The Microwave Syndrome: Further Aspects of a Spanish Study

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Abstract

A health survey was carried out in La Ñora, Murcia, Spain, in the vicinity of two GSM 900/1800 MHz cellular phone base stations. The E-field (~ 400 MHz – 3 GHz) measured in the bedroom was divided in tertiles (0.02 – 0.04 / 0.05 – 0.22 / 0.25 – 1.29 V/m). Spectrum analysis revealed the main contribution and variation for the E-field from the GSM base station. The adjusted (sex, age, distance) logistic regression model showed statistically significant positive exposure-response associations between the E-field and the following variables: fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorder, depressive tendency, feeling of discomfort, difficulty in concentration, loss of memory, visual disorder, dizziness and cardiovascular problems. The inclusion of the distance, which might be a proxy for the sometimes raised "concerns explanation", did not alter the model substantially. These results support the first statistical analysis based on two groups (arithmetic mean 0,65 V/m versus 0,2 V/m) as well as the correlation coefficients between the E-field and the symptoms (Navarro et al, "The Microwave Syndrome: A preliminary Study in Spain", *Electromagnetic Biology and Medicine,* Volume 22, Issue 2, (2003): 161 – 169). Based on the data of this study the advice would be to strive for levels not higher than 0.02 V/m for the

sum total, which is equal to a power density of 0.0001 μW/cm^2 or 1 μW/m^2, which is the indoor exposure value for GSM base stations proposed on empirical evidence by the Public Health Office of the Government of Salzburg in 2002.

Introduction

The relationship between biological/health effects and electromagnetic exposure has been widely recognized from epidemiological and experimental studies. Even some institutional consensus has been reached and formal health risk assessments for exposure to ELF, extremely low frequency fields, e.g. from powerlines and electric appliances, have recently been scheduled. In 2002 the first IARC review on this topic classified ELF magnetic fields as " possibly human carcinogen " based on epidemiological studies of childhood leukemia [1]. In 2002 the California Department of Health judged ELF magnetic fields at least possibly related with leukemia in children and adults, brain tumors in adults, miscarriage and motor neuron disease [2].

With respect to radiofrequency (30 kHz – 300 MHz) and microwave exposure (300 MHz – 300 GHz) the scientific evidence from in vitro, in vivo and epidemiological studies shows a great spectrum of biological/health effects at low level exposures [3, 4, 5, 6, 7, 8, 9]. A specific symptomatology in humans linked to radiofrequency and microwaves, named *"microwave sickness" or "radiofrequency syndrome"* was described at low level exposure which include headache, fatigue, irritability, loss of appetite, sleeping disorders, difficulties in concentration or memory, and depression [10].

The growing use of mobile communication, GSM 900/1800, cordless telephones etc in the last decade has reintroduced concerns about whether some health risks could derive from microwave exposure, especially from mobile phones and their basestations. In contrast to the public debate on health risks from mobile phone base stations, only three epidemiological studies on this issue have been published until now. A study done in France by Santini showed significant associations between symptoms fitting to the microwave sickness and the distance to mobile phone base stations [11]. It should be noted that the health related symptoms were most frequently reported at a distance of 50 – 100 m, which fits perfectly to the area with the highest microwave exposure in urban areas, where the main beam of the antennas usually hits the first houses. The second study done in Austria showed significant positive associations between the frequency selective measured electric field (GSM 900/1800) in the bedroom and cardiovascular symptoms, irrespective of the concerns of the people under study [12]. The third study was published by our group [13] where we measured the electric field via a broadband device in the bedroom of 97 participants in La Ñora, Murcia, Spain. The statistical analysis showed significantly higher symptom scores in 9 out of 16 symptoms in the group having an exposure of 0.65 V/m compared to the control group having an exposure of 0.2 V/m, both as an average mean. In the same paper we reported also significant correlation coefficients between the measured electric field and fourteen out of sixteen health related symptoms.

The aim of this paper is to present additional statistical tests like logistic regression of the La Ñora data set and a detailed investigation of the EMF spectrum in six bedrooms (8 participants) done on July 3rd, 2004.

