

## **List of References Reporting Fertility and/or Reproduction Effects from EMF or RF (with abstracts)**

**Agarwal A, Desai NR, Makker K, et al. (2009) Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertility and Sterility 92(4):1318-25.**

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.

**Agarwal A, Singh A, Hamada A, Kesari K (2011) Cell phones and male infertility: a review of recent innovations in technology and consequences. Brazilian Journal of Urology 37(4):432-54.**

Cell phones have become a vital part of everyday life. However, the health risks associated with their usage are often overlooked. Recently, evidence from several studies supports a growing claim that cell phone usage may have a detrimental effect on sperm parameters leading to decreased male fertility. Nonetheless, other studies showed no conclusive link between male infertility and cell phone usage. The ambiguity of such results is attributed to the lack of a centralized assay for measuring inflicted damage caused by cell phones. Study design, ethics, and reproducibility are all aspects which must be standardized before any conclusions can be made.

**Aitken RJ, Bennetts LE, Sawyer D, Wiklendt AM, King BV (2005) Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. International Journal of Andrology 28(3):179-179.**

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 beta-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.

**Avendaño C, Mata A, Sanchez Sarmiento CA, Doncel GF (2011) Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. Fertility and Sterility [Epub ahead of print]**

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.

**Balmori A (2009) Electromagnetic pollution from phone masts. Effects on wildlife. Pathophysiology 16(2-3):191-9.**

A review on the impact of radiofrequency radiation from wireless telecommunications on wildlife is presented. Electromagnetic radiation is a form of environmental pollution which may hurt wildlife. Phone masts located in their living areas are irradiating continuously some species that could suffer long-term effects, like reduction of their natural defenses, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive behavioral response in rats, bats and birds such as sparrows. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts. To measure these effects urgent specific studies are necessary.

**Behari J, Kesari KK (2006) Effects of microwave radiations on reproductive system of male rats. Embryo Talk 1 (Suppl.1):81-5.**

Recently, there have been reports referring to studies on health effects due to exposure of radiofrequency electromagnetic radiation (RFEMR). In this context mobile phones are often being implicated. In an attempt to quantitate this study was undertaken to examine their exposure effects. Animals were exposed continuously to 900 MHz Frequency at a specific absorption rate of approximately 0.9 W/Kg for 35 days at 2 hours per day. Rats were placed in Plexiglas cages with drilled ventilation holes, which have been attached with mobile phone hand set. After the exposure period, rats were immediately sacrificed and sperms were collected for the study of DNA double strand breaks by microgel electrophoresis (Comet assay), sperm count and testis weight was taken. To confirm this at other frequencies animals were exposed to low intensity microwaves (2.45 GHz, 0.34 mW/cm<sup>2</sup> SAR 0.1 W/Kg). A similar set of studies was undertaken after the exposure period, when the animals were similarly sacrificed. Results obtained using the mobile phone exposure shows that the chronic exposure to these radiations cause double strand DNA breaks in sperm cells. This study also shows that the mobile radiation exposure can cause statistically significant decrease in the sperm count and testes weight. A similar set of data was obtained from 2.45 GHz exposure. It is concluded that microwave induced effects on reproductive system are uniformly distributed over the electromagnetic spectrum under investigation.

**Belyaev IY, Grigoriev YG (2007) Problems in assessment of risks from exposures to microwaves of mobile communication. Radiatsionnaia biologiiia, radioecologiia / Rossiiskaia akademiia nauk 47(6):727-32.**

