MOBILE TELEPHONE BASE-STATIONS: EFFECTS ON HEALTH AND WELLBEING

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Abstract

The erection of thousands of mobile telephone base-stations has raised concerns about possible health effects caused by an exposure to electromagnetic fields. Until now, no epidemiological study has addressed this issue. We have investigated subjective symptoms and complaints, sleep quality, and cognitive performance in a cross-sectional study in people living in urban and rural areas for more than one year in proximity to one of ten selected base-stations.

A total of 365 subjects were included. They were investigated using computer presentation of tests and questionnaires. Simple choice reaction tasks, memory performance and perceptional speed were measured. Complaints and symptoms as well as sleep quality were evaluated using standardized methods. Field strengths of high-frequency EMFs were measured in 336 households.

Total HF-EMF as well as exposure related to mobile telecommunication were far below recommended levels (max. 1.4 mW m^{-2}, 95.percentile 0.57 mW m^{-2}). The proportion of inhabitants expressing strong concerns about adverse effects of the base-stations was low (5% in rural and 10% in urban areas).

Despite influences of confounding variables, including fear of adverse effects, a significant relation to measured power-density was found for cardiovascular symptoms and perceptual speed.

This pilot study was explorative, hence no far reaching conclusions can be drawn. However, effects on wellbeing and performance of very low levels of exposure to emissions from base-stations cannot be ruled out and should further be studied.

Introduction

Although there is considerable public concern about possible effects of mobile telephone base-stations on health and wellbeing no studies on that issue have been published so far. Since the introduction of modern mobile telecommunication in the early 1990ies exposure of the public to high-frequency electromagnetic fields (EMF) has about doubled [1], at least in Europe. Nevertheless, it has been stated [2] that exposure to emissions from mobile phone base-stations are not of primary interest while effects of mobile telephones themselves should be investigated. However, there is a fundamental difference between exposure from mobile phones and their base-stations that has not been considered: while exposure to emissions from mobile phones is intermittent and typically of short duration, those from base-stations could be 24 hours a day persisting for years. There is presently no consensus about long-term effects of EMFs. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) declared such effects as not established [3]. Evidence in favor and against this position is weak, because studies on that issue are scarce and some suffer from methodological deficiencies. From a precautionary point of view, however, the evidence for long-term effects is sufficient to warrant a thorough examination of possible effects on wellbeing and health from exposures to mobile telephone base-stations. It has been argued that if there are detrimental effects from exposures to modern telecommunication then we should have recognized such effects earlier due to implementation of powerful radio and television transmitters. This argument is invalid for two reasons: first of all there are only very few studies of effects from radio and TV transmitters, ecological and cluster studies mainly on brain tumors and cancer of the hematopoetic and lymphatic tissues [4-8] and on sleep and other endpoints [9, 10] that are compatible with the assumption of a moderately elevated risk, and second because emissions from base-stations of telecommunication networks differ substantially from exposures to other sources of high-frequency EMFs. It is not only the carrier frequency (900 and 1800 MHz range) that is different, but, more important, the type of modulation. While radio and TV signals are frequency or amplitude modulated, mobile telecommunication is pulse modulated with 217 Hz and multiples thereof (superframes of 8 Hz and other features like DTX and power regulation have to be considered too). Although TV signals have also a pulse component, the dynamic range is quite different as is the frequency and pulse duration. Within pulses of the GSM system the carrier wave is phase modulated, hence the amplitude remains more or less constant. Due to the very short coherence time, phase modulation is likely without biological significance, however, the ELF components of pulse modulation could be important. It is presently unknown why pulsed fields are biologically more effective than continuous waves with equal rate of energy deposition. There are a number of studies that were dedicated to exposures from mobile phones, that can cautiously be applied to immissions from base-stations as well, because exposure was in the far field. These investigations include a long-term animal study on lymphoma [11] and studies on sleep [12-14]. No human studies of long-term exposure have been reported so far, but there are numerous reports from physicians and action groups that installation of mobile telephone base-stations is associated with a number of symptoms including sleep disturbances, head aches, palpitations, vertigo, and decrease of cognitive performance in those living in the vicinity of the facility. Due to their unsystematic nature these reports cannot be taken as proof of adverse effects of these exposures. There is also the possibility that these symptoms are due to fear about negative effects and not results of actual exposure, although there are reports of symptoms occurring before subjects learned about the presence of the base-station. Of course, the steep increase in the number of base-stations during the last decade must coincide now and then stochastically with the emergence of health problems in a number of neighbors.

