parameters, including sperm concentration [β coefficient=-6.32% per unit daily duration of talking on the cell phone (h); 95% confidence interval (CI), -11.94, -0.34] and total sperm count (-8.23; 95% CI, -14.38, -1.63) in 2013; semen volume (-8.37; 95% CI, -15.93, -0.13) and total sperm count (-16.59; 95% CI, -29.91, -0.73) in 2015]. Internet use via cellular networks was also associated with decreased sperm concentration and total sperm counts in 2013 and decreased semen volume in 2015. Multivariate analyses were used to adjust for the effects of potential confounders, and significant negative associations between internet use and semen parameters remained. Consistent but nonsignificant negative associations between talking on the cell phone and semen parameters persisted throughout the three

study years, and the negative association was statistically significant in a mixed model that considered all three years of data on talking on the cell phone and semen quality. Our results showed that certain aspects of cell phone use may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, or sperm count, thus impairing male fertility.

(NE)Zhang KY, Xu H, Du L, Xing JL, Zhang B, Bai QS, Xu YQ, Zhou YC, Zhang JP, Zhou Y, Ding GR. Enhancement of X-ray Induced Apoptosis by Mobile Phone-Like Radio-Frequency Electromagnetic Fields in Mouse Spermatocyte-Derived Cells. Int J Environ Res Public Health. 14(6):616, 2017. (AE, IV, M, ME, MO) (Interacts with x-ray)

To explore the combined effects of environmental radio-frequency (RF) field and X-ray, mouse spermatocyte-derived (GC-1) cells were exposed to 1950 MHz RF field at specific absorption rate (SAR) of 3 W/kg for 24 h combined with or without X-ray irradiation at 6 Gy. After treatment, the cell proliferation level was determined by 3-(4,5-dimethyl-2-thiazolyl)-2,5-diphenyl-2-H-tetrazolium bromide (MTT) Assay and 5-Bromo-2-deoxy Uridine (BrdU) enzyme linked immunosorbent (ELISA) Assay. The apoptosis level was detected by annexin V flow cytometry assay, transferase-mediated deoxyuridine triphosphate-biotin nick end labeling (TUNEL) Assay and Caspase-3 Activity Assay. It was found that the proliferation and apoptosis level did not change in GC-1 cells after RF exposure alone. However, compared with the X-ray group, the proliferation level significantly decreased and the apoptotic rate significantly increased in the RF+X-ray group. Moreover, a significant decrease in Bcl-2 protein expression and increase in Bax protein expression were observed. The findings suggested that RF exposure at SAR of 3 W/kg did not affect apoptosis and proliferation in GC-1 cells by itself, but that it did enhance the effects of X-ray induced proliferation inhibition and apoptosis, in which B-cell lymphoma-2 (Bcl-2) and Bcl-2 associated X protein (Bax) might be involved.

(E) Zhang SQY, Du PP, Shu X, Wu HX, Mu YZ, Wu XN, Zhang Y. [The effect of pregnant rats exposed to radio frequency electromagnetic field on the hippocampal morphology and nerve growth factor of offspring rats] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 40(9):656-660, 2022. [Article in Chinese] (CE, IU, ME, MO, VO)

Objective: To explore the effects of exposure of pregnant rats to radio frequency electromagnetic field on the ultrastructure of hippocampus and the levels of obesity related protein (FTO) and nerve growth factor (NGF) in offspring rats. **Methods:** In September 2019, 36 healthy 7-week-old Wistar rats were selected, including 24 female rats (150-200 g) and 12 male rats (200-250 g) . The male and female mice were mated in the cage at 2: 1 ratio at 18: 00 every night. The smear results showed that the sperm was positive and the mating was successful. The day was regarded as the 0 day of pregnancy. Pregnant rats were randomly divided into 3 experimental groups and 3 control groups, with 4 rats in each group. The experimental group was exposed to 1 800 MHz, Wi-Fi and 1 800 MHz+Wi-Fi respectively, and the three control groups were exposed to virtual exposure. 12 hours a day for 21 days in three batches. After the end of exposure, the offspring of each group were raised for 7 weeks. The ultrastructural changes of the hippocampus were observed by transmission electron microscopy, the FTO level in the hippocampus was determined by Western blot, and the NGF level in the brain tissue was

