### Effects of Exposure to GSM Mobile Phone Base Station Signals on Salivary Cortisol, Alpha-Amylase, and Immunoglobulin A<sup>1</sup>

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**Objective** The present study aimed to test whether exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phone base stations may have effects on salivary alpha-amylase, immunoglobulin A (IgA), and cortisol levels. **Methods** Fifty seven participants were randomly allocated to one of three different experimental scenarios (22 participants to scenario 1, 26 to scenario 2, and 9 to scenario 3). Each participant went through five 50-minute exposure sessions. The main RF-EMF source was a GSM-900-MHz antenna located at the outer wall of the building. In scenarios 1 and 2, the first, third, and fifth sessions were "low" (median power flux density  $5.2 \ \mu$ W/m<sup>2</sup>) exposure. The second session was "high" (2126.8  $\ \mu$ W/m<sup>2</sup>), and the fourth session was "medium" (153.6  $\ \mu$ W/m<sup>2</sup>) in scenario 1, and vice versa in scenario 2. Scenario 3 had four "low" exposure conditions, followed by a "high" exposure condition. Biomedical parameters were collected by saliva samples three times a session. Exposure levels were created by shielding curtains. **Results** In scenarios 1 and 2, a higher concentration of alpha-amylase related to the baseline was identified as compared to that in scenario 3. IgA concentration was not significantly related to the exposure. **Conclusions** RF-EMF in considerably lower field densities than ICNIRP-guidelines may influence certain psychobiological stress markers.

Key words: GSM base stations; Mobile phone; Salivary IgA; Alpha amylase; Cortisol; Radiofrequency electromagnetic fields (RF-EMF)

#### INTRODUCTION

The use of mobile phones has increased dramatically over the last decade. Simultaneously, public concern about possible adverse effects of exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phones and mobile phone base stations on health has emerged. Although there is a large number of studies dealing with effects associated with using mobile phones, the number of publications on possible influences of base stations is (a Medline comparatively small still search performed on July 23, 2008 revealed 46 related articles only, with only 8 reporting original research in humans).

A few cross sectional studies have shown correlations between base-station originated EMF-exposure and subjective symptoms<sup>[1-5]</sup>. Experimental studies of short term exposure to EMFs emitted by base stations are rare, and their results are not unambiguous<sup>[6-8]</sup>, except the one reported by Eltiti and his colleagues<sup>[7]</sup> which included physiological measurements as well.

Most of the reports focusing on endocrine responses or the immune system published so far were limited to *in vitro* studies or animal assays<sup>[9-12]</sup>. The experiments which were conducted under laboratory conditions applied mobile phone signals differing considerably from base station signals. The advantage of a better control of relevant conditions

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has to be balanced against the artificiality of the exposure scenario. Our present study is an attempt to improve ecological validity and at the same time to preserve internal validity by performing experiments in a field laboratory (a room in a kindergarten suitably adapted for the purpose of the study), with a real world exposure source (a continuously operating base station) where actual exposure of participants was manipulated by different amounts of shielding. In order to identify potential effects on the bodily defence system, we immunochemically or enzymatically measured the concentrations of cortisol, alpha-amylase, and immunoglobulin A (IgA) in the saliva of 57 healthy persons. Cortisol is a well-established indicator of stress, used in routine clinical practice and research and also in experiments on EMF<sup>[13]</sup>. Another marker of stress that has recently acceptance is the gained salivary enzyme alpha-amylase, also representing a surrogate pointer of the psychobiology of stress<sup>[14]</sup>. The major immunoglobulin class present in saliva is IgA and has been discussed to function as an immediate defence protein against possible infections via food and air<sup>[15]</sup>. In addition, IgA is of major interest in connection to stress [16]

#### MATERIALS AND METHODS

#### Study Design and Ethical Considerations

Our study followed the design of a double blinded experiment. In our recent publication dealing with effects on well-being, the study design used had been described in detail<sup>[17]</sup>: 57 participants were exposed to different levels of RF-EMF and randomized into three experimental scenarios. The age range was from 18 to 67 years; 61.4% of the volunteers were female, and 38.6% male. Detailed oral and written information about the test design and possible risks was given. After the test persons had signed informed consent letters, medical histories were questioned. All procedures, and especially all actions in the context of data security, were consistent with the ethical guidelines stated by the expanded Helsinki Declaration and American by the Psychological Association<sup>[18-19]</sup>.

