

Studies investigating effects of radio frequency electromagnetic fields on children

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Outline

- > Laboratory studies on mobile phone exposures
 - cognitive performance (3)
 - well-being (1)
 - EEG (1)
 - Physiological parameters (1)
- > Epidemiological studies
 - Exposure during pregnancy and neuroblastoma (1)
 - Exposure during pregnancy and an behavioural problem of children at age 7 (1)
 - Exposure from broadcast transmitters and childhood leukaemia (11)
- > Ongoing research
- > Conclusions

Laboratory study I

- > Reference: Preece AW, et al. Effect of 902 MHz mobile phone transmission on cognitive function in children. Bioelectromagnetics. 2005;Suppl 7:S138-43.
- > Exposure: GSM900 mobile phone
- > Exposure duration: 30 min
- > Collective: 18 children 10-12 years of age
- > Design: 3-way crossover (sham, 0.025 and 0.25 W [max. brain SAR=0.28 W/kg]), double-blind?
- > Outcome: 22 cognitive outcomes (reaction time, accuracy, distraction)
- > Result: „There was a tendency for reaction time to be shorter during exposure to radiation than in the sham (baseline) condition, an effect that was most marked for simple reaction time. However, no effects reached statistical significance after Bonferroni correction.”

Laboratory study II

- > Reference: Haarala C, et al. Electromagnetic field emitted by 902 MHz mobile phones shows no effects on children's cognitive function. Bioelectromagnetics. 2005;Suppl 7:S144-50.
- > Exposure: GSM900 mobile phone
- > Exposure duration: 50 min
- > Collective: 32 children 10-14 years of age
- > Design: 2-way crossover (sham and 0.25 W [SAR₁ of 1.4 W/kg]), double-blind
- > Outcome: 12 cognitive outcomes (reaction time, accuracy, working memory)
- > Result: „The statistical analyses showed no significant differences between the mobile phone off and on conditions in reaction times and accuracy over all tests or in any single test.”

Laboratory study III

- > Reference: Riddervold IS, et al. Cognitive function and symptoms in adults and adolescents in relation to rf radiation from UMTS base stations. Bioelectromagnetics. 2008;29(4):257-67.
- > Exposure: 2140 (UMTS): CW and 2 type of modulation
- > Exposure duration: 45 min
- > Collective: 40 adolescents 15-16 years of age
- > Design: 4-way crossover (sham and 1 V/m), double-blind
- > Outcome: 5 cognitive tests, 11 symptoms (e.g. dizziness, claustrophobia, etc.
- > Result: „ No significant changes were found in any of the cognitive tasks. An increase in ‘headache rating’ was observed when data from the adolescents and adults were combined ($p=0.027$), an effect that may be due to differences at baseline.”

