

## **List of References Reporting Fertility and/or Reproduction Effects from Electromagnetic Fields and/or Radiofrequency Radiation (66 references)**

**(with abstracts)**

**Agarwal A, Deepinder F, Sharma RK, Ranga G, Li J. (2008) Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. *Fertility and Sterility* 89(1):124-8.**

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.

**(Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, Sharma R)  
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, Desai NR, Ruffoli R, Carpi A. (2008) Lifestyle and testicular dysfunction: a brief update. Biomed Pharmacother. 62(8):550-3.**

The incidence of testicular cancer, cryptorchidism and defective spermatogenesis is increasing probably due to environmental and lifestyle-related factors. The aim of this review is to briefly describe and comment on the principal lifestyle factors. The recent findings that the electromagnetic waves following the use of the cell phone and the prolonged exposure to the noise stress cause relevant testicular dysfunction in man or animals reinforce the hypothesis of the importance of lifestyle-related factors.

**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 (2012) 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.

**Awad H, Halawa F, Mostafa T, Atta H. (2006) Melatonin hormone profile in infertile males. International Journal of Andrology 29(3):409-13.**

Melatonin is a hormone produced by the pineal gland. There is much controversy about its relationship to the male reproductive process. In this study, seminal plasma as well as the serum melatonin levels were studied in different infertile male groups and were correlated with their semen parameters and hormonal levels. One hundred twenty male cases subdivided into six equal groups were consecutively included; fertile normozoospermic men, oligoasthenozoospermia (OA), OA with leucocytospermia, OA with varicocele, non-obstructive azoospermia (NOA) with high serum follicle stimulating hormone (FSH) and NOA with normal FSH. Semen analysis, estimation of melatonin, FSH, testosterone (T) and prolactin (PRL) hormone was carried out. Mean level of serum melatonin was higher than its corresponding seminal concentrations in all investigated groups with a positive correlation between their levels ( $r = 0.532$ ,  $p = 0.01$ ). Serum and seminal plasma melatonin levels in all infertile groups were reduced significantly compared with their levels in the fertile group. The lowest concentrations were in OA with leucocytospermia group. Melatonin in both serum and semen demonstrated significant correlation with sperm motility ( $r = 0.607$ ,  $0.623$  respectively,  $p = 0.01$ ). Serum melatonin correlated positively with serum PRL ( $r = 0.611$ ,  $p = 0.01$ ). It may be concluded that melatonin may be involved in the modulation of reproductive neuroendocrine axis in male infertility. Also, low levels of melatonin in semen were observed in infertile groups having reduced sperm motility, leucocytospermia, varicocele and NOA.

**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.

**Baste V, Riise T, Moen BE (2008) Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. European Journal of Epidemiology 23(5):369-77.**

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.

**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 biologii, radioecologii / 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.

**Davoudi M, Brossner C, Kuber W (2002) Der Einfluelektromagnetischer Wellen auf die Spermienmotilit. Journal Für Urologie Und Urogynäkologie 9(3):18-22.**

**Objective:** To evaluate the influence of electromagnetic waves (EMW) caused by mobile phones on sperm motility.

**Methods:** 13 men with a normal spermiogramm regarding the WHO criteria were included in our study. After a GSM-mobile phone was not carried or used during 5 days a first spermiogramm was analysed. Four weeks later, a second spermiogramm was performed. Five days before this second spermiogramm, men carried the mobile phone on the belt and used it 6 hours a day intensively. Spermiogramm parameters of the first and second spermiogramm were compared.

**Results:** Rapid progressive spermatozoa were reduced significantly in the second spermiogramm compared to the first. Decrease was from (mean) 32.3 % (SD ± 6.13) to (mean) 26.1 % (SD ± 6.5),  $p = 0.0004$ . In addition there was a shift to an increase of progressive spermatozoa from mean 24.8 % (SD ± 3.62) to 29.7 % (SD ± 6.11),  $p = 0.01$ . All other spermiogramm parameters like semen volume, density and morphology did not differ significantly.