#### Exposure System and Procedure

Experiments were performed in a kindergarten room located in Salzburg city. Outside the experimental room, a GSM micro-cell omni antenna (900 MHz) was mounted on the outer wall, and a number of further GSM 900 and 1 800 MHz base stations were situated in the area surrounding the building. During all the experimental sessions, band-specific exposure levels, variations of GSM 900 uplink and downlink, GSM 1 800 uplink and downlink, UMTS uplink and downlink, DECT and ISM 2.4 GHz were permanently recorded using a microwave dosimeter (ESM-140, Maschek, Kaufering, Germany). In addition, frequency selective measurements were performed using a professional FSH-3 spectrum analyzer (Rhode und Schwarz; Munich, Germany) that continuously recorded spectra and their electrical field strengths within the frequency band 30 to 3.000 MHz. Technical oversight of the study was done by an accredited expert for EMF measurements (Dr.-Ing. Martin Virnich, ANBUS Analytik GmbH, Fuerth, Germany).

Different exposure levels were produced by variation of shielding ("Swiss Shield Naturell"; ESAG GmbH., Vienna, Austria) and non-shielding placebo curtains that were optically indistinguishable. To produce a defined area of entry of the base station signal, the walls had been covered with shielding paint ("HSF53", YShield, Pocking, Germany) except for an area in close proximity to the base station antenna mounted at the outer edge of that wall. Every experiment consisted of 5 sessions of 50 min each and was carried out between 9:00 a.m. and 1:30 p.m., to minimize chronobiological variation across the subjects. During a pre-experimental period of one hour in between 8:00 and 9:00 a.m., persons were kept in maximum shielding, while health status information was obtained and psychological questionnaires were filled in. Each test person was then subjected to one of the three exposure scenarios following computerized randomization tables. Before the first session and during every of the 5 min breaks in between the sessions, participants were asked to leave the test room, to drink a glass of tap water, and to use a bath room if necessary.

During the experiments, the test persons sat on a upholstered wooden chair in a distance of about 6 meters from the micro cell antenna mounted on the outside of the building but invisible to them. Changing shielding curtains to obtain experimental variation of exposure levels was done by a technician during breaks, imperceptible to both the test person and the experimenter. The shielding curtains were always concealed by normal white curtains; therefore, neither the participants nor the experimenter had a clue as to the exposure condition. During the first five min of every session, measurements of field strength and field distributions were carried out by scanning head and thorax areas in an approximate five centimeters distance to the sitting test person using a dosimeter (ESM-140, Maschek, Kaufering, Germany; dynamic body measurements). Afterwards, the dosimeter remained fixed about 30 centimeters from the head of the test person and recorded field

strengths during the whole experiment (permanent static body measurements).

Twenty-two persons were subjected to experimental scenario 1 and 26 to scenario 2. Among them exposure level was low in the first and third of the five test sessions. Medium or high exposure levels were established in sessions 2 and 4, respectively. Scenario 3 included only nine persons and served as a control group with four subsequent sessions of low exposure level. In order to possibly gain additional information, these four low exposure sessions were followed by a fifth session with high exposure level. The small sample size in scenario 3 was due to earlier termination of measurements because the kindergarten was no longer available as a field laboratory.

#### Biochemistry

Saliva sample preparation In every session saliva samples were taken after 10, 25, and 45 min for biochemical analyses, using Salivette saliva collection devices (Sarstedt, Nürnbrecht, Germany). For each sampling, Salivettes were left for 5 min in the mouth. Immediately after sample collection, Salivettes were centrifuged for 5 min at 1000 x g, and the saliva specimen spun into 100 µL of 100 mmol/L HEPES pH7.0, 1 mg/mL bovine aprotinin to protect against proteolytic degradation. Thereafter, all saliva samples were stored in an ice water bath until the end of the daily exposure scheme. Individual saliva samples were then aliquoted and frozen at -20 °C until analysis. Aliquoted samples were used only once and residual material discarded after the test and autoclaved.