Since pioneering investigations published in the beginning of 1970th, various biological responses to non-thermal (NT) microwaves (MW), including adverse health effects, have been described by many research groups all over the world. There is strong evidence that the NT MW

biological effects depend on several physical parameters and biological variables, which must be controlled in replication studies. Apart from the fundamental importance, the development of comprehensive mechanisms for the NT MW effects is socially important. The effects of MW of mobile communications are of major concern because of the increased exposure in many countries. It has been shown that adverse effects of NT MW from GSM/UMTS mobile phones on human lymphocytes from healthy and hypersensitive to EMF persons depend on carrier frequency and modulation. Further investigations with human primary cells, animals and volunteers are needed to elucidate possible adverse effects of MW signals that are used in wireless communication. Identification of those types and frequency channels/bands for mobile communication, which do not affect human cells, is urgently needed as the high priority task for the development of safe mobile communication. Numerous data on the NT MW effects clearly indicate that the SAR-concept alone cannot underlie the safety guidelines for chronic exposures to MW from mobile communication and other approaches are needed. However, there is not enough research information to set exposure MW standards. Various genetic and epigenetic effects of signals used in mobile communication should be studied. It has been shown that NT MW affect cells of various types including stem cells and reproductive organs. Stem cells represent especially important cellular model because recent data suggest that different cancer types, including leukemia, have a fundamentally common basis that is grounded on epigenetic changes in stem cells.

**Blank M, Goodman R (2011) DNA is a fractal antenna in electromagnetic fields. International Journal of Radiation Biology 87(4):409-15.**

**PURPOSE:** To review the responses of deoxyribonucleic acid (DNA) to electromagnetic fields (EMF) in different frequency ranges, and characterise the properties of DNA as an antenna.

**MATERIALS AND METHODS:** We examined published reports of increased stress protein levels and DNA strand breaks due to EMF interactions, both of which are indicative of DNA damage. We also considered antenna properties such as electronic conduction within DNA and its compact structure in the nucleus.

**RESULTS:** EMF interactions with DNA are similar over a range of non-ionising frequencies, i.e., extremely low frequency (ELF) and radio frequency (RF) ranges. There are similar effects in the ionising range, but the reactions are more complex.

**CONCLUSIONS:** The wide frequency range of interaction with EMF is the functional characteristic of a fractal antenna, and DNA appears to possess the two structural characteristics of fractal antennas, electronic conduction and self symmetry. These properties contribute to greater reactivity of DNA with EMF in the environment, and the DNA damage could account for increases in cancer epidemiology, as well as variations in the rate of chemical evolution in early geologic history.

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

**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.

**Desai NR, Kesari KK, Agarwal A (2009) Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system. *Reproductive Biology and Endocrinology* 7:114.**

Hazardous health effects stemming from exposure to radiofrequency electromagnetic waves (RF-EMW) emitted from cell phones have been reported in the literature. However, the cellular target of RF-EMW is still controversial. This review identifies the plasma membrane as a target of RF-EMW. In addition, the effects of RF-EMW on plasma membrane structures (i.e. NADH oxidase, phosphatidylserine, ornithine decarboxylase) and voltage-gated calcium channels are discussed. We explore the disturbance in reactive oxygen species (ROS) metabolism caused by RF-EMW and delineate NADH oxidase mediated ROS formation as playing a central role in oxidative stress (OS) due to cell phone radiation (with a focus on the male reproductive system). This review also addresses: 1) the controversial effects of RF-EMW on mammalian cells and sperm DNA as well as its effect on apoptosis, 2) epidemiological, in vivo animal and in vitro studies on the effect of RF-EMW on male reproductive system, and 3) finally, exposure assessment and dosimetry by computational biomodeling.

**(Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, Irkilata HC, Irmak MK, Peker AF) Erogul O, Oztas E, Yildirim I, et al. (2006) Effects of electromagnetic radiation from a**

**cellular phone on human sperm motility: an in vitro study. Archives of Medical Research 37(7):840-3.**

**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.

**Falzone N, Huyser C, Franken DR, Leszczynski D (2010) Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa. Radiation Research 174(2):169-76.**

ALSO IN [from PubMed]: Falzone N, Huyser C, Becker P, Leszczynski D, Franken DR (2011) The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. *International Journal of Andrology* 34(1):20-6.

Abstract 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.