Whether or not there is actually an association between exposure to emissions from mobile phone base-stations and health symptoms can only be determined by epidemiological investigations. The study reported here is a pilot study on that issue. The following questions should be answered:

- How can the methodological problems, especially controlling for confounding conditions, be solved?
- What is the relation between immissions from mobile telecommunication and other sources of high-frequency EMFs?
- Are there indications of an association between exposure and symptoms?

Material and Methods

Starting point was the selection of 10 mobile phone base-stations, five in the rural area (in Carinthia) and five in densely occupied urban areas (in Vienna). These base-stations were selected by the following procedure. Two providers were asked to name about five base-stations within each region that fulfill the following requirements:

- The antenna must already be operating for at least two years
- There should have been no protest of neighbors to the erection of the base-station
- There should be no other base-station (by the same or other providers) nearby (which was possible to fulfill only in the rural area)
- There should be preferentially only transmission in the 900 MHz band.

From the specified base-stations (in total 21) selection for the study was based on inspection of the local conditions. Only those base-stations were finally eligible where within a radius of about 200 meters enough people were living to ensure participation of at least 18 subjects. By this procedure six base-stations in the rural and seven in the urban area were selected. The final decision was made such that in all parts of Carinthia and in five different districts of Vienna base-stations were included.

After selection of base-stations study areas were defined based on specifications of the antennae and local orographic conditions. An inner and an outer area were specified and within these areas an equal number of subjects should be included for investigation in order to ensure a sufficient gradient of exposure. Fig. 1 shows the inner area of one of the study regions in Carinthia.

Investigation was carried out by three students in Carinthia and three students and one medical technical assistant in Vienna that were trained to ensure a standardized procedure. Investigation was done by using a laptop computer. Handling was so simple that after a short introduction all subjects were able to fulfill the tasks without further interruption of the investigators. This procedure was chosen to minimize impact of investigators and because some tasks involved measurement of reaction times.

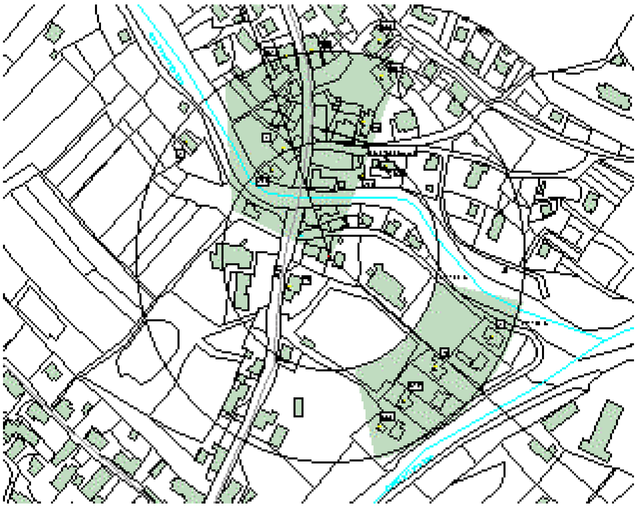

Fig.1: Example of a inner area of investigation (shaded). The directions of the main beams are indicated by straight lines.