Biochemical analyses All chemicals and biochemicals used for saliva assays were purchased from Sigma-Aldrich (Taufkirchen, Germany) unless noted otherwise. 96-well microplates were from (Nuertingen, Greiner BioOne Germany). For absorbance measurement, a Sunrise microplate reader (Tecan, Grödig bei Salzburg, Austria) was used. Washing of ELISA-plates was done with a Wellwash 4 microplate washer (Thermo Electron, Waltham, MA, USA). Data calculation was performed using Deltasoft software (Biometallics, Princeton, NJ, USA).

Determination of the total protein content of saliva samples was done following the method of Bradford<sup>[20]</sup> using bovine serum albumin as standard.

Salivary cortisol levels were examined by a competitive enzyme-linked immunoadsorbent assay (ELISA) on microplates coated with goat-antirabbit-IgG with rabbit anti-cortisol-antiserum (Fitzgerald, Concord, MA, USA) and a cortisol-3-O-adipic acid dihydrazide-horseradish peroxidase (HRP) conjugate as specific competitor, synthesized essentially as described by Basu *et al.*<sup>[21]</sup>. HRP activity was measured with 0.1 mg/mL tetramethyl benzidine and 0.01%  $H_2O_2$  in 0.1 mol/L sodium acetate pH 6.0 at room temperature and detected at 450 nm (reference 595 nm). Saliva samples were prediluted in PBS immediately prior to the assay. All samples were assayed in triplicates, and cortisol concentrations calculated with respect to appropriate standard concentrations of cortisol (hydrocortisone) run on each plate using a 4 parameter fit equation. Detection range was 0.05 to 20 ng cortisol/mL as defined by 10 versus 90% B/B<sub>0</sub>.

Salivary α-Amylase (1,4 a-D-glucanohydrolase, EC 3.2.1.1) was assayed essentially according to the method of Gillard et al.<sup>[22]</sup> using 1 mmol/L p-nitrophenyl a-maltoside as substrate with some minor modifications and adaptation to a microplate format. Briefly, 10 µL of saliva samples were diluted with 100 µL of 11 mmol/L p-nitrophenyl α-maltoside in 11 mmol/L HEPES pH 7.0 prewarmed to 37 °C. Absorbance was immediately measured at 405 nm (reference 595 nm). Plates were then further incubated for 4 h at 37 °C, or in case of very low activities, also overnight. Absorbance was measured again at the end of the incubation period and subtracted by the respective zero-time-point values, and the increase of specific absorbance was calculated per hour. Assays were performed in triplicates, and enzyme activities calculated as mU/mL with respect to the molar extinction coefficient of p-nitrophenole, with 1 mU defined as a substrate conversion of 1 nmol/min in an assay volume of 1 mL.

Salivary IgA (sIgA) concentrations were measured using a sandwich ELISA with a matched pair of mouse monoclonal anti-human-IgA antibodies (G18-1 for capture, and alkaline phosphatase-labeled G20-359 for detection, both from Pharmingen (Becton-Dickinson, Vienna, Austria). Just before the assay, saliva samples were prediluted in phosphate buffered saline (PBS). Alkaline phosphatase activity was measured with 10 mmol/L 4-nitrophenylphosphate in 0.1 mol/L diethanolamine-HCl, 2 mmol/L MgCl<sub>2</sub>, pH 9.5 at room temperature, and detected at 405 nm (reference 595 nm). All samples were assayed in triplicates, and sIgA concentrations were calculated with respect to appropriate standard concentrations of human IgA run on each plate. Linear detection range was 25 to 500 ng IgA/mL.

