資料6

高周波帯域におけるヒト研究の分野

杏林大学細胞生理学教室
寺尾　安生

高周波数電磁場の発生源

高周波数電磁界（10メガヘルツから300ギガヘルツ）に関する**ヒト**の研究について述べる。

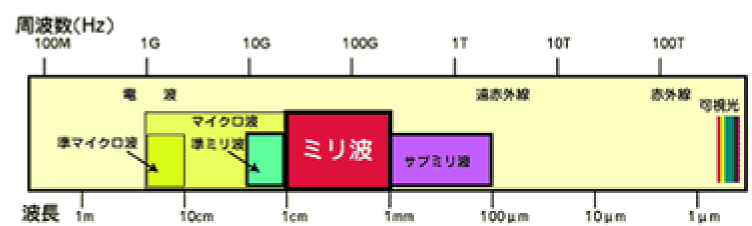
発生源

ほぼ**人工的な**電磁波(一部自然)

- 高周波熱溶接装置、医用ディアテルミー(3〜30MHz)
- FMラジオ(30〜300MHz)
- 携帯電話、テレビ放送、電子レンジ、ワイヤレスLAN (0.3〜3GHz)
- レーダー、衛生放送、マイクロ波通信(3〜30ギガヘルツ)、太陽(3〜300ギガヘルツ)

ミリ波(30-300GHz)、サブミリ波（300GHz-3THz)

次世代の移動通信システムである第 5 世代移動通信システム(5G)、超高速無線LANは、準ミリ波・ミリ波帯と呼ばれる 6GHz 以上の高い周波数帯も活用する。



人体への暴露の影響
(物理的特性）

- 10ギガヘルツ以上の高周波電磁界のほとんどは**皮膚表面**で吸収、ごく一部だけが皮下組織へ透過

  →高周波電磁界の主要な作用は**熱作用**

- **低レベル**の高周波電磁界ばく露は、それに見合った微量の熱を発生するが、人体の生理的な温度調節機構によって気づかないうちに**消去**される。

  →低ばく露環境での非熱的影響（非熱作用）では**生体への影響は確認されていない**。

- ICNIRPの基準では50倍の安全率を設けて、体重1キログラム当たり0.08ワット（4ワット/50＝0.08ワット）を一般環境のばく露制限値としている。理論的にはこの制限値ばく露で深部体温は0.02℃上昇する計算

- **高ばく露環境**では、周波数が10ギガヘルツ以上の高周波電磁界については、電力密度が1000W/㎡以上のばく露で白内障や熱傷
- そのような環境は強力なレーダーの至近距離でのみ

高周波EMFのヒトへの影響

脳は携帯電話との距離が短い。

●脳腫瘍　(長期的影響）

●認知機能/脳波(覚醒時・睡眠時）・誘発電位/睡眠/脳血流への影響
（短期的影響）

●眼への影響

携帯電話による症状の誘発

●ばく露実験による症状の誘発

●電磁波過敏症

長期の影響

●生殖能力

Systematic review of wireless phone use and brain cancer and other head tumors

INTERPHONE研究(国際共同疫学研究、2010)

ヘビーユーザーにおける脳腫瘍のリスク増加を示唆

2010年 神経膠腫、髄膜腫、 2011年 聴神経鞘腫

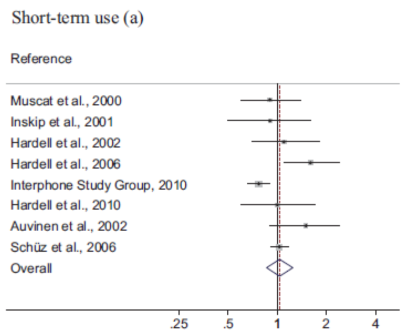
（一部腫瘍でヘビーユーザーでodds比が有意に1を超える腫瘍があった）

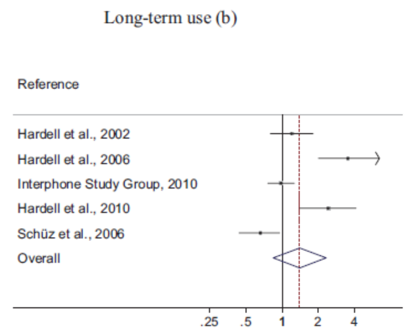
国際がん研究機関（IARC）(2011)は電磁界の発がん性評価について、

「発がん性があるかもしれない(グループ2B)」

TABLE 1. Results of Studies on Time Since First Cell Phone Use and Risk of Glioma, and Variation in Effect Estimates Attributable to Heterogeneity