Change in headache

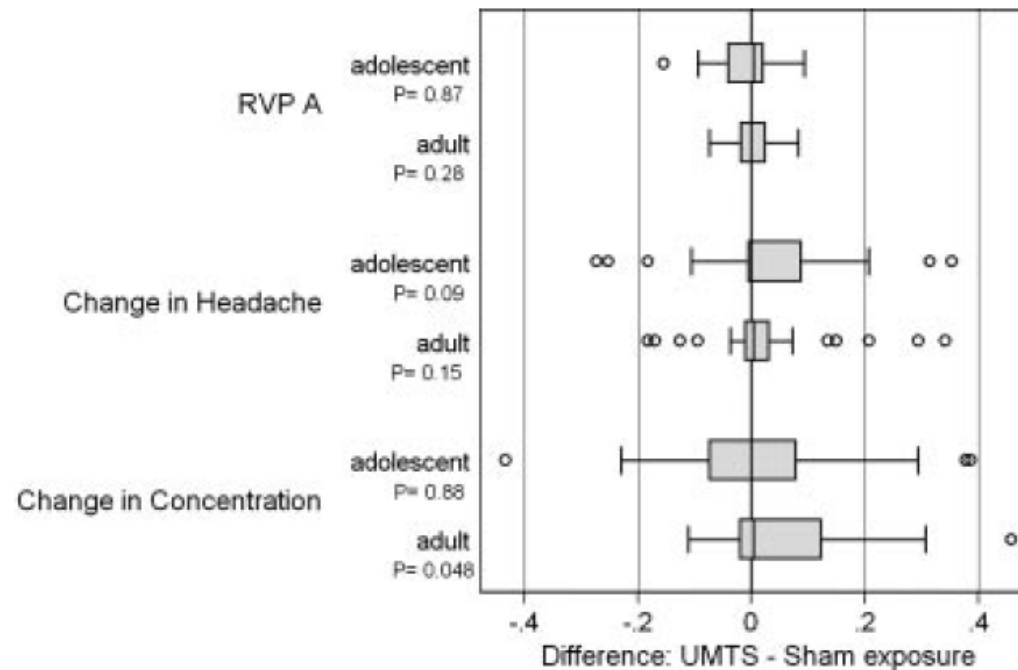


Fig. 3. Box plots illustrating the difference between sham and UMTS exposure for RVP A, 'change in headache' and 'change in concentration'. Note: Upper adjacent value is the largest data-point smaller than the 75th percentile plus 3/2 times the inter quartile range. The lower adjacent value is defined in a similar way. The dots refer to single values outside the 75th percentile.

Riddervold, et al. 2008

Laboratory study IV

- > Reference: Krause CM, et al. Mobile phone effects on children's event-related oscillatory EEG during an auditory memory task. Int J Radiat Biol. 2006 Jun;82(6):443-50.
- > Exposure: GSM900 mobile phone
- > Exposure duration: 30 min
- > Collective: 15 children 10-14 years of age
- > Design: 2-way crossover (sham and 0.25 W [SAR₁ of 1.4 W/kg])
- > Outcome: Event related brain oscillatory EEG during an auditory memory task (encoding and recognition)
- > Result: „ During memory encoding, active MP modulated the event-related desynchronization/synchronization responses in the ~ 4-8 Hz EEG frequencies. During recognition, the active MP transformed the brain oscillatory responses in the ~4-8 Hz and ~ 15 Hz frequencies.”

Laboratory study V

- > Reference: Nam KC, et al. Effects of RF exposure of teenagers and adults by CDMA cellular phones. Bioelectromagnetics 2006: 27 (7), 509-514.
- > Exposure: CDMA mobile phone (825-848 MHz)
- > Exposure duration: 30 min
- > Collective: 21 adolescents, mean age: 16 years
- > Design: 2-way crossover (sham and 300mW test mode), double-blind
- > Outcome: Physiological parameters such as systolic and diastolic blood pressures, heart rate, respiration rate, and skin resistance.
- > Result: „All the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the teenager group ($P < .0001$).” [after Bonferroni correction]

Summary laboratory studies

- > Basically the same picture as in the adult studies
- > no cognitive effects found
- > One study on EEG reports effect
- > One study on physiological effects with mixed findings

Epidemiology I

Exposure during pregnancy

- > Reference: De Roos AJ, et al. Parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring. *Epidemiology* 2001; 12 (5), 508-517.
- > Study design: case-control
- > Data collection: telephone interview
- > Collective: 538 children with neuroblastoma between 1992 and 1994 from the US + 504 age-matched controls
- > Exposure: probable exposure of mothers to RF-EMF on the job (assessed by a industrial hygienist).
- > Analysis: logistic regression adjusted for child's age and maternal race, age and education
- > Results: OR for maternal job with RF-EMF exposure: 2.8 (95%-CI: 0.9-8.7) cellular phone use: OR=2.1 (0.4-11.0)
- > Conclusions: "Overall, there was scant supportive evidence of strong associations between parental exposures in electromagnetic spectrum and neuroblastoma in offspring."

Epidemiology II

Exposure during pregnancy

- > Reference: Divan HA, et al. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. *Epidemiology*. 2008;19(4):523-9.
- > Study design: birth cohort study
- > Data collection: written questionnaire
- > Collective: 13,159 children (participation rate: 65%)
- > Exposure: self reported mobile phone use during pregnancy and after birth
- > Outcome: Strengths and Difficulties questionnaire: abnormal, borderline, normal
- > Analysis: ordinal logistic regression adjusted for confounding factors (sex of child, age of mother, smoking during pregnancy, mother's psychiatric problems, socio-occupational level)

Results behavioral problems

TABLE 2. Association of Prenatal and Postnatal Exposure to Cell Phone Use With Overall Behavioral Problems Score

	Postnatal Exposure				Prenatal Exposure ^a	
	No		Yes		Unadjusted OR	Adjusted OR (95% CI) ^b
	Unadjusted OR	Adjusted OR (95% CI) ^b	Unadjusted OR	Adjusted OR (95% CI) ^b		
Prenatal exposure						
No	1.0 ^c	1.0 ^c	1.25	1.18 (0.96–1.45)	1.0 ^c	1.0 ^c
Yes	1.77	1.58 (1.29–1.93)	2.16	1.80 (1.45–2.23)	1.74	1.54 (1.32–1.81)
Postnatal exposure ^d	1.0 ^c	1.0 ^c	1.26	1.18 (1.01–1.38)		

n = 12,068 with information about prenatal and postnatal exposure; n = 12,112 with information about prenatal exposure; n = 13,054 with information about postnatal exposure.