#### Data Handling

Values obtained for the different parameters of each individual test person were corrected for dilution by the aprotinin-buffer additive and normalized to the mean values of the first exposure phase (i.e. maximum shielding) to compensate for the variation in individual levels of the parameters tested. For cortisol, each sample was corrected for the diurnal drift in morning cortisol levels based on the individual awakening times of the test persons using a 3rd degree polynomial equation deduced from the data published by Westermann and his co-workers<sup>[23]</sup>.

#### Statistics

For statistical data analyses, the software packages *SPSS* 14.0 (SPSS, Chicago, IL, USA), *Statistica* 6.0 (Statsoft, Tulsa, OK, USA) and Sigma Plot 10.0 were used. All values for each of the sessions were related to the baseline concentrations (session 1) of the particular parameter.

All saliva parameters were analyzed by ANOVA for repeated measurements in one factor (sessions) and fixed between-subjects factor (scenario). Scenario/ sessions interaction would indicate exposure effects. In addition, linear contrasts were used to compare the different exposure levels. In a second step, the mean concentrations of sessions 2-4 of cortisol, IgA and alpha-amylase were calculated. Means were then related to the baseline. In order to obtain homogeneity of variances the values were log transformed.

Age, gender, and degree of self rated electromagnetic hypersensitivity were included as covariates in these analyses.

#### Dosimetry

Narrow band measurements via spectrum analyzers showed that the RF-EMF spectrum was dominated by two GSM-900 MHz downlink signals, one broadcast control channel (BCCH) plus one traffic channel (TCH), originating from a 50-cm-micro-cell omni-directional antenna mounted on the outer wall of the building. During the experiments, the GSM 900 antenna operated with constant BCCH and variable TCH output, leading to a fluctuation in field strength by a factor of two (3 dB). At exposure situation "high", other RF-EMF sources like public radio, TV channels, GSM 1800, DECT, UMTS, WiFi etc., had power densities of at least a factor of 400 below the GSM-900 downlink signals mentioned before.

Results of the permanent (static) measurements showed stable exposure conditions during each of the sessions. Overall power flux densities given as a median were 5.2  $\mu$ W/m<sup>2</sup> (5th percentile (*P5*)=1.4, 95th percentile (*P95*)=15.5) for low, 153.6  $\mu$ W/m<sup>2</sup> (*P5*=21.3, *P95*=468.0) for medium, and 2126.8  $\mu$ W/m<sup>2</sup> (*P5*=827.3, *P95*=4908.4) for high. Table 1 shows power flux densities by scenario and session. The dynamic body measurements via the ESM-140 showed comparable power densities for the three key body regions (forehead, mouth, chest) examined.

Power Flux Densities During the Different Scenarios									
R	Scen	ario 1	Scenario 2			Scenario 3			
Session	P5	P50	P95	P5	P50	P95	P5	P50	P95
1	1.6	5.2	15.7	1.5	5.7	14.7	1.9	6.5	26.0
2	694.5	1858.0	3829.8	30.5	168.4	446.5	1.5	5.1	16.5
3	1.1	3.9	13.8	1.4	5.4	16.0	1.6	5.0	16.0
4	16.0	128.8	490.8	912.6	2130.5	5389.7	1.6	5.2	14.3
5	1.2	4.7	14.3	1.6	5.6	14.1	1289.8	2939.0	4967.7

TABLE 1

*Note.* 5th, 50th (median), and 95th percentiles of the distribution of microwave power densities for each session and scenario, measured by microwave dosimeter ESM-140 placed 30 cm from the head of the person. Results for "High exposure" sessions are presented in dark grey background, and "medium exposure" sessions in light grey background.

#### RESULTS

#### Sample Characteristics

Among the 57 participants, 35 were female, and 22 were male, aged 18-67 years (mean 40.72, *SD* 12.75). Table 2 shows some important characteristics of the sample. There were no statistically significant differences between the groups allocated to the three scenarios in none of these variables and in baseline levels of saliva parameters as well.