**Falzone N, Huyser C, Becker P, Leszczynski D, Franken DR (2010) The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. International Journal of Andrology 33:1-7.**

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 ( $9.2 \pm 0.7 \mu\text{m}^2$  vs.  $18.8 \pm 1.4 \mu\text{m}^2$ ) and acrosome percentage of the head area ( $21.5 \pm 4\%$  vs.  $35.5 \pm 11.4\%$ ) 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  $22.8 \pm 12.4$  and  $31.8 \pm 12.8$  ( $p < 0.05$ ), 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.

**Fejes I, Závaczki Z, Szöllosi J, Koloszár S, Kovács L, Pál A (2004) Relationship between regular cell phone use and human semen quality. Abstracts of the 20th Annual Meeting of the ESHRE, Berlin, Germany, 27–30 June 2004.**

**Introduction:** Environmental factors can be responsible for the deteriorative sperm parameters detected in the last decades. The effects of the electromagnetic field of mobile phones ( $\square$ 900MHz) on human spermatogenesis have not been studied yet. Our aim was to determine possible relationship between regular cell phone use and the different human semen attributes.

**Methods:** Localisation: University of Szeged, Dept. Obstetrics and Gynaecology, Hungary. History taking was supplemented with questions, how long patient owns mobile phone, how long it is standby in a day (in hours) near the patient, and how long it transmits daily (in minutes). Semen analyses were performed using Makler sperm counting chamber. Sperm concentration, motility according to WHO guidelines, motile sperm count and progressively motile sperm count were assessed. Comparison between non-users and very active users has been drawn. Statistical analyses were performed using SPSS 11.0 software.

**Results:** A total of 451 patients were examined during the 13 months of study period. Among the 221 men corresponded the criteria and completed the study, significant correlations were found between duration of standby position and sperm concentration ( $r=-0.161$ ,  $p=0.04$ ) length of daily transmission and rapid progressive or slow progressive motility ( $r=-0.191$ ,  $p=0.005$ ;  $r=0.323$ ,  $p<0.001$ , respectively) and between the duration of standby position and rapid progressive motile sperm concentration ( $r=-0.218$ ,  $p=0.005$ ). Furthermore, difference was found between daylong standby and non-standby users in sperm concentration ( $59.11 \times 10^6/\text{ml}$  vs  $82.97 \times 10^6/\text{ml}$ ,  $p=0.021$ ,  $N=51$  vs  $46$ ) and between prolonged transmitters and non-transmitters in rapid progressive motility ( $36.31\%$  vs  $51.34\%$ ,  $p=0.007$ ,  $N=16$  vs  $61$ ). **Conclusions:** The prolonged use of cell phones may have negative effect on spermatogenesis and male fertility, that presumably deteriorates both concentration and motility. Further controlled randomised studies are necessary to percise the correlation coefficients.

**Also [From Pubmed]: Fejes I, Závaczki Z, Szölloosi J, et al. (2005) Is there a relationship between cell phone use and semen quality? Archives of Andrology 51(5):385-93.**

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.

**Fragopoulou A, Grigoriev Y, Johansson O, et al. (2010) Scientific Panel on Electromagnetic Field Health Risks: Consensus points, recommendations, and rationales. Reviews on Environmental Health 25(4):307-17.**

In November, 2009, a scientific panel met in Seletun, Norway, for three days of intensive discussion on existing scientific evidence and public health implications of the unprecedented global exposures to artificial electromagnetic fields (EMF). EMF exposures (static to 300 GHz) result from the use of electric power and from wireless telecommunications technologies for voice and data transmission, energy, security, military and radar use in weather and transportation. The Scientific Panel recognizes that the body of evidence on EMF requires a new approach to protection of public health; the growth and development of the fetus, and of children; and argues for strong preventative actions. New, biologically-based public exposure standards are urgently needed to protect public health worldwide.