**Conclusion:** Our data suggest a decreased motility of rapid progressive spermatozoa caused by electromagnetic waves of GSM-mobile phones. These findings may have an impact in counselling subfertile men.

**Deepinder F, Makker K, Agarwal A (2007) Cell phones and male infertility: dissecting the relationship. Reproductive Biomedicine Online 15(3):266-70.**

There has been a tremendous increase in the use of mobile phones in the past decade and concerns are growing about the possible hazardous effects of radio-frequency electromagnetic waves (EMW) emitted by these devices on human health. Preliminary studies, though with limitations in study design, suggest a possible link between cell phone use and infertility. A recent study found that use of cell phones adversely affects the quality of semen by decreasing the sperm counts, motility, viability and morphology. Evidence of detrimental effect of mobile phones on male fertility is still equivocal as studies have revealed a wide spectrum of possible effects ranging from insignificant effects to variable degrees of testicular damage. Although previous studies suggested a role of cell phone use in male infertility, the mode of action of EMW emitted from cell phones on the male reproductive system is still unclear. EMW can affect the reproductive system via an EMW-specific effect, thermal molecular effect or combination of both. Studies performed on human males are scarce and therefore further studies with a careful design are needed to determine the effect of cell phone use on male-fertilizing potential.

**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.**

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.**

**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.**

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, Szölloosi J, Koloszar S, Kovacs L, Pal 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 (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 precise the correlation coefficients.

**(Fejes I, Závaczki Z, Szölloosi J, Koloszar S, Daru J, Kovacs L, Pal A)**

**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, Margaritis LH, Morgan L, Richter E, Sage C)  
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, Lyaginskaya AM, Merkulov AV, Shagina NB, Maltsev VN, Lévêque P, Ulanova AM, Osipov VA, Shafirkin AV.) 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.

**Irgens A, Kruger K, Ulstein M. (1999) The effect of male occupational exposure in infertile couples in Norway. *Journal of Occupational and Environmental Medicine* 41(12):1116-1120.**

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.

**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, Kim YJ, Lee SK, Seo JN, Jung KC, Kim N, Gimm YM.)  
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.

**Koldayev VM, Shchepin YV. (1997) Effects of electromagnetic radiation on embryos of sea-urchins. *Bioelectrochemistry and Bioenergetics* 43:161-164.**

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.

**Kubinyi G, Thuroczy G, Bakos J, Boloni E, Sinay H, Szabo LD.(1996) 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.**

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<sup>2</sup>, 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.

**Khurana VG, Teo C, Bittar RG. (2009) Health risks of cell phone technology. Surgical Neurology 72(4):436-7; author reply 437.**

**Comment on Pawl R. (2008) Cell phones more dangerous than cigarettes! Surgical Neurology 70(5):445-6.**

Dear Editor:

The editorial by Dr Pawl [12] is timely and discusses an emerging public health concern. This reignited debate [9] has not escaped the attention of the US Congress, whose Subcommittee on Domestic Policy chaired by Congressman Dennis Kucinich held a landmark hearing regarding this topic on September 25, 2008 [7]. The proposed health ramifications of ubiquitous and chronic immersion in the electromagnetic fields (EMFs) of cell phones and transmission masts are not only limited to brain tumors but also include salivary gland tumors [13], male infertility [1,5], behavioral disturbances [4], and electrohypersensitivity (previously "microwave sickness syndrome") [10]. Since the publication of the seminal BioInitiative Report [2] in August 2007 by a multinational group of recognized scientists, physicians, and policy makers, important steps have been taken in many countries [8], urging evidence-based precaution as compelling new long-term epidemiologic data accrue from the Hardell group and World Health Organization-administered INTERPHONE consortium [6]. It is recommended that serial age-adjusted primary central nervous system tumor incidence rates from databases, such as those of the Central Brain Tumor Registry of the United States [3], be carefully followed in time for trends. Although there is no currently proven mechanism via which cell phone radiation can cause neoplasia, it is notable that there are more than one dozen peer-reviewed papers from laboratories in at least 7 countries including the United States showing that cell phone or similar low-intensity EMFs can break DNA or modulate it structurally [11], despite comments stating otherwise [14]. A simple precautionary step includes using a landline in preference to a cell phone whenever possible. If talking on a cell phone, a wired earpiece or speaker-phone mode should be used to increase the distance between the antenna (external or concealed) and the user's head. Restricting children's cell phone usage should also be strongly considered given the recent testimony of Dr Ronald Herberman and Dr David Carpenter [7].