Geographical Area and Time Schedule

The study was done in La Ñora, a town in the south-east of Spain, close to Murcia, with 1900 inhabitants, situated on the slope of a hill. For the mobile phone coverage of La Ñora two masts had been sited on two different positions near the top of the hill above the village. The start of the transmission of both stations is not clear. However for the GSM 900 base station the siting is not earlier than 1997/1998, for the GSM 1800 base station was sited in December 1999. The questionnaires have been distributed in October 2000 and collected in November 2000. Broad band measurements (~400 MHz – 3 GHz) in 97 bedrooms as well as some frequency selective measurements have been done in February and March 2001.

In July 2004 frequency selective measurements were done in 6 bedrooms of former study participants.

Questionnaire

We used a questionnaire, translated to Spanish, of the Santini publication [10] which refers to demographic data: Address, sex, age, distance to mobile phone basestations, exposure time (years, days per week, hours per day). The questionnaire also collected information about proximity to power lines < 100 m, proximity to transformer stations < 10 m, use of personal computers > 2 hours per day and the use of cellular phones > 20 minutes per day. Finally a symptom checklist allowed to know the frequency of 16 health related symptoms: 0 = never, 1 = sometimes, 2 = often, 3 = very often.

Many of the symptoms were those described as microwave/radiofrequency syndrom/sickness: Fatigue, irritability, headache, nausea, loss of appetite, sleeping disorders, depression, feeling of discomfort, difficulty in concentration, loss of memory, skin alterations, visual disorder, auditory disorder, dizziness, gait difficulty and cardiovascular alterations. The questionnaires were distributed in La Ñora in frequently used locations (hair dresser, pharmacy) in October/November 2000 and collected in November/December 2000. From 144 questionnaires returned, 97 measurements in the bedrooms were done in 2001. The difference of 47 subjects was due to the impossibility to read the name or address in order to get the contact, no interest in the measurements, not at home at the scheduled measurement time or symptoms of the health questionnaire checked with an "x" instead of the proposed numbers "0", "1", "2", or "3". In 2004 the analysis of the La Ñora data set had been done with n=94 subjects having full information on exposure values from 2001, sex, age and symptoms except for one subject, where all information was available except for the "skin disorder question" n=93.

Exposure Assessment

The exposure to mobile phone basestations was assessed in 2001 with a portable broad band measurement device (~ 400 MHz – 3 GHz) called LX-1435. The electric field meter had been calibrated with a network analyzer HP-8510C inside the anechoic chamber of the University of Valencia, Spain. The electric field probe was held around 1 meter from the walls and 1.2 meters above the ground, to avoid reflection of the waves in the walls and metallic structures and moved around a circle of 25 centimeters´ radius, orientating the dipole antenna to get the maximum electric field strength above the bed.

The measurements were performed from 11:00 h to 19:00 h on February 24th, 2001, and on March 10th, 2001, in the respondents´ home. The bedroom was chosen because the pineal gland and its hormone melatonin is considered one of the target organs for EMF, having secretion peaks during the sleep.

To check the intensity of TV and radio channels (ultra short wave range), as well as the number and type of channels of the GSM 900/1800 base stations, measurements of the spectral power density were performed with a probe antenna and a portable spectrum analyser. The probe was mounted on a linen phenolic tripod about 1.2 meters above ground. Location of the probe was the same in both days, on a hill next to the town. With the spectrum analyser we scanned the GSM 900/1800 MHz bands, at the beginning of the journey, taking the average for a period of 6 minutes. The spectrum was similar in both days, with a difference in the peak estimation (carriers of the channels) of about 1 dB in radio and TV channels, GSM 900/1800 showed small differences, around 3 dB, associated to the working channels that were dependent on the traffic of cellular phones.