Study	Short-term use[a] Exposed cases (exposure period)[b]	OR (95% CI)	Long-term use[a] Exposed cases[b]	OR (95% CI)	Ever used[a] Exposed cases[b]	OR (95% CI)
Muscat et al. [2000] [c]	49 (1–3 years)	0.9 (0.6–1.4)	—	—	66	0.7 (0.5–1.1)
Inskip et al. [2001] [c]	31 (0.5–3 years)	0.9 (0.5–1.6)	—	—	201	1.0 (0.7–1.4)
Auvinen et al. [2002]	25 (≤2 years)	1.5 (0.9–2.4)	—	—	36	1.5 (1.0–2.4)
Hardell et al. [2002] [b,c]	36 (1–6 years) (analog)	1.1 (0.7–1.8)	43 (>6 years)	1.2 (0.8–1.8)	79	1.1 (0.8–1.6)
Hardell et al. [2006] [b,c]	100 (digital)	1.6 (1.1–2.4)	48 (analog)	3.5 (2.0–6.4)	68 (analog)	2.6 (1.5–4.3)
Schüz et al. [2006] [c]	266 (1–4 years)	1.03 (0.91–1.17)	28	0.66 (0.44–0.95)	580	0.97 (0.89–1.06)
Interphone Study Group [2010]	800 (1–4 years)	0.77 (0.66–0.90)	252	0.98 (0.76–1.26)	1666	0.81 (0.70–0.94)
Hardell et al. [2010]	33 (1–5 years)	1.0 (0.6–1.7)	38	2.4 (1.4–4.1)	106	1.3 (0.9–1.9)
Combined OR	—	1.03 (0.86–1.24)	—	1.40 (0.84–2.31)	—	1.07 (0.89–1.29)
I^2	—	63.6%	—	87.0%	—	75.5%
Heterogeneity *P*	—	0.008	—	<0.001	—	<0.001





(Repacholi et al., 2012)

著者	年	診断	症例、対照	odds ratio	follow up(期間）
Poulsen et al	2013	Melanoma、squamouns cell carcinoma	355,701名の形態電話使用者を調査	1.2(0.65-2.22	13年間
Al-Qhatani et al	2016	parotid gland tumor	26/61	3.47(1.3-923)	7年間
Shresta et al Leng & Zang	2015 2016	Pituitary tumor	Case report 80 cases, 240control	Increased risk with mobile phone use	