**Girgert R, Gründker C, Emons G, Hanf V (2008) Electromagnetic fields alter the expression of estrogen receptor cofactors in breast cancer cells. Bioelectromagnetics 29(3):169-76.**

Breast cancer is the most common malignancy of women in Western societies. The increasing exposure to electromagnetic fields has been suspected to contribute to the rising incidence of breast cancer in industrialized countries. The majority of breast tumors is treated with the partial antiestrogen tamoxifen. Most tumors become resistant to tamoxifen in the course of treatment resulting in treatment failure. Electromagnetic fields reduce the efficacy of tamoxifen similar to tamoxifen resistance. In this study we investigated the mechanism by which electromagnetic fields influence the sensitivity to tamoxifen. In cells exposed to 1.2 microT of a 50 Hz electromagnetic field gene expression of cofactors of the estrogen receptors was compared to sham exposed cells. Using a gene array technology several cofactors were found to be differentially expressed. The expression of the coactivators, SRC-1 and AIB1, and of two corepressors, N-CoR and SMRT, was quantified by RT-PCR. Both coactivators were expressed more strongly in the exposed cells while the expression of two corepressors decreased. The RNA analysis was confirmed by Western blots. The contradirectional changes in gene expression of



coactivators and corepressors by electromagnetic fields results in a lower sensitivity to tamoxifen. Electromagnetic fields may contribute to the induction of tamoxifen resistance in vivo.

**Grigoriev YG, Grigoriev OA, Ivanov AA, et al. (2010) Confirmation studies of Soviet research on immunological effects of microwaves: Russian immunology results. *Bioelectromagnetics* 31(8):589-602.**

This paper presents the results of a replication study performed to investigate earlier Soviet studies conducted between 1974 and 1991 that showed immunological and reproductive effects of long-term low-level exposure of rats to radiofrequency (RF) electromagnetic fields. The early studies were used, in part, for developing exposure standards for the USSR population and thus it was necessary to confirm the Russian findings. In the present study, the conditions of RF exposure were made as similar as possible to those in the earlier experiments: Wistar rats were exposed in the far field to 2450 MHz continuous wave RF fields with an incident power density in the cages of 5 W/m<sup>2</sup> for 7 h/day, 5 days/week for a total of 30 days, resulting in a whole-body SAR of 0.16 W/kg. Effects of the exposure on immunological parameters in the brain and liver of rats were evaluated using the complement fixation test (CFT), as in the original studies, and an additional test, the more modern ELISA test. Our results, using CFT and ELISA, partly confirmed the findings of the early studies and indicated possible effects from non-thermal RF exposure on autoimmune processes. The RF exposure resulted in minor increases in formation of antibodies in brain tissue extract and the exposure did not appear to be pathological. In addition, a study was conducted to replicate a previous Soviet study on effects from the injection of blood serum from RF-exposed rats on pregnancy and foetal and offspring development of rats, using a similar animal model and protocol. Our results showed the same general trends as the earlier study, suggesting possible adverse effects of the blood serum from exposed rats on pregnancy and foetal development of intact rats, however, application of these results in developing exposure standards is limited.

**Gul A, Celebi H, Uğraş S (2009) The effects of microwave emitted by cellular phones on ovarian follicles in rats. *Archives of Gynecology and Obstetrics* 280(5):729-33.**

**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.

**Gutschi T, Mohamad Al-Ali B, Shamloul R, Pummer K, Trummer H (2011) Impact of cell phone use on men's semen parameters. *Andrologia* 43(5):312-6.**

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.

**Hardell L, Carlberg M, Ohlson CG, Westberg H, Eriksson M, Hansson Mild K (2007) Use of cellular and cordless telephones and risk of testicular cancer. *International Journal of Andrology* 30(2):115-22.**

A case-control study on testicular cancer included use of cellular and cordless telephones. The results were based on answers from 542 (92%) cases with seminoma, 346 (89%) with non-seminoma, and 870 (89%) controls. Regarding seminoma the use of analog cellular phones gave odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.9-1.6, digital phones OR = 1.3, CI = 0.9-1.8, and cordless phones OR = 1.1, CI = 0.8-1.5. The corresponding results for non-seminoma were OR = 0.7, CI = 0.5-1.1, OR = 0.9, CI = 0.6-1.4, and OR = 1.0, CI = 0.7-1.4, respectively. There was no dose-response effect and OR did not increase with latency time. No association was found with place of keeping the mobile phone during standby, such as trousers pocket. Cryptorchidism was associated both with seminoma (OR = 4.2, CI = 2.7-6.5) and non-seminoma (OR = 3.3, CI = 2.0-5.6), but no interaction was found with the use of cellular or cordless telephones.