Subject for the investigation were chosen within the selected areas by prior telephone contact in Vienna and by personal visits in Carinthia. In Vienna a random selection of households based on telephone register entries was performed, while in Carinthia houses were randomly selected by the investigators on their visit. If upon three trials no contact could be accomplished the next entry was chosen until 36 subjects, 18 within the inner and 18 within the outer area, for each base-station were investigated. Subjects were told the investigation is about environmental health issues (the specific problems of EMF exposure or base-stations was not mentioned) and will afford approx. one hour of their time. In order to be eligible, subjects must be older than 18 years and inhabit the present house for at least one year and stay usually there for at least 8 hours a day.

The investigation consisted of the following parts:

- Sociodemographic data, sources of EMF exposure within the household, regular use of mobile telephones
- Evaluation of environmental quality, subjective scaling of the impact different environmental factors could possibly have on health of the subjects
- Subjective scaling of different symptoms (Zerssen Scale, [15])
- Investigation of sleeping problems (Pittsburgh Sleeping Scale)
- Memory task (short and medium term memory)
- Choice reaction task (reaction to three different stimuli)
- Perceptual speed (comparison of two sequences of digits under speed conditions)

All questionnaires and tests were presented by the computer following a standard sequence. Data were stored in a coded format not changeable by the investigators.

While subjects were working at the computer, in Vienna air samples were taken in the sleeping room that were subsequently tested for presence of volatile organic compounds and formaldehyde. In Carinthia 24-hour noise measurements were taken and air quality was obtained from the counties routine measurement program.

After completion of the questionnaires and tests, dates were arranged for the visit of a technician to measure exposure to EMFs. Measurements of high-frequency EMFs were done by a specialist from a certified center in

Vienna (TGM). A biconic field probe (PBA 10200, ARC Seibersorf research, Austria) was used connected to a spectrum analyzer (FSP, Rhode & Schwarz). Measurements were done in the sleeping room, and in Carinthia additionally at a place where the maximum immission was expected.

A total of 365 subjects were investigated (185 in Vienna and 180 in Carinthia). In some cases EMF measurement were not possible due to the absence of the inhabitants at the arranged date. Therefore, only data from 336 subjects could be finally evaluated. Subjects were between 18 and 91 years old, 44±16 years on average. Fifty-nine percent were female, and 41% male. Average duration of residence in the house was 19±16 years, and subjects stayed for 10±5 hours a day in the immediate neighborhood.

Statistical analysis of effects of exposure to the immission from the base-station was done by analyses of covariance (ANCOVA) based on the following procedure. First the measured immissions were classified into three groups: values up to 0.05 mW m^{-2}, values from 0.05 to 0.1 mW m^{-2}, and values above 0.1 mW m^{-2}. This classification together with the area (rural vs. urban) and the interaction were the fixed factors, age, sex, usage of a mobile telephone, and the subjective rating of negative consequences on health of the base-station were used as covariables. A hierarchical model was chosen, such that the effect of the covariates on the dependent variable was tested first. By this method effects of these potentially confounding variables on the results of the fixed factors and especially on the evaluation of the influence of the immissions of the base-station can be eliminated. Normality was assessed by Kolmogorov-Smirnov tests using Lilliefors p-values. Homogeneity of variance was tested by Levene's tests. For all tests a p-value of 0.05 was considered significant. p-values between 0.05 and 0.1 were rated as statistical tendency.

Results

Immissions of high-frequency EMFs were generally low and ranged from 0.0002 to 1.4 mW m^{-2}, the greater portion of that immission was from mobile telecommunication (approx. 70%), that was between 0.00001 and 1.412 mW m^{-2}. Fig.2 shows the distribution of immissions from the GSM base-station measured in the sleeping rooms.

Subjects rated possible negative consequences of different environmental factors on their health. Base stations were rated somewhat below consequences of traffic noise and traffic exhaust (see Fig.3). There were, as expected, pronounced differences between urban and rural areas with respect to ratings of traffic immissions and particulate matter, however, rating of health consequences of base stations were almost equal in Vienna and Carinthia. Only about 8% of subjects expressed strong concerns (5% in rural and 10% in urban areas). Using a mobile phone, which was the case in 74% of subjects, did not influence ratings of possible adverse effects of base-stations .