## Exposure and Variation of Concentrations of Saliva Parameters

Variance analysis revealed a significant effect for session (P<0.001) in cortisol, but not for alpha-amylase and IgA. No significant effects for scenario and for scenario/session-interaction were detected for any parameter. *A posteriori* tests showed a significant increase of the cortisol concentration in scenario 3 from session 4 (low exposure; M=1.40, SD=0.46) to session 5 (high exposure; M=2.01, SD=0.76) (P=0.002).

Linear contrasts of sessions 2-4 in scenario 1 (HM=high-low-medium exposure) and scenario 2 (MH=medium-low-high exposure) vs. scenario 3 (LL=low-exposure throughout) reached the level of significance in alpha-amylase (P=0.037) (Table 3).

Participants in scenarios 1 and 2 had a significantly higher alpha-amylase concentration, related to the baseline, than those in scenario 3. Cortisol and IgA showed no significant contrasts between the scenarios.

#### TABLE 2

	Scenario 1	Scenario 2	Scenario 3	Р
Age	38 (13)	44 (13)	39 (12)	0.298
Female	55%	69%	56%	0.538
City >20.000 Inhabitants	59%	58%	78%	0.544
Health Concerns with Base Stations	28.95 (20.37)	27.08 (22.06)	24.89 (23.40)	0.814
sCortisol (ng/mL)	2.97 (1.36)	3.66 (2.18)	2.92 (1.07)	0.341
sAlpha-Amylase (mU/mL)	1.75 (1.09)	2.47 (1.47)	2.14 (1.02)	0.142
sIgA (µg/mL)	263 (236)	180 (111)	142 (131)	0.154

*Note.* Characteristics of subjects allocated to the scenarios, age, gender, city of inhabitance, and health concerns regarding base stations (higher value indicates higher concern). Alpha amylase, IgA, and cortisol in saliva from baseline measurements. *P*-values from Kruskal-Wallis-Test or Chi-Square-Test. Results are expressed as means+SD (standard deviations).

TABLE 3

Mean Relative Changes of Saliva Parameter Concentrations (Linear Contrast Analysis)								
	HM	MH	LL	P*	P **	P ***		
Cortisol	1.213 (0.257)	1.186 (0.380)	1.356 (0.345)	0.333	0.228	0.244		
Alpha-Amylase	1.049 (0.351)	1.004 (0.228)	0.843 (0.130)	0.055	0.052	0.037		
IgA	0.973 (0.277)	0.972 (0.245)	1.167 (0.359)	0.100	0.127	0.087		

*Note.* Mean relative changes (in brackets: standard deviations) in relation to baseline concentrations of saliva parameters during sessions 2 to 4 per scenario. (HM = high-low-medium exposure, scenario 1; MH = medium-low-high exposure, scenario 2; LL=low-low-low exposure, scenario 3. *P* values indicate results from univariate linear contrasts, log-transformed data: \* = HM vs. LL, \*\* = MH vs. LL, \*\* = HM, and MH vs. LL. Diurnal change correction was applied for cortisol.

#### Single Case Analysis

In an explorative analysis of individual participants, we found some cases worth to be mentioned. The cortisol curve of a male scenario 2-participant shows a delayed, but extremely strong reaction in the last session. Here, an increase to about 400% of the normalized base level was observed. Amylase concentration changes in a female subjected to scenario 2 suggested visible dose-related exposure effects in sessions 2 (medium) and 4 (high). The opposite reaction was observed in IgA of another female participant of scenario 2. For a participant of scenario 3, we found an increase of the IgA concentration during the experiment that stopped abruptly during the high exposure in session 5, in effect even leading to a decrease.

#### DISCUSSION

Compared to traditional laboratory experiments, field laboratory experiments in the area of EMF research show some distinct advantages. First, in our daily life situations, we are not exposed to constant flux densities like those present in an anechoic chamber usually applied in most experimental setups. In real life, as in field laboratory experiments, the organism has to permanently adapt to varying exposure levels with uneven distributions of the field, for instance, because of reflections. Second, for the test person, the situation present in a field laboratory is much less artificial. This is a central issue, since psychological and physiological coping of the experimental situation could overlay EMF effects. On the other hand, in laboratory experiments, a number of confounding variables can be controlled.