脳腫瘍については、聴神経腫瘍、神経膠腫、髄膜腫、下垂体腫瘍、耳下腺腫瘍など新規の研究は少なく、これまでのデータの再解析でも有意な結果はでていない。

電磁波の暴露と認知機能 (記憶、注意、集中力）

authors	electromagnetic field	Task performed	findings
Preece et al. (1999)	915-MHz GSM, mobile telecommnunication	short- and long-term memory, simple and choice reaction time, and sustained attention	significant shortening of reaction time in choice reaction time, no change in simple reaction time
Koivisto et al. (2000a)	900-MHz GSM, mobile phone	Simple and choice reation time tasks, vigilance task	no significant reaction time in choice reaction time, reduction in simple reaction and vigilance task
Koivisto et al. (2000b)	900-MHz GSM, mobile phone	12 cognitive tasks including simple reaction time and vigilance tasks, mental arithmetics task	speeding up of response times in simple reaction time and vigilance tasks, the cognitive time needed in a mental arithmetics task was decreased
Haarala et al. (2003b,2004)	902-MHz GSM pulsed EM field	short term memory task	Failure to confirm above results, no effects on adults' and children's cognitive function
Lass et al. (2002)	450-MHz RF modulated at 7 Hz	3 cognitive tasks including memory recognition task	no significant effects in exposed group, showing worse performance and greater intersubject variability. Fewer errors on the memory recognition task in exposed subjects.
Edelstyn & Oldershaw (2002)	900-MHz GSM mobile phone	6 widely used cognitive tasks	exposure facilitated cognitive tasks involving attentional capacity and one task that involved processing speed
Zwamborn et al. (2003)	UMTS-like signal at 10 V/m.	reaction time, memory comparison, dual-tasking, selective visual attention, and filtering irrelevant information	No significant effects on the cognitive functions
Smythe & Costall (2003)	900-MHz GSM mobile phone	short- and long-term memory tasks	males exposed to an active phone made fewer spatial errors than those exposed to an active phone condition, while females were largely unaffected
Maier et al. (2004)	900-MHz GSM-type RF	Discrimination of auditory stimuli	Exposure significantly reduced the subsequent performance of the task
Curcio et al. (2004)	900MHz GSM	acoustic simple reaction time task, visual search task, arithmetic descending subtraction task, acoustic choice reaction time task	Significant reduction of both simple and choice reaction times, subjects exposed before testing performed more rapidly than those exposed during testing
Besset et al. (2005)	900-MHz GSM	europsychological battery of 22 tasks screened information processing, attention, memory, and executive function	no significant effect of RF exposure on task performance
Russo et al. (2006)	888-MHz continuous-wave (CW) or GSM RF	reaction-time task, 10-choice serial reaction time task, subtraction task, and vigilance task,	no significant effects of RF exposure on task performance
Keetley et al. (2006)	GSM RF radiation	Rey's audiovisual learning test, digital span test, digital symbol substitution test, speed of comprehension test, trail making task, reaction time task, choice reaction time task, and inspection time task	simple and choice reaction times showed significant impairment
Eliyahu et al. (2006)	GSM mobile phone RF radiation	spatial item recognition task, spatial item recognition task, spatial compatibility tasks	exposure of the left hemisphere of the brain resulted in slower left-hand responses in the second session compared to the first, for the spatial item recognition task and one spatial compatibility task