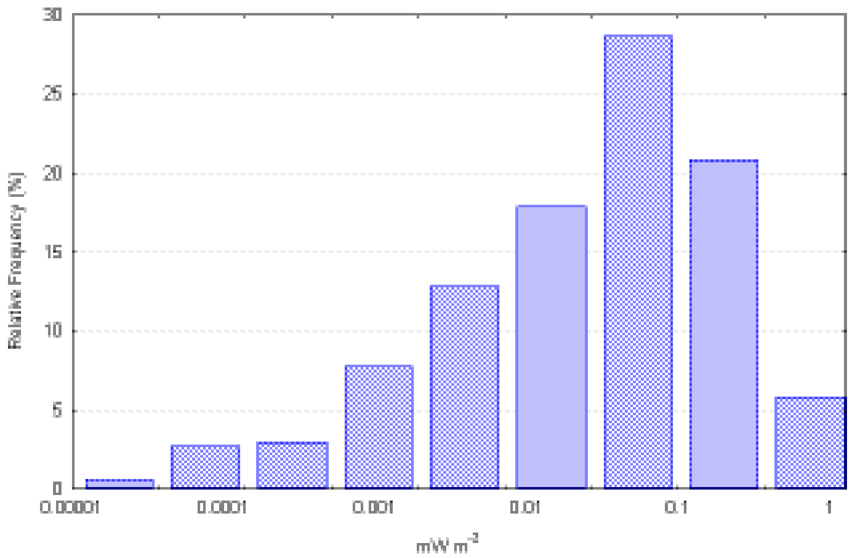

Fig. Error! Unknown switch argument.**:** Frequency distribution of immissions from the GSM base-station in the sleeping room of the subjects

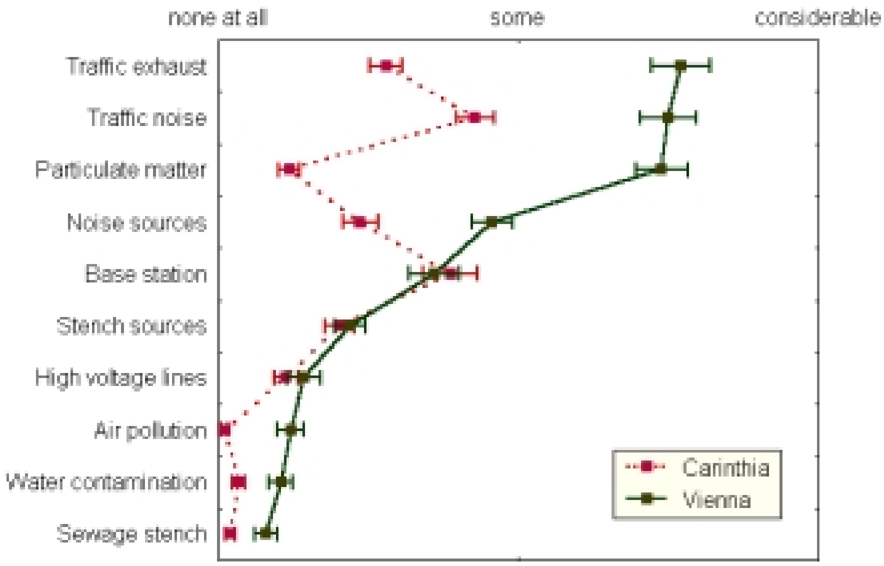

Fig. Error! Unknown switch argument.**:** Mean (±SEM) of ratings of possible health consequences of different environmental factors on subjects health for urban (Vienna) and rural (Carinthia) areas

Table 1 gives an overview of results from ANCOVA on the different tests of cognitive performance. Only p-values for the GSM immission factor are shown, table 2 shows the full table of results for the test of perceptual speed.