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January 2, 2012

Cindy Sage, Sage Associates, CHE-EMF

[14] Vogel G. Fraud charges cast doubt on claims of DNA damage from cell phone fields. *Science* 2008;321:1144-5.

#### Commentary

Obviously, I cannot agree with Dr Khurana more. His cautions are in line with my own, as stated in the referenced editorial. He is one of the finders; I am just a messenger. Hopefully, the committee action initiated by Congressman Kucinich will lead to appropriate further research and regulatory changes as needed.

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#### **Larsen AI, Olsen J, Svane O. (1991) Gender-specific reproductive outcome and exposure to high-frequency electromagnetic radiation among physiotherapists. *Scandinavian Journal of Work and Environmental Health* 17(5):324-329.**

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.

#### **La Vignera S, Condorelli RA, Vicari E, D'Agata R, Calogero AE (2011) Effects of the exposure to mobile phones on male reproduction: a review of the literature. *Journal of Andrology* Jul 28. [Epub ahead of print]**

The use of mobile phones is now widespread. A great debate is going on about the possible damage that the radiofrequency electromagnetic radiation (RF-EMR) emitted by mobile phones exerts on different organs and apparatuses. 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 human beings. Studies on the experimental animals have been conducted in rats, mice, and rabbits using a similar design based upon mobile phone radiofrequency exposure for a variable length of time. Altogether the results of these studies show that RF-EMR decreases sperm count and motility, and increases the oxidative stress. In human beings, two 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 mobile phones. The results show 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, motility (particularly the rapid progressive one), normal morphology, and viability. These abnormalities seem to be directly related with the length of mobile phone use.

#### **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

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**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.

**Li DK, Yan B, Li Z, Gao E, Miao M, Gong D, Weng X, Ferber JR, Yuan W (2010) Exposure to magnetic fields and the risk of poor sperm quality. Reproductive Toxicology 29(1):86-92.**

We conducted a population-based case-control study among healthy sperm donors to study exposure to magnetic fields (MFs) and poor sperm quality. All participants wore a meter to capture daily MF exposure. After controlling for confounders, compared to those with lower MF exposure, those whose 90th percentile MF level  $\geq$  1.6mG had a two-fold increased risk of abnormal sperm motility and morphology (odds ratio (OR): 2.0, 95% confidence interval (CI): 1.0-3.9). Increasing duration of MF exposure above 1.6 mG further increased the risk ( $p=0.03$  for trend test). Importantly, the association and dose-response relationship were strengthened when restricted to those whose measurement day reflected their typical day of the previous 3 months (a likely period of spermatogenesis). Age-adjusted Spearman Rank Order Correlations showed an inverse

correlation between MF exposure and all semen parameters. Our study provides some evidence for the first time that MF exposure may have an adverse effect on sperm quality.

**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.

**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)*. 2009;64(6):561-5.**

**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.

**Makker K, Varghese A, Desai NR, Mouradi R, Agarwal A. (2009) Cell phones: modern man's nemesis? *Reprod Biomed Online*. 2009 Jan;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.