Terao et al (2006)	800-MHz mobile phone	Precued choice reaction time task	Exposure did not have any significant effect on reaction time or accuracy
Eliyahu et al. (2006)	GSM mobile phone RF radiation	spatial item recognition task, spatial item recognition task, spatial compatibility tasks	exposure of the left **hemisphere of** the brain resulted in slower left-hand responses in the second session compared to the first, for the spatial item recognition task **and** one spatial compatibility task
Wilén et al. (2006)	mobile phone radiation	tests of arousal and vigilance, short-term memory, and reaction times	No significant effects of RF radiation on any cognitive variable
Haarala et al. (2007)	continuous or GSM signal operating at 0.25 W	simple reaction time, 10-choice reaction time, subtraction, verification, vigilance, and memory (n-back test).task	No significant difference on response between exposure to either the left or right hemisphere and sham exposure
Regel et al. (2007)	900-MHz GSM	Simple reaction time task, 2-choice reaction time task, n-back task, visual selective attention task	reduction of reaction time with increasing field strength for the 1-back task, and similar relations at trend level for the 2-back task and the choice reaction time task, but no significant effect on the simple reaction time or 3-back task.
Cinel et al. (2007)	900MHz GSM-like and continuous wave signals	auditory order threshold task	Replication of the Maier et al (2004) study on a larger number of subjects, no significant effect of exposure to RF EMF
Terao et al. (2007)	Mobile phone (1.95 GHz EMF at 0.27W net antenna input power, 250 mW)	visually guided saccade (VGS), gap saccade (GAP), and memory guided saccade (MGS) task	no significant effect on saccade tasks
Riddervold et al. (2008)	2140-MHz base station-like signal modulated as UMTS, or a 2140-MHz continuous-wave signal	reaction time (RTI) Rapid Visual Information Processing (RVP), Paired Associated Learning (PAL)	no significant effect on cognitive functions
Furubayashi et al. (2009)	2.14 GHz, 10 V/m (W-CDMA)	Precued choice reaction time task	no significant effect on cognitive functions
Okano et al. (2010)	Mobile phone (1.95 GHz EMF at 0.27W net antenna input power, 250 mW)	antisaccade task, overlap saccade task, memory guided saccade task	no significant effect on inhitibion of saccades
Curcio et al. (2012)	902.40 MHz GSM-EMF	somatosensory task	RTs in a somatosensory task resulted unaffected.
Vecchio et al (2012)	902.40 MHz GSM-EMF	visual go/no-go task	faster reaction time to go stimuli in the post- than pre-exposure
Sauter et al (2015)	TETRA EMF (385 MHz)	Cognitive function	negative impact of a short-term EMF-effect of TETRA on cognitive function and well-being
Malek et al (2015)	Short-term exposure GSM, UMTS	Cognitive performance, physiological measures	o statistical significant difference between the exposure and sham exposure towards cognitive performance and physiological effects
Guxens et al (2016)	RF- EMF	Cognitive fundtion	improved visuomotor coordination with residential presence of RF-EMF indoor sources and higher personal cell phone use
Martes et al (2017)	RF-EMF from mobile-phone base stations		perceived exposure was associated with higher symptom reporting scores in both cross-sectional and longitudinal analyses, as well as with sleep disturbances in cross-sectional analyses.