Table 1: Results of ANCOVA of different tests of cognitive preformance. p-values for the GSM immission factor are shown.

Test	p-value
Memory	
immediate memory	0.166
short-term memory (1 min)	0.354
short-term memory (5 min)	0.761
short-term memory (15 min)	0.883
Choice reaction task	
reaction time	0.485
total score	0.178
Perceptual speed	
total score	0.061

For perceptual speed a tendency for better performance in the lower immission category was found. Table 2 shows a highly significant effect of the area, which was due to better results in the urban area, and of age, indicating decreasing performance with increasing age.

Table 2: Detailed results of ANCOVA for total score of perceptual speed as dependent variable. Factors and covariables are shown in the column 'source of variation'.

Source of variation		df	MSQ	F	p-value
Covariates	Combined	4	54.980	19.721	0.000
	Concerns about base-station	1	2.618	0.939	0.333
	Age	1	216.469	77.648	0.000
	Sex	1	0.028	0.010	0.920
	Use of mobile phone	1	0.803	0.288	0.592
Main effects	Combined	3	28.562	10.245	0.000
	Area (rural/urban)	1	69.948	25.090	0.000
	GSM Immission	2	7.869	2.823	0.061
Interaction		2	0.036	0.001	0.999

Symptoms were grouped into three categories: Exhaustion, digestive, and cardiovascular symptoms. The average symptom scores were subjected to ANCOVA. Effect of immission from the base-station was not significant for ‘exhaustion’ (p=0.222) and digestive symptoms (p=0.590). However, cardiovascular symptom scores differed significantly for the exposure categories with higher scores as the exposure increases. Table 3 shows the details of the analysis and fig. 4 means (±SEM) for exposure categories and differentiated for subjects with and without concerns about the base-station.

Table 3: Detailed results of ANCOVA for cardiovascular symptoms score as dependent variable. Factors and covariables are shown in the column ‘source of variation’.

Source of variation		df	MSQ	F	p-value
Covariates	Combined	4	5.477	7.418	0.000
	Concerns about base-station	1	12.534	16.975	0.000
	Age	1	0.972	1.316	0.252
	Sex	1	8.045	10.895	0.001
	Use of mobile phone	1	0.358	0.484	0.487
Main effects	Combined	3	2.545	3.446	0.017
	Area (rural/urban)	1	0.106	0.143	0.705
	GSM Immission	2	3.764	5.098	0.007
Interaction		2	0.606	0.820	0.441

While there was a significant effect of sex and concerns about the base-station still the effect of immissions from the celltower was highly significant (p=0.007).

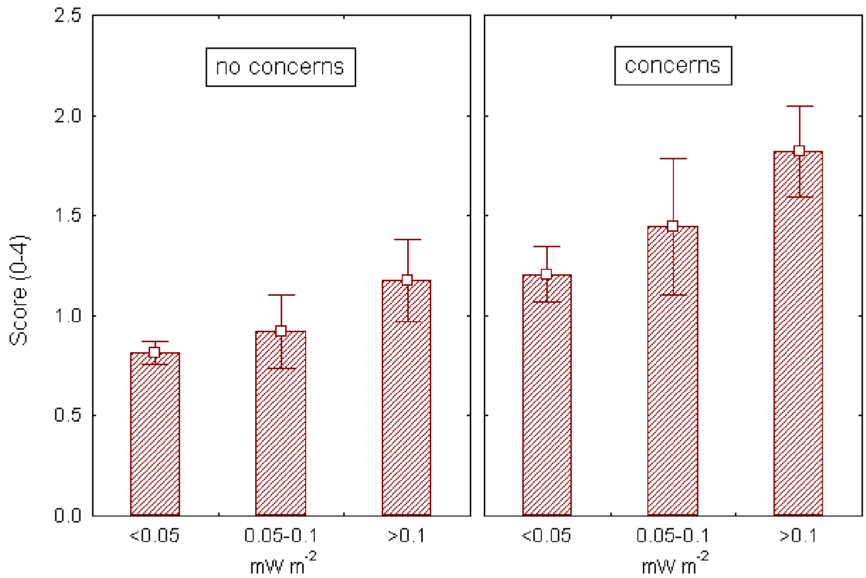

Fig. Error! Unknown switch argument.**:** Mean (±SEM) of cardiovascular symptoms score for exposure categories and stratified according to concerns expressed by subjects about negative influence of the base-station on health.