^aOR for prenatal exposure adjusted for postnatal exposure.

^bAdjusted for sex of child, age of mother, smoking during pregnancy, mother's psychiatric problems, and socio-occupational levels.

^cReference category.

^dOR for postnatal exposure adjusted for prenatal exposure.

from Divan et al, 2008

Epidemiology III: Broadcast transmitters and childhood leukaemia

Table 6. Summary of studies on transmitters and cancer.

Reference	Source of exposure	Comparison	End points	No. of cases	Results [OR (95% CI)]	Setting	Comments
Selvin et al. 1992	MW antenna	Internal	Childhood cancer Childhood leukemia	123 52	Random pattern	San Francisco	Analysis of spatial data; no epidemiologic parameters
Maskarinec et al. 1994	LF radio (23.4 kHz)	< 2.6 miles	Childhood leukemia	12	2.0 (0.06–8.3)	Hawaii	Case-control; SIR analysis on same cases: 2.09 (1.08–3.65)
Hocking et al. 1996	TV antenna	Inner/outer	All age leukemia Childhood leukemia		1.24 (1.09–1.40) 1.58 (1.07–2.34)	Northern Sydney	8–0.2 $\mu\text{W}/\text{cm}^2$
Dolk et al. 1997b	TV and FM radio	< 2 km	Adult leukemia	23	1.83 (1.22–2.74)	Sutton Coldfield	
Dolk et al. 1997a	TV and FM radio	< 2 km	Leukemia	79	0.97 (0.78–1.21)	All of Great Britain	
McKenzie et al. 1998	TV antennas	Continuous $\mu\text{W}/\text{cm}^2$ model	Childhood leukemia			Sydney	Reanalysis of Hockings et al. (1996) with LGA analysis
Cooper et al. 2001	TV and FM radio	< 2 km	All age leukemia Childhood leukemia	20 1	1.32 (0.81–2.05) 1.13 (0.03–6.27)	Sutton Coldfield	Reanalysis, more timely cancer data
Michelozzi et al. 2002	Radio station	< 6 km	Childhood leukemia Adult leukemia	8 23	2.2 (1.0–4.1) 1.2 (0.8–1.8)	Vatican	
Park et al. 2004	AM radio	< 2 km (approximately)	Leukemia	55	1.70 (0.84–3.45)	Korea	Definition of exposed area not clear

from Environ Health Persp (2004) ,112, 1741ff

Cluster/Publication bias?
 Ecological fallacy(confounding)?
 Exposure assessment?

Epidemiology III

childhood Leukaemia

- > Reference: Ha M et al. Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer. Am J Epidemiol. 2007;166(3):270-9.
- > Study design: case-control
- > Data collection: medical records
- > Collective: 1,928 leukaemia patients, 956 brain cancer patients and 3,082 controls
- > Exposure: 31 AM radio transmitters with a power of ≥ 20 kW from South Korea: distance and modelling
- > Analysis: conditional logistic regression adjusted for SES and population density
- > Results: No association found for leukaemia and brain cancer

TABLE 1. Odds ratios and 95% confidence intervals of childhood leukemia according to the level of exposure to radio-frequency radiation from AM radio transmitters among children under the age of 15 years, South Korea, 1993–1999

