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Effects of mobile phone exposure (GSM 900 and WCDMA/UMTS) on polysomnography based sleep quality: An intra- and inter-individual perspective

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ABSTRACT

Background: Studies on effects of radio frequency-electromagnetic fields (RF-EMF) on the macrostructure of sleep so far yielded inconsistent results. This study investigated whether possible effects of RF-EMF exposure differ between individuals.
Objective: In a double-blind, randomized, sham-controlled cross-over study possible effects of electromagnetic fields emitted by pulsed Global System for Mobile Communications (GSM) 900 and Wideband Code-Division Multiple Access (WCDMA)/Universal Mobile Telecommunications System (WCDMA/UMTS) devices on sleep were analysed.
Methods: Thirty healthy young men (range 18–30 years) were exposed three times per exposure condition while their sleep was recorded. Sleep was evaluated according to the American Academy of Sleep Medicine standard and eight basic sleep variables were considered.
Results: Data analyses at the individual level indicate that RF-EMF effects are observed in 90% of the individuals and that all sleep variables are affected in at least four subjects. While sleep of participants was affected in various numbers, combinations of sleep variables and in different directions, showing improvements but also deteriorations, the only consistent finding was an increase of stage R sleep under GSM 900 MHz exposure (9 of 30 subjects) as well as under WCDMA/UMTS exposure (10 of 30 subjects).
Conclusions: The results underline that sleep of individuals can be affected differently. The observations found here may indicate an underlying thermal mechanism of RF-EMF on human REM sleep. Nevertheless, the effect of an increase in stage R sleep in one third of the individuals does not necessarily indicate a disturbance of sleep.

1. Introduction

Effects of radio frequency-electromagnetic fields (RF-EMF) exposure on the power spectrum of the Non-REM (NREM) sleep electroencephalogram (EEG) have repeatedly been shown (for review see SCENIHR (2014) and Schmid et al. (2012a)). On the other hand effects on sleep parameters characterizing the macrostructure of sleep have less often been reported and the observed effects are less consistent (see Table 1). Altogether 11 out of 19 studies did not find any effect of RF-EMF exposure while eight reported an effect on at least one sleep parameter. The number of investigated parameters, however, varies considerably between studies and is not explicitly mentioned in all of them. The very first study looking at effects of exposure to RF-EMF in the mobile phone communication frequency range (Mann and Roschke, 1996) found a significantly shorter sleep latency and a significantly less amount of R sleep after an 8 h exposure to a pulsed (217 Hz) 900 MHz field with 0.5 W/m^2 power flux density in a sample of 12 young males. This observation could not be confirmed by the same group in studies with a lower (0.2 W/m^2) (Wagner et al., 1998) and a higher (50 W/m^2) (Wagner et al., 2000) power flux density. A significantly reduced amount of wake after sleep onset has been observed by Borbély et al. (Borbely et al., 1999) in a sample of 24 young males after an intermittent exposure (15 min on/15 min off) for 8 h during the night with a pulsed 900 MHz base station signal

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Table 1
Main findings of studies on electromagnetic fields associated with mobile phone technology on sleep architecture.

Authors	*N*	*n/Gender*	*Age*	*Signal type*	*Exposure duration*	*Number of variables (macrostructure)*	*Changes with exposure*
Mann and Roschke (1996)	12	Males	21–34	GSM 900 (217 Hz) Handset-like signal	During 8 h bed time	10 classical sleep variables + duration of various sleep stages in 1st, 2nd, 3rd of the night	Reduced sleep latency Reduced REM sleep (% SPT)
Wagner et al. (1998)	22	Males	18–37	GSM 900 (217 Hz) Handset-like signal	During 8 h bed time	10 classical sleep variables	No effects
Wagner et al. (2000)	20	Males	19–36	GSM 900 (217 Hz) Handset-like signal	During 8 h bed time	12 conventional sleep parameters	No effects
Borbely et al. (1999)	24	Males	20–25	GSM 900 (2, 8, 217, 1736 Hz) Base station like signal	Alternating 15 min on-15 min off intervals during entire night sleep	Sleep latency and sleep stages according to standard criteria 1st, 2nd half, entire night	Reduced WASO
Huber et al. (2000)	16	Males	20–25	GSM 900 (2, 8, 217, 1736 Hz) Base station like signal	30 min prior to a 3 h daytime sleep episode in the morning after 4 h of restricted night sleep	9 sleep variables according to standard criteria	No effects
Huber et al. (2002)	16	Males	20–25	GSM 900 (Non-modulated continuous wave and pulse-modulated signal) Handset-like signal	30 min prior to 8 h bed time	9 sleep variables according to standard criteria	No effects
Hinrichs et al. (2005)	13	12 Females	20–28	GSM 1800 (Far-field characteristic, 1736 Hz pulse frequency) Base station like signal	Whole night	14 classical sleep parameters	No effects
Loughran et al. (2005)	50	23 Females	18–60	GSM 900 (217 Hz) handset-like signal	30 min prior to 7 h night sleep	10 visually scored sleep variables	Reduced REM sleep latency
Hung et al. (2007)	10	Males	18–28	GSM 900 (2, 8, 217 Hz) Handset-like signal	30 min prior to a 90 min sleep opportunity in the afternoon (13:30 h) after restriction of night sleep to 6 h	1 Parameter (sleep onset : 3 consecutive min S2)	Prolonged sleep latency
Fritzer et al. (2007)	10	Males	22–37	GSM 900 (2, 8, 217 Hz and 1736 Hz) handset-like signal	8 h	10 classic sleep variables and 7 additional REM-parameters	No effects
Regel et al. (2007)	15	Males	20–26	GSM 900 (2, 8, 217 Hz and 1736 Hz) Handset-like signal	30 min prior to 8 h bed time	9 visually scored sleep variables	No effects
Danker-Hopfe et al. (2011)	30	Males	18–30	GSM 900 (217 Hz), Hand-set like signal WCDMA/UMTS (1966 MHz)	8 h during sleep	177 variables including 15 conventional parameters reported	Increased stage REM sleep and decreased NREM stage 2 sleep, less stage shifts from slow wave sleep to NREM stage 1 sleep.
Lowden et al. (2011)	48	27 Females 21 Males	18–44	GSM 884 (2,8,217 Hz and 1736 Hz) Handset-like signal	3 h prior to sleep	15 sleep scoring variables	Increased NREM stage 2 sleep, decreased NREM stage 4 sleep and slow wave sleep, increased NREM stage 3 latency