Analysis of sleep included sleep length, problems falling and staying asleep, recovery during sleep, and a number of symptoms of insufficient sleep. From these information a sleep quality score was computed and analyzed by ANCOVA. The results are shown in table 4 and fig.5.

Table 4: Detailed results of ANCOVA for sleep quality score as dependent variable. Factors and covariables are shown in the column 'source of variation'.

Source of variation		df	MSQ	F	p-value
Covariates	Combined	4	323,407	11,770	0,000
	Concerns about base-station	1	482,088	17,545	0,000
	Age	1	661,076	24,059	0,000
	Sex	1	87,286	3,177	0,076
	Use of mobile phone	1	63,176	2,299	0,130
Main effects	Combined	3	42,571	1,549	0,202
	Area (rural/urban)	1	57,795	2,103	0,148
	GSM Immission	2	34,959	1,272	0,282
Interaction		2	58,404	2,126	0,121

A highly significant effect of concerns about negative health implications of the base-station was found with poorer sleep quality in those concerned. As expected also age had a significant influence. All other factors were not significant and only a tendency was seen for sex. It is important to note that without considering the influence of the subjects concerns about the base-station the effect of exposure would have been statistically significant.

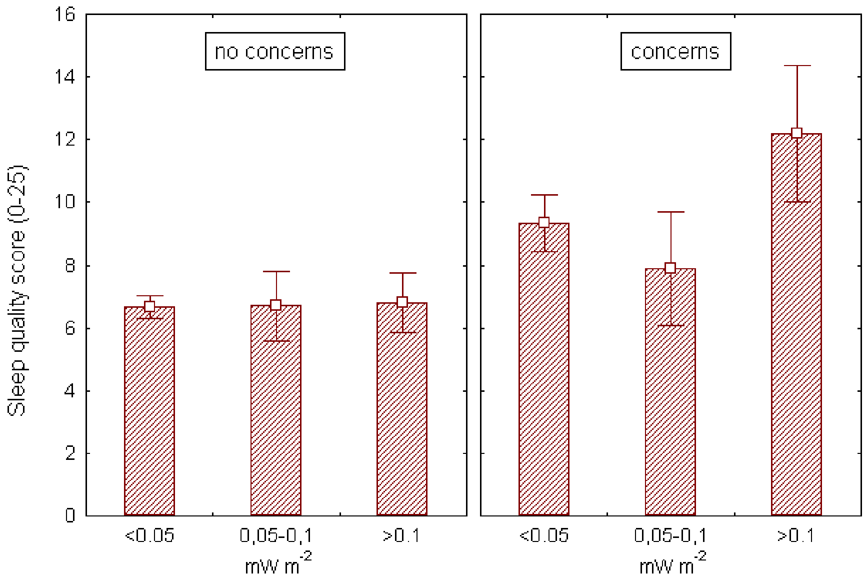

Fig. Error! Unknown switch argument.**:** Mean (±SEM) of sleep quality score (higher values indicate poorer quality) for exposure categories and stratified according to concerns expressed by subjects about negative influence of the base-station on health.