Biochemically measuring the concentrations of certain stress and immune system parameters is regarded reliable. Assays used in our study for analyzing cortisol and IgA are widely accepted methods applied in routine clinical work as well as in experimental investigations. The method used to detect alpha-amylase is an enzymatic assay available than thirty vears<sup>[22]</sup>. Another for more well-established method, the Bradford-assay, was applied to assess the summative protein concentration as a control parameter<sup>[20]</sup>. Research reports have

shown that the reliability of measurements in saliva is comparable to that obtained in serum, and today saliva measurement methodologies are increasingly used<sup>[14, 16, 24-28]</sup>.

In the present study, analyses of variance with repeated measurement factor (time) revealed a significant effect for time in cortisol, but no effects in the other parameters tested. We also found a significant cortisol level change in scenario 3 from session 4 (low exposure) to session 5 (high exposure) (P=0.002). Such kind of change could not be detected in the other scenarios in that intensity. Furthermore, this was accompanied by an insignificant decrease (P<0.10) of IgA level detected in parallel. These results seem to be consistent with other studies that identified cortisol as a modulator of immune function, down regulating immune parameters such as IgA<sup>[23-24,29]</sup>.

In line with available evidence, the normal daily cortisol concentration pattern should not increase at midday unless there is a stressor. Therefore, it is justified to assume that the higher exposure was responsible for this change in scenario 3 Nevertheless we did not find any exposure effects on cortisol in scenarios 1 and 2-although these scenarios included a higher number of participants. This situation might be explained with a finding that was assumed to be present, but had not yet been described elsewhere to the best of our knowledge; when analyzing individual time course curves of cortisol (and, to a lighter degree, possibly also of the other parameters tested in this study), it appeared evident to us that in some persons, effects on concentration seemed to be present during the same phase of exposure, and in other individuals, up to approximately one hour or probably even longer delayed effects can be observed. In other words, there might be some types of responders who reacted immediately, while others reacted in a delayed fashion, or even did not react at all at higher exposure doses applied for 50 min only. This observation might also explain why in scenarios 1 and 2, statistical significance was not reached for cortisol, because such effects "subtract" each other when analyzing time curses.

The missing significance in scenarios 1 and 2 might also be attributed to the different exposure patterns in the scenarios used. In scenarios 1 and 2, test persons were shielded much shorter before a high exposure condition. It was likely that participants had already been exposed to EMFs on their way to the field laboratory. When they arrived at the test place, they came into a situation that shielded them much higher than in usual daily life situations. In scenario 3, participants remained in that situation for more than 4 hours (including the pre-testing period). It was likely therefore that their stronger cortisol reaction during high exposure came from a more relaxed, regenerated body, already somewhat adapted to optimum shielding during the prolonged period of low exposure.

It is obvious that some of these results raise great doubt that changes of the stress and immune parameters measured would always occur exactly within the session in which people are subjected to higher exposure levels. As onset of possible changes and symptoms are discussed controversially<sup>[30-31]</sup>, we tried to focus on further analysis of a longer period of time. For this, we summed up sessions 2 to 4 and compared scenarios 1 and 2 with scenario 3. In scenarios 1 and 2 during that time, all three different exposure levels were allocated, while in scenario 3 there was low exposure throughout the phases. Using that kind of analysis, statistically significant differences in alpha-amylase levels were observed: higher exposed participants in scenarios 1 and 2 showed higher concentrations of alpha-amylase in relation to the baseline than scenario 3 participants. For cortisol and IgA, no significant change was found using that kind of analysis.

On one hand, alpha-amylase was used as a substitute parameter to indirectly measure the adrenalin vs. noradrenalin balance<sup>[32]</sup>. On the other hand, recent research on salivary alpha-amylase gave strong evidence that alpha-amylase itself was a reliable parameter for stress, although its exact connections to cortisol remained largely unclear<sup>[25]</sup>. Higher alpha-amylase concentrations seem to show higher levels of stress. Therefore, one could interpret that the differences presented here are caused by higher exposure levels in scenario 1 and 2. On the other hand, amylase does not increase in session 5 at high exposure, but cortisol does. Any possible delayed effect on amylase concentration of session 5 in scenario 3 might be present but could not be measured in our study, as saliva sampling ended within session 5.