**Kesari KK, Kumar S, Behari J (2011) Effects of radiofrequency electromagnetic wave exposure from cellular phones on the reproductive pattern in male Wistar rats. *Applied Biochemistry and Biotechnology* 164(4):546-59.**

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.

**Kilgallon SJ, Simmons LW (2005) Image content influences men's semen quality. *Biology Letters* 1(3):253-5.**

There is increasing evidence from non-human animals that males adjust their ejaculate expenditure according to the risk of sperm competition. In this study we show that, after controlling for lifestyle factors known to influence semen quality, human males viewing images depicting sperm competition had a higher percentage of motile sperm in their ejaculates. Many lifestyle variables were confirmed to influence semen quality, including the recent suggestion that storage of mobile phones close to the testes can decrease semen quality.

**Kim YW, Kim HS, Lee JS, et al. (2009) Effects of 60 Hz 14 microT magnetic field on the apoptosis of testicular germ cell in mice. *Bioelectromagnetics* 30(1):66-72.**

We recently reported that continuous exposure, for 8 weeks, of extremely low frequency (ELF) magnetic field (MF) of 0.1 or 0.5 mT might induce testicular germ cell apoptosis in BALB/c mice. In that report, the ELF MF exposure did not significantly affect the body weight or testicular weight, but significantly increased the incidence of testicular germ cell death. In the present study, we aimed to further characterize the effect of a 16-week continuous exposure to ELF MF of 14 or 200 microT on testicular germ cell apoptosis in mice. There were no significant effects of MF on body weight and testosterone levels in mice. In TUNEL staining (In situ terminal deoxynucleotidyl transferase-mediated deoxy-UTP nick end labeling), germ cells showed a significantly higher apoptotic rate in exposed mice than in sham controls ( $P < 0.001$ ). TUNEL-positive cells were mainly spermatogonia. In an electron microscopic study, degenerating spermatogonia showed condensation of nuclear chromatin similar to apoptosis. These results indicate that apoptosis may be induced in spermatogenic cells in mice by continuous exposure to 60 Hz MF of 14 microT.

**Lee JW, Kim KS, Lee SM, Eom SJ, Troitsky RV (2002) A novel design of thermal anomaly for mammary gland tumor phantom for microwave radiometer. *IEEE Transactions on Bio-medical Engineering* 49(7):694-9.**

Microwave radiometry is the spectral measurement technique of resolving electromagnetic radiation of all matters which temperature is above absolute zero. This technique utilizes the electromagnetic noise field generated by a thermal volume similar to a mechanism existing in biological tissues. One particular application of microwave radiometry is for analyzing

temperature differentials of inside of human body to detect and diagnose some crucial pathological conditions. For the general evaluation of a microwave radiometer, we propose a new type of phantom containing a mammary gland tumor imitator by considering biological heat diffusion effects propagated by a real tumor. Theoretical researches of human tumor revealed the fact that temperature distribution of tissues around a tumor formed a Gaussian statistics. To comply with the physiological property of the real tumor, we built a mammary gland tumor imitator composed of two parts (pseudotumor and thermal anomaly) and observed its temperature distribution when it was placed inside a phantom. Our results showed that the thermal properties of tumor imitator well agreed with heat-transfer properties of a real tumor and the proportional linear relationship existed between the location of tumor imitator and the intensity of radiometer measurements. From this relationship, we could also estimate several parameters related with our phantom, such as the minimum detectable size and maximum detectable depth of a tumor imitator.