**Moskowitz JM (2011) Research on the effects of cell phone radiation on human sperm.**

**CEAC. Available at:**

**[http://www.ci.berkeley.ca.us/uploadedFiles/Planning\\_and\\_Development/Level\\_3\\_-\\_Commissions/Commission\\_for\\_Community\\_Environmental\\_Advisory/CEAC2011-04-07\\_1i-Effects\\_of\\_CellPhoneRadiation\\_onHumanSperm-Moskowitz.pdf](http://www.ci.berkeley.ca.us/uploadedFiles/Planning_and_Development/Level_3_-_Commissions/Commission_for_Community_Environmental_Advisory/CEAC2011-04-07_1i-Effects_of_CellPhoneRadiation_onHumanSperm-Moskowitz.pdf)**

The following terms were used in a PubMed search: (cell or mobile) phone sperm. Fourteen English-language, papers were found that examined the effects of cell phone radiation on human sperm including nine original studies and five review papers. Eight of the nine original studies reported adverse effects of cell phone radiation on at least one of four outcomes: sperm count (C), motility (M), viability (V) or morphology (S). The adverse effects obtained in these studies were as follows: C/M/V/S (Agarwal et al., 2008a); M/V (Agarwal et al., 2009; De luliis et al., 2009); M/S (Wdowiak et al, 2007); M (Erogul et al, 2006; Fejes et al., 2005); and S (Falzone et al., 2008; Falzone et al., 2011). The ninth study examined sperm for signs of pre-apoptosis but found no evidence for this mechanism (Falzone et al., 2010). Cell phone radiation was associated with decreased sperm motility (M) in six of the eight studies that assessed this outcome. The next most commonly observed effect was reduced viability (V) in three studies. Note that not all studies measured each of these four outcomes. The research abstracts from the search follow. The original studies are in the first section followed by the review papers. The abstracts are listed in alphabetical order by first author.

**Nakamura H, Nagase H, Ogino K, Hatta K, Matsuzaki I. (2000) Uteroplacental circulatory disturbance mediated by prostaglandin F(2alpha) in rats exposed to microwaves. Reproductive Toxicology 14(3):235-240.**

To clarify the effects of microwaves on pregnancy, uterine or uteroplacental blood flow and endocrine and biochemical mediators, including corticosterone, estradiol, prostaglandin E(2) (PGE(2)), and prostaglandin F(2)alpha (PGF(2)alpha), were measured in rats exposed to continuous-wave (CW) microwave at 2 mW/cm(2) incident power density at 2450 MHz for 90 min. Colonic temperature in virgin and pregnant rats was not significantly altered by microwave treatment. Microwaves decreased uteroplacental blood flow and increased progesterone and PGF(2)alpha in pregnant, but not in virgin rats. Intraperitoneal (i.p.) administration of angiotensin II, a uteroplacental vasodilator, before microwave exposure prevented the reduction in uteroplacental blood flow and the increased progesterone and PGF(2)alpha in pregnant rats. Increased corticosterone and decreased estradiol during microwave exposure were observed independent of pregnancy and pretreatment with angiotensin II. These results suggest that microwaves (CW, 2 mW/cm(2), 2450 MHz) produce uteroplacental circulatory disturbances and ovarian and placental dysfunction during pregnancy, probably through nonthermal actions. The uteroplacental disturbances appear to be due to actions of PGF(2)alpha and may pose some risk for pregnancy.

**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, Karabarbounis A, Margaritis LH (2004) Effect of GSM 900-MHz mobile phone radiation on the reproductive capacity of *Drosophila melanogaster* *Electromagnetic biology and medicine* 23:29-43.**

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.

**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 $\mu\text{W}/\text{cm}^2$  where 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.