覚醒時脳波への影響

authors	electromagnetic field	Parameters assessed	findings
Reiser et al. (1995)	GSM mobile phone	EEG power	Increased power of EEG frequencies in the 18–35 Hz
Röschke and Mann (1997)	GSM mobile phone positioned at 40cm from vertex	EEG power	No significant effect on the EEG
Borbély et al. (1999)	900-MHz "pseudo GSM signal"	EEG power	Increased resting EEG power in the 11–11.5 Hz bin only
Hietanen et al. (2000)	Analogue and GSM at 900 and 1800 MHz, hand-sets	EEG power	effect in only absolute but not relative power in one frequency band in one of four brain regions
Lebedeva et al. (2000)	900-MHz signal directed at the back of the head	EEG power	"dimensional complexity" was more sensitive to the effects of RF signals than conventional indices.
Freude et al. (2000)	900-MHz GSM phone	EEG power during a visual monitoring task	decrease of EEG power in all regions except frontal
Huber et al. (2000)	900-MHz GSM signal	EEG power before sleep	Resting EEG reduced in the 10.5–11 Hz range
Huber et al. (2002)	900-MHz GSM signal, hand-set continuous-wave 900-MHz signal	Waking EEG	Increased power in the alpha band for pulse-modulated EMF only
D'Costa et al. (2003)	GSM phone positioned behind the head, the antenna pointing toward the head.	EEG power	EEG alpha (8–12 Hz) and beta (13–30 Hz) bands showed significant differences when the full power mode was on
Kramarenko and Tan (2003)	GSM phone on standby	EEG power	A slow-wave delta (2.4–6 Hz) appeared in areas on the side of the phone in adults, the slow waves with lower amplitude (1–2.5 Hz) appeared earlier in children
Hinrikus et al. (2004)	450-MHz microwaves with 7-Hz on–off modulation	EEG power	Changes in the EEG in the frontal region
Papageorgiou et al. (2004)	GSM-like signal	EEG power during a memory test	exposure decreased the power in males and increased it in females , no effect of exposure on performance in the memory test, no details of experimental setup given
Curcio et al. (2005)	900-MHz GSM phone	EEG power	A small increase in some frequencies in the alpha band, stronger under exposure
Maby et al. (2006)	undefined GSM mobile phone	EEG power	decrease in EEG power in the theta, alpha, and beta bands, decrease in the variations in the delta band, in the epileptic patients an increase in power in all EEG bands
Bachmann et al. (2007)	450-MHz signal, pulse modulated at 1000 Hz, 30min	EEG power	Significant changes in the ratio of the EEG power in the beta and theta frequency bands
Vecchio et al. (2007)	GSM phone located at the left side of the head	EEG connectivity	the connectivity between both brain hemispheres in parts of the alpha band (8–12 Hz)
Regel et al. (2007)	GSM-type pulsed or continuous, planar antenna.	EEG power	An increase in frequencies in the alpha band
Perentos et al. (2007)	900-MHz GSM mobile phone or a 900-MHz continuous wave	specified EEG bands	No significant effect of either type of signal on any EEG band
Hinrikus et al. (2008)	7-, 14-, and 21-Hz pulse-modulated 450-MHz microwaves	EEG power	Significant changes in the alpha (8–13 Hz) and beta (15–20 and 22–38 Hz) bands with the 14- and 21-Hz modulations, No effect of the 7-Hz modulation
Croft et al. (2008)	875-MHz GSM phone	EEG power	An increased power in the alpha band, larger on the ipsilateral compared to the contralateral side in posterior regions
Kleinlogel et al. (2008)	1950 MHz UMTS (SAR 0.1 and 1 W/kg), pulsed 900 MHz GSM (1 W/kg)	EEG power	No significant changes in the measured parameters
Croft et al. (2010)	2nd generation (2G) GSM, and 3rd generation (3G) W-CDMA	EEG power (alpha activity)	young adults' alpha was greater in the 2G compared to Sham**,** no effect was seen in the adolescent or the elderly groups no effect of 3G exposures was found in any group
Vecchio et al. (2010)	GSM-EMF	inter-hemispheric functional coupling of electroencephalographic rhythms delta (about 2-4 Hz), theta (about 4-6 Hz), alpha1 (about 6-8 Hz), alpha2 (about 8-10 Hz), and alpha3 (about 10-12 Hz)	Increased inter-hemispheric synchronization of the dominant (alpha) EEG rhythms in elderly during GSM
Vecchio et al. (2012)	GSM-EMF	inter-hemispheric functional coupling of electroencephalographic rhythms delta (about 2-4 Hz), theta (about 4-6 Hz), alpha1 (about 6-8 Hz), alpha2 (about 8-10 Hz), and alpha3 (about 10-12 Hz)	increases in inter-hemispheric functional coupling of electroencephalographic α rhythms
Trunk et al. (2013)	3rd generation (3G) Universal Mobile Telecommunications SystemUMTS	EEG power (alpha activity)	No measurable effects on the EEG spectral power in delta, theta, alpha, and beta frequency bands
Lustenberger et al (2015)	900 MHz (2 Hz pulse, 20 Hz Gaussian low-pass filter and a ratio of peak-to-average of 4) RF EMF	EEG power (delta andntheta activity)	No reproducible within-subject RF EMF effects on sleep spindle and delta-theta activity
Eggert et al (2015)	TETRA RF 385MHz	Slow cortical actitity	No evidence of RF-EMF exposure-dependent brain activity modifications
Ghosn R et al(2017)	GSM RF 900 MHz	EEG power (alpha activity)	Significant decrease of the alpha band spectral power during closed-eyes condition