**Magras IN, Xenos TD (1997) RF radiation-induced changes in the prenatal development of mice. *Bioelectromagnetics* 18(6):455-61.**

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/cm<sup>2</sup> and 1053 nW/cm<sup>2</sup> 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.

**Sheynkin Y, Jung M, Yoo P, Schulsinger D, Komaroff E (2005) Increase in scrotal temperature in laptop computer users. *Human Reproduction* 20(2):452-5.**

**BACKGROUND:** Scrotal hyperthermia has been identified as a risk factor for male infertility. Laptop computers (LC) have become part of a contemporary lifestyle and have gained popularity among the younger population of reproductive age. LC are known to reach high internal operating temperatures. We evaluated the thermal effect of LC on the scrotum.

**METHODS:** Right and left scrotal temperature (ScT) was measured in 29 healthy volunteers in two separate 60 min sessions. ScT was recorded from thermocouples on a digital datalogger every 3 min with the working LC in a laptop position and in the same sitting position with approximated thighs without LC.

**RESULTS:** ScT increased significantly on the right and left side in the group with working LC (2.8 degrees C and 2.6 degrees C, respectively; P<0.0001) and without LC (2.1 degrees C, P<0.0001). However, ScT elevation with working LC was significantly higher (P<0.0001).

**CONCLUSIONS:** Working LC in a laptop position causes significant ScT elevation as a result of heat exposure and posture-related effects. Long-term exposure to LC-related repetitive transient scrotal hyperthermia is a modern lifestyle feature that may have a negative impact upon

spermatogenesis, specifically in teenage boys and young men. Further studies of such thermal effects on male reproductive health are warranted.

**Lee GM, Neutra RR, Hristova L, Yost M, Hiatt RA (2002) A nested case-control study of residential and personal magnetic field measures and miscarriages. *Epidemiology* 13(1):21-31. Erratum in *Epidemiology* 2003 4(2):255.**

We conducted a nested case-control study (177 cases, 550 controls) to assess the relation between retrospective magnetic field measures and clinical miscarriage among members of the northern California Kaiser Permanente medical care system. We also conducted a prospective substudy of 219 participants of the same parent cohort to determine whether 12-week and 30-week exposure assessments were similar. We evaluated wire codes, area measures, and three personal meter metrics: (1) the average difference between consecutive levels (a rate-of-change metric), (2) the maximum level, and (3) the time-weighted average. For wire codes and area measures we found little association. For the personal metrics (30 weeks after last menstrual period), we found positive associations. Each exposure was divided into quartiles, with the lowest quartile as referent. Starting with the highest quartile, adjusted odds ratios and 95% confidence intervals were 3.1 (95% CI = 1.6-6.0), 2.3 (95% CI = 1.2-4.4), and 1.5 (95% CI = 0.8-3.1) for the rate-of-change metric; 2.3 (95% CI = 1.2-4.4), 1.9 (95% CI = 1.0-3.5), and 1.4 (95% CI = 0.7-2.8) for the maximum value; and 1.7 (95% CI = 0.9-3.3), 1.7 (95% CI = 0.9-3.3), and 1.7 (95% CI = 0.9-3.3) for the time-weighted average. The odds ratio conveyed by being above a 24-hour time-weighted average of 2 milligauss was 1.0 (95% CI = 0.5-2.1). Exposure assessment measurements at 12 weeks were poorly correlated with those taken at 30 weeks. Nonetheless, the prospective substudy results regarding miscarriage risk were consistent with the nested study results.

Comment in

- *Epidemiology*. 2002 Jan;13(1):1-4.
- *Epidemiology*. 2002 Mar;13(2):237-8.
- *Epidemiology*. 2002 May;13(3):372.