**Peyman A, Khalid M, Calderon C, Addison D, Mee T, Maslanyj M, Mann S. (2011) Assessment of exposure to electromagnetic fields from wireless computer networks (wi-fi) in schools; results of laboratory measurements. *Health Phys.* 100(6):594-612.**

Laboratory measurements have been carried out with examples of Wi-Fi devices used in UK schools to evaluate the radiofrequency power densities around them and the total emitted powers. Unlike previous studies, a 20 MHz bandwidth signal analyzer was used, enabling the whole Wi-Fi signal to be captured and monitored. The radiation patterns of the laptops had certain similarities, including a minimum toward the torso of the user and two maxima symmetrically opposed across a vertical plane bisecting the screen and keyboard. The maxima would have resulted from separate antennas mounted behind the top left and right corners of the laptop screens. The patterns for access points were more symmetrical with generally higher power densities at a given distance. The

spherically-integrated radiated power (IRP) ranged from 5 to 17 mW for 15 laptops in the 2.45 GHz band and from 1 to 16 mW for eight laptops in the 5 GHz band. For practical reasons and because access points are generally wall-mounted with beams directed into the rooms, their powers were integrated over a hemisphere. These ranged from 3 to 28 mW for 12 access points at 2.4 GHz and from 3 to 29 mW for six access points at 5 GHz. In addition to the spherical measurements of IRP, power densities were measured at distances of 0.5 m and greater from the devices, and consistent with the low radiated powers, these were all much lower than the ICNIRP reference level.

**Pyrpasopoulou A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras IN, Xenos TD, Tsiboukis TD, Karkavelas G. (2004) Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. *Bioelectromagnetics* 25(3):216-227.**

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<sup>2</sup>, 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.

**Redmayne M, Smith E, Abramson MJ (2011) Adolescent in-school cellphone habits: a census of rules, survey of their effectiveness, and fertility implications. *Reproductive Toxicology* 32:354-9.**

We explored school cellphone rules and adolescent exposure to cellphone microwave emissions during school with a census and survey respectively. The data were used to assess health and policy implications through a review of papers assessing reproductive bio-effects after exposure to cellphone emissions, this being most relevant to students' exposure. All schools banned private use of cellphones in class. However, 43% of student participants admitted breaking this rule. A high-exposure group of risk-takers was identified for whom prohibited in-school use was positively associated with high texting rates, carrying the phone switched-on >10 hours/day, and in-pocket use. The fertility literature is inconclusive, but increasingly points towards significant time- and dose- dependent deleterious effects from cellphone exposure on sperm. Genotoxic effects have been demonstrated from „non-thermal“ exposures, but not consistently. There is sufficient evidence and expert opinion to warrant an enforced school policy removing cellphones from students during the day.

**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.

**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.

**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.

**Stefanis P, Drakeley A, Gazvani R, Lewis-Jones Di (2006) Growing concern over the safety of using mobile phones and male fertility. Archives of Andrology 52(1):9-14**

There are growing concerns about the possible hazards of electromagnetic waves emitted by mobile phones on human health. One of the biggest concerns is their possible association with increased risk of cancer and their possible effects on cellular DNA. Electromagnetic waves can inflict their results through both thermal and non-thermal effects. There are many animal studies that show that electromagnetic waves have a wide range of damaging effects on the male reproductive system and sperm parameters. However, similar studies are quite limited in humans, and the results of animal studies should be interpreted with caution when considering their application to humans. Large controlled studies are required before confirming such possible effects on male fertility.

**Tuan Anh Vu; Uyen Dinh Nguyen. (2010) Evaluation of human testis absorption in the near field of cellular phone. Communications and Electronics (ICCE), Third International Conference on**

Due to the recent explosion of users in the area of mobile communications and, conveniently, most users place the cellular phone in the trouser's pocket. In this paper, a cellular phone antenna is placed close proximity to the trouser's pocket. Using FDTD (Finite Difference Time Domain) method and the male Visible Human model, the SAR (Specific Absorption Rate) distribution is calculated for the male testis. In addition, an attempt is made to simulate the reduction of SAR absorption by using simple grid metal covering the antenna.

**Vu TA, Nguyen UD (2010) Evaluation of human testis absorption in the near field of cellular phone. IEEE. conference paper. DOI:10.1109/ICCE.2010.5670642**

Due to the recent explosion of users in the area of mobile communications and, conveniently, most users place the cellular phone in the trouser's pocket. In this paper, a cellular phone antenna is placed close proximity to the trouser's pocket. Using FDTD (Finite Difference Time Domain)

method and the male Visible Human model, the SAR (Specific Absorption Rate) distribution is calculated for the male testis. In addition, an attempt is made to simulate the reduction of SAR absorption by using simple grid metal covering the antenna.