睡眠（脳波）への影響

authors	electromagnetic field	power of exposure	findings
Reite et al. (1994)	27.12MHz modulated at 42.7Hz		decreased sleep latency by 2min, increased deepsleep by 1min
Mann & Röschke (1996)	900MHz GSM		reduced sleep onset latency, reduced percentage REM sleep with increased power density of alpha wave
Wagner et al. (1998)	900-MHz GSM	0.5 and 0.2 W/m2	failed to replicate Mann and Röschke (1996)
Borbély et al. (1999)	"pseudo GSM"900-MHz		reduced number of waking episodes after sleep onset, EEG power spectra during the first of the night's episodes of REM sleep
Wagner et al. (2000)	GSM 900-MHz, 50 W/m2	2 W/m2	no significant effects on sleep architecture or EEG spectral power density
Huber et al. (2000)	900MHz GSM, antenna		increased spectral power in alpha and beta bands (9.75–11.25 Hz and 12.5–13.25 Hz) in the first non-REM sleep phase.
Huber et al. (2002)	900MHz GSM, hand-set		significant rise in the 12.25–13.5 Hz band during sleep
Loughran et al. (2005)	894.6-MHz mobile phone	larger sample (50)	increase in spectral power only in the 11.5–12.25 Hz range
Regel et al. (2007)	900MHz GSM	similar as Huber et al. (2002)	dose-related increase in spectral power in the 10.75–11.25 Hz and 13.5–13.75 Hz bands during non-REM sleep
Fritzer et al. (2007)	"pseudo" GSM900-MHz	similar as Borbély et al.	No significant differences in any parameter
Hung et al. (2007)	900-MHz GSM	different ELF pulse modulations	an increase in sleep latency, no change was seen in 1–4 Hz EEG power
Lowden et al. (2011)	884 MHz GSM, on-DTX and DTX mode	10 g psSAR of 1.4 W/kg	decreased time in Stages 3 and 4 slow-wave sleep, increased alpha range in the sleep EEG
Danker-Hopfe et al. (2011)	900MHz GSM, mobile phones W-CDMA		No evidence indicative of a negative impact on sleep architecture
Nakatani-Enomoto et al. (2013)	1950 MHz, mobile phones W-CDMA	SAR 1.52 and 0.13 W/kg	No significant differences sleep variables and power EEG spectra
Burgess et al (2017)	No effect on the electroencephalogram	390–400MHz	No significant effect on EEG

脳血流（代謝）/脳血液関門への影響

authors	electromagnetic field	imaging modality /task perfomed	findings
Huber et al. (2002)	900-MHz GSM, mobile phone	PET	significant increase in rCBF in the dorsolateral prefrontal cortex of the left (exposed) hemisphere
Huber et al. (2005)	900-MHz GSM, base-station-like and mobile phone-like exposure	PET	Increased rCBF the dorsolateral prefrontal cortex on the side of exposure only for mobile phone-like exposure
Haarala et al. (2003)	902-MHz GSM-phone signal	PET / visual working memory task	bilateral decrease in rCBF in the auditory cortex, no significant change in the task performance
Aalto et al. (2006)	900-MHz GSM	PET	reduced rCBF close to the antenna, and an elevation at various other locations deeper in the brain
Mizuno et al. (2009)	195MHz, W-CDMA	PET	no significant rCBF changes caused by the EMF
Volkow et al. (2011)	acute cell phone exposure	PET	increased cerebral metabolic rates of glucose in the brain regions closest to the active handset
Kwon et al. (2012)	902.4-MHz GSM, mobile phone	PET	no significant rCBF changes caused by mobile phone
Soderqvist et al. (2015)	RF-EMF（890MHz, SAR=0.2, 2.0W/kg）	BBB	no significant effect on BBB function