**Makker K, Varghese A, Desai NR, Mouradi R, Agarwal A (2009) Cell phones: modern man's nemesis? *Reproductive Biomedicine Online* 18(1):148-57.**

Over the past decade, the use of mobile phones has increased significantly. However, with every technological development comes some element of health concern, and cell phones are no exception. Recently, various studies have highlighted the negative effects of cell phone exposure on human health, and concerns about possible hazards related to cell phone exposure have been growing. This is a comprehensive, up-to-the-minute overview of the effects of cell phone exposure on human health. The types of cell phones and cell phone technologies currently used in the world are discussed in an attempt to improve the understanding of the technical aspects, including the effect of cell phone exposure on the cardiovascular system, sleep and cognitive function, as well as localized and general adverse effects, genotoxicity potential, neurohormonal secretion and tumour induction. The proposed mechanisms by which cell phones adversely affect various aspects of human health, and male fertility in particular, are explained, and the emerging molecular techniques and approaches for elucidating the effects of mobile phone radiation on

cellular physiology using high-throughput screening techniques, such as metabolomics and microarrays, are discussed. A novel study is described, which is looking at changes in semen parameters, oxidative stress markers and sperm DNA damage in semen samples exposed in vitro to cell phone radiation.

**Otitolaju AA, Obe IA, Adewale OA, Otubanjo OA, Osunkalu VO (2010) Preliminary study on the induction of sperm head abnormalities in mice, *Mus musculus*, exposed to radiofrequency radiations from global system for mobile communication base stations. *Bulletin of Environmental Contamination and Toxicology* 84(1):51-4.**

The exposure of male mice to radiofrequency radiations from mobile phone (GSM) base stations at a workplace complex and residential quarters caused 39.78 and 46.03%, respectively, in sperm head abnormalities compared to 2.13% in control group. Statistical analysis of sperm head abnormality score showed that there was a significant ( $p < 0.05$ ) difference in occurrence of sperm head abnormalities in test animals. The major abnormalities observed were knobbed hook, pin-head and banana-shaped sperm head. The occurrence of the sperm head abnormalities was also found to be dose dependent. The implications of the observed increase occurrence of sperm head abnormalities on the reproductive health of humans living in close proximity to GSM base stations were discussed.

**Panagopoulos DJ, Margaritis LH (2008) Mobile telephony radiation effects on living organisms. In: Harper AC, Buress RV, eds. *Mobile Telephones*. Nova Science Publishers, Inc: 107-49.**

A number of serious non thermal biological effects, ranging from changes in cellular function like proliferation rate changes or gene expression changes to cell death induction, decrease in the rate of melatonin production and changes in electroencephalogram patterns in humans, population declinations of birds and insects, and small but statistically significant increases of certain types of cancer, are attributed in our days to the radiations emitted by mobile telephony antennas of both handsets and base stations. This chapter reviews briefly the most important experimental, clinical and statistical findings and presents more extensively a series of experiments, concerning cell death induction on a model biological system. Mobile telephony radiation is found to decrease significantly and non-thermally insect reproduction by up to 60%, after a few minutes daily exposure for only few days. Both sexes were found to be affected. The effect is due to DNA fragmentation in the gonads caused by both types of digital mobile telephony radiation used in Europe, GSM 900MHz, (Global System for Mobile telecommunications), and DCS 1800MHz, (Digital Cellular System). GSM was found to be even more bioactive than DCS, due to its higher intensity under equal conditions. The decrease in reproductive capacity seems to be non-linearly depended on radiation intensity, exhibiting a peak for intensities higher than  $200 \mu\text{W}/\text{cm}^2$  and an intensity “window” around  $10 \mu\text{W}/\text{cm}^2$  were it becomes maximum. In terms of the distance from a mobile phone antenna, the intensity of this “window” corresponds under usual conditions to a distance of 20-30 cm. The importance of different parameters of the radiation like intensity, carrier frequency and pulse repetition frequency, in relation to the recorded effects are discussed. Finally, this chapter describes a plausible biophysical and biochemical mechanism which can explain the recorded effects of mobile telephony radiations on living organisms.