Discussion

In most countries there are no legal restrictions concerning the erection of mobile telephone base-stations that are related to protection of the public to possible adverse effects of microwave irradiation. Compliance with guidelines limiting the exposure to EMFs is easily guaranteed because the cellular structure of modern telecommunication networks forces to low emission power. Usually current guideline values like those of ICNIRP [3] are exceeded only within a few meters distance from the antenna. The basis for these guidelines are, however, short-term immediate effects from the increase of body temperature caused by absorption of electromagnetic energy. While this does not preclude the possibility that protection from thermal effects at the same time protects from other effects that occur only at longer exposure duration, there is an increasing evidence of effects in the low-dose range that cannot be attributed to heating and that are not accounted for in the derivation of the mentioned guidelines. However, it should be stressed that there are a number of not trivial problems to be solved, if this evidence should be included. E.g. it will be hardly possible to derive guideline values for a broad range of frequencies and different types of modulation.

Long-term exposure could have effects that are completely different from immediate effects and could occur without eliciting such short-term effects. This is the case for environmental conditions that lead to an accumulation within the organisms. This can be an accumulation of a substance or a metabolite, like in exposure to some air pollutants, or an accumulation of micro-lesions that occur as a consequence of the exposure. There is a great number of biologically plausible mechanisms that could finally lead to impaired health or wellbeing, but unfortunately up to now none of these mechanisms are sufficiently worked out and empirically tested to provide a solid basis for prediction and explanation of observations and likewise for derivation of guidelines. Especially concerning exposure to EMFs from modern telecommunication it is possible that not (only) the energy transported by the field is of significance but also the ELF component of the modulation. While the broadcast channel usually operates with all time slots occupied and at highest and constant power, transmission channels vary according to the number of customers connected. The lower the number of calls the more prominent the pulses. There is evidence for differences between biological effects of continuous waves and pulsed fields [see U.S. Government Interagency Working Group 1999] that cannot be explained by any established mechanism. Only the so called microwave hearing effect has been satisfactorily been attributed to thermoelastic expansion. Possible mechanisms for cumulative dose have been put forward for exposure to emissions from mobile phones [16] that may *mutatis mutandur* be applied to emissions from celltowers as well.

In interpreting the results of our study one has to keep in mind that the study was exploratory and hence no correction has been introduced for multiple testing and no precise statistical hypothesis has been formulated in advance. However, there are several results that are remarkable and that warrant further examination. Generally, ratings were higher for most symptoms in subjects expressing concerns about health effects from the base-station. There are several possible explanations for this observation: subjects who experience health problems might search for an explanation in their environment and blame whatever appears to them as a likely cause, another would be that subjects with concerns are more anxious and also tend to give a more negative view of there body functions, still another explanation could be that some people have an answer stile that is more shifted to the negative, which would affect all scales, it is also possible that there are differences in sensibility that lead to a differentiation within the population in a group that has a low threshold for adverse reactions and they correctly attribute their symptoms to the exposure and a group that is relatively unaffected. Irrespective of these explanations there seem to be effects of exposure that occur independent of the fear of the subjects that the base-station could affect their health. This is the case for cardiovascular symptoms. Although subjects with concerns about negative effects of the base-station scored higher, there is a significant gradient in both those with and those without such concerns, pointing to a direct impact of the exposure. Despite the fact that no clear relationship has been found for sleeping problems, effects on sleep could still be an intervening step in the production of these cardiovascular symptoms. The recuperation of the circulatory system during sleep is essential for its integrity. Whether prolonged exposure to low levels of ELF or pulse modulated high-frequency EMFs could interfere with trophotropic processes should further be investigated. In workers exposed to RF EMFs changes in the diurnal pattern of blood pressure were observed consistent with the assumption of an effect on regulatory functions [17].

In contrast to the evaluated symptoms no influence of concerns about negative effects of the base-station was found for cognitive performance. A slight impairment was noted only in one of the tests. The effect of exposure on perceptual speed is consistent with an earlier observation in children living near an military radio station in Latvia [18].