	No. of controls	Lymphocytic leukemia			Myelocytic leukemia			All leukemia		
		No. of cases	Odds ratio*	95% confidence interval	No. of cases	Odds ratio*	95% confidence interval	No. of cases	Odds ratio*	95% confidence interval
Total radio-frequency radiation exposure (mV/m)†										
Quartile 1	513	514	1.00	Referent	177	1.00	Referent	737	1.00	Referent
Quartile 2	514	241	0.69	0.50, 0.96	110	0.74	0.46, 1.18	362	0.75	0.58, 0.97
Quartile 3	515	188	0.57	0.41, 0.78	122	0.96	0.62, 1.49	330	0.70	0.55, 0.90
Quartile 4	513	353	0.93	0.67, 1.29	100	0.55	0.33, 0.93	494	0.83	0.63, 1.08
Unknown	9	4	0.34	0.06, 1.87	1	0.28	0.02, 3.52	5	0.39	0.10, 1.54
<i>P</i> _{trend} ‡				0.05			0.1			0.44
Peak radio-frequency radiation exposure (mV/m)§										
Quartile 1	513	360	1.00	Referent	130	1.00	Referent	525	1.00	Referent
Quartile 2	515	239	1.14	0.85, 1.54	105	0.67	0.43, 1.06	367	0.95	0.75, 1.20
Quartile 3	514	229	0.92	0.68, 1.24	92	0.76	0.49, 1.17	349	0.86	0.68, 1.09
Quartile 4	513	468	1.40	1.04, 1.88	182	0.63	0.41, 0.97	682	1.02	0.81, 1.29
Unknown	9	4	0.39	0.07, 2.26	1	0.29	0.02, 3.67	5	0.43	0.11, 1.75
<i>P</i> _{trend} ‡				0.07			0.25			0.43

from Ha et al, 2008

Methods

- > Study design: case-control
- > Data collection: German childhood cancer registry (cases) and community registries (controls)
- > Collective: 1,959 leukaemia patients (age: 0-14, diagnosed: 1984-2003) and 5,848 controls
- > Exposure: 16 AM and 8 FM radio transmitters with a power of $\geq 200\text{kW}$ from Germany. Exposure modelled 1 year prior to diagnosis
- > Analysis: conditional logistic regression without adjustment for confounders
- > Results: No association found:
 - neither for the whole sample
 - neither for restricted sample to i) different time periods, ii) children 0-4 years of age, iii) who did not move
 - nor distance

Distance vs. exposure

Table 5. Results Regarding Total RF-EMF Exposure From AM Transmitters and Risk of Childhood Leukemia Comparing 2 Case-Control Studies Conducted in Germany (1984–2003) and Korea (1993–1999)

	Germany	95% CI	Korea	95% CI
<i>Total RF-EMF exposure^a</i>				
Reference category (quartile 1)	<0.518 V/m		<0.518 V/m	
High-exposure category (quartile 4)	≥0.917 V/m		≥0.917 V/m	
Odds ratio and 95% CI (all cases)	0.88	0.63, 1.22	0.83	0.63, 1,08
Odds ratio and 95% CI (lymphoid leukemia)	0.99	0.70, 1.39	0.93	0.67, 1.29
<i>Distance to the nearest AM transmitter</i>				
Reference category	10–<15 km		>20 km	
High-exposure category	<2 km		≤2 km	
Odds ratio and 95% CI (all cases)	1.15	0.60, 2.22	2.15	1.00, 4.67
Odds ratio and 95% CI (lymphoid leukemia)	1.56	0.77, 3.16	1.60	0.69, 3.72

from Merzenich et al, 2008

Summary epidemiology

- > Some first findings that are difficult to interpret: behavioural problems in children due to mobile phone exposure during pregnancy.
- > Previous positive associations between childhood leukaemia and broadcast transmitters were not confirmed in two large-scale case-control studies.

Ongoing studies

- > MobilEe: Exposure to mobile phone radiation in the everyday life of children and adolescents and symptoms (K. Radon, Munich).
- > In the UK a case-control study is ongoing investigating the relationship between mobile phone base station radiation and childhood leukaemia (P. Elliot, London).
- > Brain tumour and use of mobile phones: CEFALO (M. Feychting, Stockholm; L. Klæboe, Oslo; P. McKinney, Leeds; M. Rööslì, Bern; J. Schüz, Copenhagen).
- > Brain tumour and use of mobile phones: Mobi Kids (E. Cardis)
- > Birth cohorts: many studies ongoing but not designed for RF-EMF questions

Conclusions

- > Few studies available
- > Required:
 - epidemiological studies with exposure during pregnancy
 - long term studies (prospective cohorts)
- > I expect several false positive findings from ongoing birth cohort studies not specialised on EMF.
- > Behavioural effects also important: e.g.
 - Van den Bulck J. Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up. *Sleep*. 2007;30(9):1220-3.
 - Lajunen H-R, et al. Are computer and cell phone use associated with body mass index and overweight? A population study among twin adolescents. *BMC Public Health*, 2007;7:24