Provocation study

authors	electromagnetic field	Symptoms assessed	findings
Koivisto et al. (2001)	pulsed 902-MHz field, 30min, 1hr	rate subjective symptoms and sensations	No significant differences were found between exposure conditions, although fatigue and headaches increased toward the end of sessions.
Hietanen et al. (2002)	RF EMFs	Blood pressure, heart rate, and breathing rate, report any abnormal feelings.	more symptoms were reported during sham exposure than during real exposure, subjects could not indate sham exposure from real exposure
Rubin et al. (2006)	900-MHz GSM mobile phone radiation, 50min	Subjective scoring of the severity of headaches and various other symptoms such as nausea, fatigue, and dizziness	Prevalence of various symptoms experienced was higher in sensitive than non-sensitive subjects. No difference in detecting real/sham exposure between sensitive and non-sensitive subjects.
Wilén et al. (2006)	900-MHz (GSM) RF radiation, 30min	Physiological parameters such as heart-rate variability, electrodermal activity, and respiration rate, cognitive function tests	No significant effects of RF radiation on any physiological parameter were found. "Sensitive" subjects showed differences in heart-rate variability compared to controls
Oftedal et al. (2007)	450-MHz RF modulated at 7 Hz	headache, discomfort, and various physiological parameters	increase in headache and discomfort was found after sham but not after real exposure; subjects could not perceive being exposed .no effects on heart rate and blood pressure..
Zwamborn et al. (2003)	UMTS-like signal at 10 V/m., GMS signal at 0.7V/m	cognitive functions and self-reported well-being	A significant decrease in well-being after UMTS exposure, No significant effects were seen using GSM signals either at 900 or 1800 MHz
Regel et al. (2006)	2140-MHz UMTS base-station-like RF signal	self-reported well-being	Subjects were also not able to discriminate between exposure levels, but they reported more health complaints when they suspected exposure
Eltiti et al. (2007)	GSM and UMTS fields, 10 mW/m2	Well-being, physiological functions, perception of EMF	well-being of the sensitive but not of the control subjects was decreased after GSM and UMTS exposure, skin conductance and heart rate were higher than in controls, but these parameters were not influenced by exposure. Perception of the on/off status of the field not better than chance in either group
Riddervold et al. (2008)	2140-MHz signal modulated as UMTS, or a 2140-MHz continuous-wave signal, 45 min	self-reported symptoms and perceptions of air temperature, air humidity, and air quality	no significant effect on symptoms and perceptions
Landgrebe et al. (2008)	mobile telephone exposure	fMRI	electrosensitive subjects, the areas of the brain that are activated in anticipation of, and during, sham exposure are the same that are activated in both sensitives and nonsensitives when they are exposed to heat
Rubin et al. (2008)	mobile telephone exposure	occurrence of symptoms	Well-being in those who use the label "electrosensitive" was worse than in the subjects that reported being sensitive to mobile phones but that did not use the label "electrosensitive," or in controls without symptoms.
Furubayashi et al. (2009)	UMTS-like signal at 10 V/m, 30min	Psychological and cognitive parameters, autonomic functions, perception of EMF and level of discomfort	The subjects with mobile phone-related symptoms did experience a higher level of discomfort than controls, but this was independent of the type of exposure. Perception of the on/off status of the field not better than chance in either group
Lindholmら(2011)	GSM mobile phone	26 children(age 14ー15歳) GSM 900MHz	During the short-term RF exposure, local cerebral blood flow did not change, no change in ear canal temprature, autonomic nervous system no change
Choi et al. (2014)	3 G mobile phones	26 adults and 26 teenagers	RF radiation emitted by WCDMA mobile phones demonstrated no effects in either adult or teenager subjects.

頭痛、疲労感、自覚的･不安感、生理的指標、集中力低下、不注意などが報告されているが、睡眠不足、休養不足などRFへのばく露以外の要素も関連している可能性は否定できない。

電磁過敏症

著者	暴露の種類	被験者数	帯域	結果
Augnerら(2008)	GSM携帯電話基地局のRF間欠的暴露	57人	900MHz	自称電磁波過敏症の罹患率は低い、心理ストレスを示す因子との相関なし
Cinelら(2008)	連続波またはGSM携帯電話基地局のRF暴露	エセックス大学職員496人	888MHz	有意な症状悪化なし
Hillertら(2008)	GSM携帯電話	71人の電磁波過敏者	884MHz RF	過敏群は、非過敏群に比較して、電磁波を検知する能力に差なし。
Riddervoldら(2008)	UMTS携帯電話基地局のRF全身暴露	若年者40人、成人40人	2140MHz RF	暴露による影響の差なし
Furubayashiら(2009)	W-CDMA携帯電話基地局	5000人（女性のみ）、うち43人のMPRS被験者	2.14GHz RF	MPRS群は、非MPRS群に比較して、心理・認知能力・自律神経機能など暴露、偽暴露への反応に差なし
Kwonら(2011)	Smart phone(WCDMA)	10名の電磁波過敏症被験者 10名の健常被験者	1950MHz　RF	30分の暴露で循環・呼吸器系のパラメータへの影響はなし。
Eltitiら (2015)	Base stationからのEMF	56 IEI-EMF and 120 control	420 MHz for TETRA, 900 and 1800 MHz forGSM, and 2020 MHz for UMTS	EMF exposureと被験者の健康の間に有意な関連はない。
Antdrianome et al (2016)	-	30 IEI-EMF and 25 control	-	significantly different sleep scores, no difference in saliva melatonin, urine 6-sulfatoxymelatonin
Antdrianome et al (2017)	-	30 EHS patients, 25 normal subjects	-	High levels of saliva alpha amlyase seen in electrohypersensitive patients
van Moorselaarら(2017)	Radiofrequencyないし低周波数域の電磁波の暴露	成人42名	RF、VLF	電磁波の暴露を検知することができた。
Verrenderら(2018)	Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF)	3 participants aged 44-64	902-928 MHz	暴露による過敏群は、非過敏群の症状の差がなかった