**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.

**Weisbrot D, Lin H, Ye L, Blank M, Goodman R. (2003) Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*. *Journal of Cell Biochemistry* 89(1):48-55.**

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 1.4W/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.

**Weyandt, TB, Schrader, SM, Turner, TW, Simon, SD. (1996) Semen analysis of military personnel associated with military duty assignments. *Reproductive Toxicology* 10(6):521-528.**

A collaborative study between the U.S. Army Biomedical Research and Development Laboratory (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 were identified. 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.

**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.

**Yoshida Y, Seto T, Ohsu W, Hayashi S, Okazawa T, Nagase H, Yoshida M, Nakamura H (1995) [Endocrine mechanism of placental circulatory disturbances induced by microwave in pregnant rats]. *Nippon Sanka Fujinka Gakkai Zasshi* 47(2):101-108. [Article in Japanese]**

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/cm<sup>2</sup> 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.

**Youbicier-Simo, BJ, Lebecq, JC, Bastide, M. (1998) Mortality of chicken embryos exposed to EMFs from mobile phones. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1998. Exposure to mobile phone-radiated EMFs during development worsens embryonic mortality in chicken.**

Conclusion: Exposure to mobile phone-radiated EMFs during development worsens embryonic mortality in chickens.

Method: We previously reported that continuous exposure of chicken embryos to electromagnetic fields (EMFs) emitted by television and computer worsens embryonic death (Bioelectromagnetics, 1997, 18: 514-523). The present study was designed to assess the effects of EMFs radiated by mobile phones on the development of chicken embryos. Two groups of 60 eggs each were incubated (21 days,  $38 \pm 1^\circ\text{C}$ , 45-55% humidity, permanent darkness) under the following electromagnetic exposure conditions: control group (without the telephone); exposed group (24h/24h exposure with the telephone switched on and placed downwards, 10 mm above the eggs; the letter were distributed on a plateform with locations numbered from 1 to 60; see exposure system in page 2). The mobile phone used (Bosch, CARTEL SL 2G2, Germany) radiates in the radiofrequency band with 2 W power. The VLF and ELF values measured at different positions at the level of the eggs are outlined as ratios, adjacent to the exposure system (page 2). The values over and under the bar correspond to the telephone switched off and on respectively. Embryonic mortality was evaluated by candling the eggs and numbering dead embryos at two-day intervals from embryonic day 3 (ED3) to embryonic day 13 (ED13): ED3, ED5, ED7, ED9, ED11, ED13. Counting could not be performed from ED14 to hatching (ED21) because the eggs had become so opaque (intense vascularization, increased embryo body size) that the embryos could hardly be mirrored through the shell. For the latter period, embryonic mortality was assessed by opening the eggs from which the chicks did not hatch at ED21. Three independent experiments were carried out. Embryonic mortality was expressed either as cumulative mortality (previous + current counts) or as total death rate (percentage of necropsied embryos from ED3 to ED21). In the exposed group, EMF exposure was accompanied by increased embryonic loss during the whole embryonic period, while noticeable variations in the control group occurred mainly at the end of incubation (ED21); furthermore mean total death rate (TDR) for the three experiments was 6-fold higher in EMF-exposed group than in their control counterparts (72.3% vs. 11.9%; see Table 1). Consistently, necropsy distribution in the exposed group was essentially restricted to an area around the source of EMF (mobile phone), which contrast with rather sparse distribution in the control group (see the diagrams of cumulative mortality in page 2). Together these findings demonstrate that exposure to mobile phones-radiated EMFs during development worsens embryonic mortality. [Note that this experiment was funded by the company which made the protection-antenna being tested. SF.]  
<http://www.electric-words.com/cell/abstracts/yo13240.html>

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