The results of this pilot study indicate that effects of very low but long lasting exposures to emissions from mobile telephone base-stations on well-being and health cannot be ruled out. The effects observed on performance and cardiovascular symptoms should further be studied. Especially diurnal variation in cardiovascular functions should be explored.

Acknowledgements

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References

[1] Hamnerius I, Uddmar Th. (2000): Microwave exposure from mobile phones and base stations in Sweden. Proceedings of the International Conference on Cell Tower Siting, Salzburg, p.52-63, www.land-salzburg.gv.at/celltower

[2] World Health Organisation, International EMF Project, Agenda for research. www.who.int/peh-emf/research_agenda/agenda_priorities.htm

[3] International Commission on Non-Ionizing Radiation Protection (1998) Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74:494-522

[4] Selvin S, Schulman J, Merrill DW (1992): Distance and risk measures for the analysis of spatial data: a study of childhood cancers. Soc Sci Med 34(7), 769-777

[5] Dolk H, Elliot P, Shaddick G, Walls P, Thakrar B (1997a): Cancer incidence near radio and television transmitters in Great Britain, Part II. All high-power transmitters. Am J Epidemiol 145, 10-17

[6] Dolk H, Shaddick G, Walls P, Grundy C, Thakrar B, Kleinschmidt I, Elliot P (1997b): Cancer incidence near radio and television transmitters in Great Britain, Part I. Sutton Coldfield Transmitter. Am J Epidemiol 145, 1-9

[7] Maskarinec G, Cooper J, Swygert L (1994): Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. J Environ Pathol Toxicol Oncol 13(1), 33-37

[8] Hocking B, Gordon IR, Grain ML Hatfield GE (1996): Cancer incidence and mortality and proximity to TV towers. Med J Australia 165, 601-605

[9] Altpeter E, Battaglia M, Bader A, Pfluger D, Minder CE, Abelin Th (2000): Ten years experinece with epidemiological research in the vicinity of the short-wave broadcasting area Schwarzenburg: What does the story tell us? Proceedings of the International Conference on Cell Tower Siting, Salzburg, p.127-132, www.land-salzburg.gv.at/celltower

[10] Kolodynski AA, Kolodynska VV (1996): Motor and psychological functions of school children living in the area of the Skundra Radio Location Station in Latvia. Sci Tot Env 180, 87-93

[11] Repacholi MH, Basten A., Gebski V, Noonan D, Finnie J, Harris AW (1997): Lymphomas in Eμ-Pim1 transgenic mice exposed to pulsed 900 MHz electromagnetic fields. Radiat Res 147 (5), 631-640

[12] Mann K, Röschke J (1996): Effects of pulsed high-frequency electromagnetic fields on human sleep. Neuropsychobiology 33(1), 41-47

[13] Wagner P, Röschke J, Mann K, Hiller W, Frank C (1998): Human sleep under the influence of pulsed radiofrequency electromagnetic fields: a polysomnographic study using standardized conditions. Bioelectromagnetics 19(3), 199-202

[14] Borbély AA, Huber R, Graf T, Fuchs B, Gallmann E, Achermann P (1999): Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram. Neurosci Lett 275(3), 207-210

[15] Zerssen D v, Koeller DM (1976): Die Befindlichkeitsskala. Testzentrale Göttingen.

[16] Adey WR (1997): Bioeffects of mobile communication fields; possible mechanisms for cumulative dose. In Mobile Communications Safety, edited by N. Kuster, Q.Balzano and J.C. Lin. p.103-140. New York, Chapman and Hall

[17] Szmigielski S, Sobiczewska E, Kubacki R, Ciolek Z (2000): Cardiovascular symptoms in subjects occupationally exposed to HF electromagnetic fields. Proceedings of the International Conference on Cell Tower Siting, Salzburg, p.119-124, www.land-salzburg.gv.at/celltower

[18] Kolodynski AA, Kolodynska VV (1996): Motor and psychological functions of school children living in the area of the Skundra Radio Location Station in Latvia. Sci Tot Env 180, 87-93