電磁過敏症者の自己申告による症状と、RFの暴露は必ずしも関係がないといわれている。
長期的(数日から数カ月)ばく露に関連する症状に関しても、これまでヒトを対象とした観測的研究の結果から、因果関係を示す証拠は認められていない。

生殖能力

Baste et al. (2016)

- 妊娠中の母親の携帯電話使用は胎児にとり**有害なリスクではない**。

Zhou et al. (2017), Mahmoudabadi et al. (2015)

- 妊娠中の母親の携帯電話使用により**自然流産の増加**

Zilberlicht et al. (2015), Roser et al (2015). Zarei et al (2015),

- 精子と携帯電話の使用の関連に関する研究は質が低い
  →ばく露との潜在関連性には疑問

不妊クリニック通院男性患者のコホート研究（Lewisら、2016)
提供精子に対するRF-EMF(1950MHz, SAR=2.0, 6.0W/kg)へのばく露研究
（Nakatani-Enomotoら、2016)
→**ばく露との関連なし**

再現性の検証が必要。

高周波の影響のこれまでの研究

携帯電話システムの急速な普及に伴い、電波の安全性を確保するために多くの研究がなされてきた。

これまでのところ、国際的なガイドラインの指針値より弱い電波ばく露条件においては、熱作用・刺激作用以外の作用が存在することを示す**明確な科学的証拠は見つかっていない**。

これまでの研究を総合すると、一部に影響があるとする研究がある一方、ないとする研究も多い。

信頼できる研究の条件

①ばく露条件に関する情報が詳細に記述されていること
②十分なばく露評価期間がとられた研究であること
③ばく露と評価指標への影響との因果関係に関する分析が適切にされていること

(生体電磁環境に関する検討会　第一次報告書より)

超高周波EMF

- 超高周波数であるミリ波(30-300GHz)、サブミリ波（300GHz-3THz)
  今後利用が拡大すると考えられる領域

- しかし、現状では非熱データに関する研究データの蓄積は少ない。
  →結論が出せる状況ではない。

Partyla et al (2017)

- ２０名の男性被験者に３０分間のミリ波(入射電力密度 0.1mW/cm2, 皮膚表面のSAR 1.5W/kg)

- 寒冷昇圧試験で痛みの感覚の増加、拡張期の血圧上昇を認めたとの報告

今後の課題

- 被験者の主観的評価、認知機能、生理学的視標、脳波、誘発電位、睡眠や脳血流に対する高周波電磁界の影響については否定的な研究も多い（とくに2006年以降の研究）。ただし、人体への影響は関心の高い領域であり、positive, negative両方のデータがあるため、今後も注視していく必要がある。

- これまでの研究はいずれも主として急性暴露に関するものであり、健康や疾病に対する長期的な影響の検討は少ない。脳腫瘍の発生、生殖能力への影響などについては、否定的であるが、今後も引き続き検討していく必要がある(とくに超高周波帯）。

- 新しく利用が拡大しつつある、ミリ波（30～300GHz）およびサブミリ波（テラヘルツ波300GHz～3THz）の生体への影響についての検討も必要

- ウエラブル端末など体の近傍(10-20cm)での使用が増加しつつある。

  → 端末近傍の電磁波を適切に評価する必要
  局所ばく露、ばく露時間などの考慮(パルス波など）
  人体モデルを用いた暴露のシミュレーション、
  ドシメトリーなどが大切。