**Sage C, Johansson O, Sage SA (2007) Personal digital assistant (PDA) cell phone units produce elevated extremely-low frequency electromagnetic field emissions. *Bioelectromagnetics* 28(5):386-92.**

Initial tests indicate that personal and occupational use of personal digital assistants (PDAs or palm-held wireless units) produce high intensity bursts of extremely-low frequency electromagnetic fields (ELF-EMF). These emissions could result in comparatively high ELF-EMF exposure in persons that carry a PDA close to the body (i.e., in a pocket or on a belt); or held to the head for cell phone conversations. ELF-EMF emissions of 10 microT were recorded on PDAs during normal office use over a 24 h test period. Results of ELF-EMF measurements show that email transmit and receive functions produce rapid, short-duration ELF-EMF spikes in the 2-10 microT range, each lasting several seconds to over a minute apparently depending on file download size. Some units produced spikes as high as 30-60 microT during email activities. Cell phone activity on PDAs produced continuously elevated ELF-EMF readings in the 0.5-1 microT range, as opposed to the rapid spiking pattern for email receipt and transmission. Switching the PDA unit from "OFF" to "ON" position resulted in single ELF-EMF pulses of over 90 microT on two units. Email downloads into the PDA can occur randomly throughout the day and night when the unit is "ON"; thus the user who wears the PDA may be receiving high-intensity ELF-EMF pulses throughout the day and night. The frequency of email traffic on the PDA, and the power switching unit (battery unit) may affect the frequency and intensity of ELF-EMF emissions.

**Salama N, Kishimoto T, Kanayama HO (2010) Effects of exposure to a mobile phone on testicular function and structure in adult rabbit. *International Journal of Andrology* 33(1):88-94. Comment in: *International Journal of Andrology* 33(1):95; author reply 96-7.**

The accumulating effects of exposure to electromagnetic radiation emitted by a conventional mobile phone (standby position) on the testicular function and structure are not yet fully investigated. To study these effects longitudinally, a total of 24 adult male rabbits were randomly and equally divided into three groups. Rabbits in the first (phone) group were exposed, in specially designed cages, to radio frequency emitted from the mobile phone (800 MHz) in a standby position opposite to that of testes for 8 h daily for 12 weeks. The second group consisted of the stress controls which were kept in the same kind of cages to appreciate any cage-induced anxiety. The third group included the ordinary controls which were kept in the conventional roomy cages. Semen analysis and sperm function tests (viability, hypo-osmotic swelling and acridine orange) were conducted weekly. Histological testicular sections and serum total testosterone were also evaluated. A drop in the sperm concentration appeared in the phone group at week 6. This became statistically significant at week 8, compared with the two control (stress and ordinary) groups (133, 339 and 356 x 10<sup>6</sup>/mL, respectively) and to the initial sperm count (341 x 10<sup>6</sup>/mL) of this group. Motile sperm population showed similarity amongst the three study groups until week 10 when it declined significantly, and thereafter in the phone and stress control groups, with more significant decline in the phone animals (50, 61 and 72.4%, respectively). Histological examination showed also a significant decrease in the diameter of seminiferous tubules in the phone group vs. the stress and ordinary controls (191 microm vs. 206 and 226 microm, respectively). The other study points did not show any difference. In

conclusion, low intensity pulsed radio frequency emitted by a conventional mobile phone kept in the standby position could affect the testicular function and structure in the adult rabbit.

**Sommer AM, Grote K, Reinhardt T, Streckert J, Hansen V, Lerchl A (2009) Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: a multi-generation study. Radiation Research 171(1):89-95.**

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<sup>2</sup>), 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.

**Wdowiak A, Wdowiak L, Wiktor H (2007) Evaluation of the effect of using mobile phones on male fertility. Annals of agricultural and environmental medicine: AAEM 14(1):169-72.**

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.



**Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS (2007) Effects of cellular phone emissions on sperm motility in rats. Fertility and Sterility 88(4):957-64.**

**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.