determined by ELISA. **Results:** Transmission electron microscopy showed that the nuclei of hippocampal tissue of female and male rats in the 1800 MHz group were slightly contracted, the cytoplasm was slightly edema, and the nuclei of male rats were obviously irregular. In the offspring of male and female rats in the Wi-Fi group, the nucleus of hippocampal tissue contracted seriously, the cell membrane was irregular, and the cytoplasm appeared obvious edema. In the 1800 MHz+Wi-Fi group, the nuclei of hippocampal tissue of both male and female offspring rats were severely contracted, the nuclear membrane was irregular, and the cytoplasm was severely edema. there was no significant difference in FTO level among the groups (P>0.05) . Compared with other groups, NGF content in hippocampus of offspring rats in the 1800 MHz+Wi-Fi group was significantly higher (P<0.05) . **Conclusion:** Exposure to radio frequency electromagnetic fields will damage the morphological structure of hippocampal tissue of offspring and stimulate the increase of NGF expression in the hippocampus.

(E) Zhang Y, Li Z, Gao Y, Zhang C. Effects of fetal microwave radiation exposure on offspring behavior in mice. J Radiat Res. 56(2):261-268, 2015. (BE, CE, IU, VO) (SAR 2 W/kg)

The recent rapid development of electronic communication techniques is resulting in a marked increase in exposure of humans to electromagnetic fields (EMFs). This has raised public concerns about the health hazards of long-term environmental EMF exposure for fetuses and children. Some studies have suggested EMF exposure in children could induce nervous system disorders. However, gender-dependent effects of microwave radiation exposure on cognitive dysfunction have not previously been reported. Here we investigated whether in utero exposure to 9.417-GHz microwave throughout gestation (Days 3.5-18) affected behavior, using the open field test (OFT), elevated-plus maze (EPM), tail suspension test (TST), forced swimming test (FST) and Morris water maze (MWM). We found that mice showed less movement in the center of an open field (using the OFT) and in an open arm (using the EPM) after in utero exposure to 9.417-GHz radiation, which suggested that the mice had increased anxiety-related behavior. Mice demonstrated reduced immobility in TST and FST after in utero exposure to 9.417-GHz radiation, which suggested that the mice had decreased depression-related behavior. From the MWM test, we observed that male offspring demonstrated decreased learning and memory, while females were not affected in learning and memory, which suggested that microwaves had gender-dependent effects.

(E) Zheng F, Gao P, He M, Li M, Tan J, Chen D, Zhou Z, Yu Z, Zhang L. Association between mobile phone use and self-reported well-being in children: a questionnaire-based cross-sectional study in Chongqing, China. BMJ Open. 5(5):e007302, 2015. (BE, CE, FC, HU)

OBJECTIVES: In the past decade, the **mobile phone** (MP) has become extremely popular among children and the average age at which children own their first MP has decreased. The potential health effects of children's exposure to MP have been the subject of widespread public concern. The aim of our study is to investigate the associations between MP use and well-being in children. DESIGN: Cross-sectional study. SETTING: The questionnaires were completed in class with items regarding demographics, MP usage, self-reported well-being (symptoms were taken from the questionnaire of the HBSC survey) and

possible confounding factors between October 2011 and May 2012 in Chongqing, China. Data were analysed using χ(2) tests and logistic regression models. PARTICIPANTS: Among the 793 children invited to participate, 781 returned the questionnaires. RESULTS: In total, 746 (94.1%) valid questionnaires were received. Fatigue was significantly associated with the years of MP usage (OR 1.85; 95% CI 1.07 to 3.22) and the daily duration of MP calls (OR 2.98; 95% CI 1.46 to 6.12). Headache was significantly associated with the daily duration of MP calls (OR 2.85; 95% CI 1.23 to 6.57). However, after adjusting for confounders only, the association between fatigue and MP usage remained statistically significant. There was no significant association between MP use and other physical symptoms in children. CONCLUSIONS: The present study indicated that there was a consistent significant association between MP use and fatigue in children. Further in-depth research is needed to explore the potential health effects of MP use in children.