In addition to our statistical analyses, we explored reactions of individual participants. We found noticeable curves in some individuals, as described in the results section. In sum these findings suggest that some people seem to react strongly on exposure. Further, there seemed to be inter-individual differences regarding ignition of reaction: some of the participants showed immediate changes, others delayed changes. There was no intra-individual association between different parameters.

In general, the results presented give additional indications strengthening existing reports that contradict the hypothesis that flux densities lower than the security standards of ICNIRP (International Commission on Non-Ionizing Radiation Protection)

would not induce stress or might have negative effects on the human immune system. These findings were also supported by the large reviews contained in the Bioinitiave Report 2007, especially those of section 7 dealing with stress response<sup>[33]</sup>, and section 8 on effects on the human immune system<sup>[34]</sup>. Nevertheless, studies with the same or comparable parameters in the EMF area are scarce. Mann and his colleagues<sup>[35]</sup> investigated cortisol concentrations during RF-EMF exposure at night. Cortisol showed a slight increase immediately after the onset of exposure, persisting for approximately 1 hour. The authors concluded that a kind of adaptation took place - as also discussed by us above. Radon et al.<sup>[13]</sup> measured salivary IgA, melatonin and cortisol in eight male persons. Although they used rather high power flux densities (1 W/m<sup>3</sup>), they found no significant differences between exposure and sham. Unfortunately, sample size was very small and raw data instead of relative changes had been analyzed by that research group, although variance in saliva parameters is usually large. Djeridane et al.<sup>[36]</sup> measured serum cortisol in 20 men for four weeks of regular mobile phone RF-EMF exposure. During the test period, cortisol concentration decreased by 12 % and increased again to pre-level in the post-experimental period. Obviously, this seems to be opposite to our findings and to the findings of Mann and his colleagues. Nevertheless, this actually makes sense: it is very likely that healthy subjects exposed only a short time to EMF react "healthily" to this stressor, with an increased cortisol level. After longer periods of exposure-several days, weeks, months-the body cannot keep on this short time-reaction to the stressor. Research on Multiple Chemical Sensitivity (MCS) had shown that MCS-patients partly could not adequately react to stress and show very low levels of cortisol<sup>[37]</sup>. This could be understood as a long term result of exposure to environmental hazards, in our case RF-EMFs.

Our results presented here must be seen in the context with other scientific work published recently. Friedman et al. showed that RF-EMF emitted by mobile phones could change a whole cascade of biochemical reactions<sup>[38]</sup>. The spectrum of possible effects reaches from the induction of transcription and other cellular processes to proliferation. Schwarz et al.<sup>[39]</sup> showed that EMF-signals from UMTS (Universal Mobile Telecommunication System) at 1950 MHz could cause genetic alterations in some human cells in vitro. They observed a significant increase of comet tail factor and centromere-negative micronuclei in human cultured fibroblasts from a specific absorption rate (SAR) of 0.05 W/kg on (SAR-safety limit: 2 W/kg). Others observed similar adverse effects following GSM exposure, and several studies identified chromosomal instabilities and even genotoxic effects which also included double-strand breaks<sup>[40-45]</sup>. It is common medical study knowledge that a combination of possible genotoxic effects, a possible increase of proliferation, and a possible weakening of the bodily defence system finally might lead to severe health consequences. As reviewed by Nittby et al.<sup>[46]</sup>, RF-EMFs can also show effects on the blood-brain barrier.

#### CONCLUSION

In conclusion, our work supports the assumption that RF-EMF in considerably lower field densities than ICNIRP-guidelines<sup>[47]</sup> can potentially influence certain psychobiological stress markers. Additional scientific work needs to be carried out, aiming to better identify the various possibilities of stress response, chronobiological mechanisms and interactions of common immune parameters. Furthermore, studies on long term effects of RF-EMF would be especially important.

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