(E) Zhou LY, Zhang HX, Lan YL, Li Y, Liang Y, Yu L, Ma YM, Jia CW, Wang SY. Epidemiological investigation of risk factors of the pregnant women with early spontaneous abortion in Beijing. Chinese Journal of Integrative Medicine. 23(5):345-349, 2017. (CE, F, HU)

OBJECTIVE: To determine the risk factors of the pregnant women with early spontaneous abortion [i.e., miscarriages] in Beijing. METHODS: A total of 34,417 cases of pregnant women were participated in the survey from January 2000 to December 2013. A questionnaire was informed to each woman. The content of questionnaire includes four parts: general condition, obstetrical history, past history and family history, and living environment and habits. The mental condition was evaluated with Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS). RESULTS: A total of 32,296 questionnaires were collected. The spontaneous abortion rate in the total sample was 3.0%. There was no significant difference between the normal pregnancy group and spontaneous abortion group in terms of general condition, obstetrical and past history (P>0.05). Significant differences between the two groups were found in terms of decoration during pregnancy, keeping pets, near mobile communication base station within 100 m around the residence, drinking during pregnancy, having a cold during pregnancy and SAS (P<0.05). Having a cold during pregnancy, decoration during pregnancy, near mobile communication base station within 100 m around the residence, keeping pets and high SAS were determined the independent risk factors of spontaneous abortion by Logistic regression analysis. CONCLUSIONS: Having a cold during pregnancy, decoration, keeping pets, near mobile communication base station within 100 m around the residence and high SAS are the independent risk factors of spontaneous abortion in Beijing.

(E) Zhou Z, Shan J, Zu J, Chen Z, Ma W, Li L, Xu J. Social behavioral testing and brain magnetic resonance imaging in chicks exposed to mobile phone radiation during development. BMC Neurosci 17(1):36, 2016. (BE, CE, DE, IU, NU) (3.03 μW/cm^2)

Background: The potential adverse effect of mobile phone radiation is currently an area of great concern in the field of public health. In the present study, we aimed to investigate the effect of mobile phone radiation (900 MHz radiofrequency) during hatching on postnatal social behaviors in chicks, as well as the effect on brain size and structural maturity estimated using 3.0 T

magnetic resonance imaging. At day 4 of incubation, 76 normally developing chick embryos were divided into the control group (n = 39) and the radiation group (n = 37). Eggs in the radiation group were exposed to mobile phone radiation for 10 h each day from day 4 to 19 of incubation. Behavioral tests were performed 4 days after hatching. T2-weighted MR imaging and diffusion tensor imaging (DTI) were subsequently performed. The size of different brain subdivisions (telencephalon, optic lobe, brain stem, and cerebellum) and corresponding DTI parameters were measured. The Chi-square test and the student's t test were used for statistical analysis. $P < 0.05$ was considered statistically significant. **Results:** Compared with controls, chicks in the radiation group showed significantly slower aggregation responses (14.87 ± 10.06 vs. 7.48 ± 4.31 s, respectively; $P < 0.05$), lower belongingness (23.71 ± 8.72 vs. 11.45 ± 6.53 s, respectively; $P < 0.05$), and weaker vocalization (53.23 ± 8.60 vs. 60.01 ± 10.45 dB/30 s, respectively; $P < 0.05$). No significant differences were found between the radiation and control group for brain size and structural maturity, except for cerebellum size, which was significantly smaller in the radiation group (28.40 ± 1.95 vs. 29.95 ± 1.41 cm(2), $P < 0.05$). The hatching and heteroplasia rates were also calculated and no significant difference was found between the two groups. **Conclusions:** Mobile phone radiation exposure during chick embryogenesis impaired social behaviors after hatching and possibly induced cerebellar retardation. This indicates potential adverse effects of mobile phone radiation on brain development.