On July 3rd, 2004 from 11:00 to 19:00 h the spectrum of the electric field from 80 MHz – 2.5 GHz was measured in six bedrooms in La Ñora. The points of measurement were randomly selected from the study population which had been divided in three exposure groups (low, intermediate, high) with respect to the measured electric field in 2001. The aim was to check the exposure situation inside the houses in several places to validate the measurements of 2001 and to get the portion of radio, TV and GSM of the electromagnetic spectrum. A calibrated hand-held spectrum analyzer, FSH3 (100 kHz – 3 GHz) from the manufacturer Rhode & Schwarz, Germany and calibrated electric-field probes EFS 9218 (9 kHz – 300 MHz) and USLP 9143 (300 MHz – 5 GHz) from the manufacturer Schwarzbeck, Germany were used. A volume of about one m^3 above the surface of the bed was examined holding the antennas in different polarization directions as well as different directions in order to pick up the highest signals. The spectrum analyzer was adjusted: detector: max peak, trace: max hold. In order to differentiate broadcast control channels (BCCH) from traffic channels (TCH) both GSM spectra (GSM 900/1800) had been analysed at the time of measurements. The traces were stored in the spectrum analyzer and analysed via FSH View Version 7.0 on the PC afterwards.

Results

From n=94 participants under study, 47 were female, 47 male. The age span was 14 to 81 years, with a median age of 39 years. In the questionnaire the distances to the next GSM 900/1800 base stations were given in six different categories.

Table 1: Distance to next GSM 900/1800 base stations

93 % reported to be exposed to the mobile phone base stations for more than one year. The time spent in the house of the study site, was more than 8 hours per day for at least 6 days in 94 % of the respondents.

17 % reported to be exposed to an electric transformer distance less than 10 m. 43 % reported to live closer than 100 m to a high voltage power line. 40 % reported that they live at a distance of less than 4 km from a radio / TV transmitter. Using a mobile phone for more than 20 minutes per day was reported by 29 %. Working on a personal computer more than two hours per day was reported by 14 % of the study participants.

TV and radio channels maintained constant intensity during the 2001 measurements, however the traffic channels of the mobile phone base stations (GSM 900/1800) showed typical fluctuations. Table 2 shows the measured broad band electric field in V/m and the corresponding power density in $\mu W/cm^2$ and $\mu W/m^2$ in the bedroom in 2001.

Distance	Frequency	Percent
< 10 m	7	7.4
10 – 50 m	6	6.4
50 – 100 m	9	9.6
100 – 200 m	30	31.9
200 – 300 m	14	14.9
> 300 m	28	29.8
Total	94	100.0

Table 2: Broad band measurement in the bedroom 2001

E-field Power density Power density

[V/m] [µW/cm^2] [µW/m^2]

n valid 94 94 94

missing 0 0 0

average 0.27 0.051615 516.15

median 0.11 0.003157 31.57

SD 0.35 0.107775 1077.75

Minimum 0.02 0.000088 0.88

Maximum 1.29 0.442028 4420.28

The frequency selective measurements done in 2004 in six bedrooms showed that the variance of the broad band signal is mostly due to differences in the strength of the GSM 900/1800 signal. Because the broad band measurements had an attenuation in the FM frequency range of 15 dB the contribution of the FM signals to the broad band results are of small influence. The TV signals showed also to be quite small in comparison to the GSM 900/1800 signal as well. In order to attribute the proportion of different signals to a health outcome a frequency selective exposure assessment on an individual level is prefered. Figure 1 shows the results of the frequency selective measurements of 2004.

Figure 1: Exposure distribution (GSM 900/1800, FM, TV) in six bedrooms 2004

***** IMAGE HERE *****

For the logistic regression model we divided the broad band measured electric field in three exposure categories: Low exposure 0.02 – 0.04 V/m (1 – 4 µW/m^2), intermediate exposure 0.05 – 0.22 V/m (6 – 128 µW/m^2) and high exposure 0.25 – 1.29 V/m (165 – 4400 µW/m^2). We calculated a raw model to derive the odds ratio (OR) and the corresponding 95%-confidence interval (95%-CI) as well as the probability value (p-value) for all 16 health related symptoms for the intermediate and the high exposure category – using the low exposure category as the reference. In the second model we controlled for sex and age. In the third model we controlled for sex, age and distance to the next mobile phone base station reported by the study participants. The distance was added in order to see if there is any significant contribution to the model (which still includes the measured electric field, sex and age) from this variable. If one assumes the reversed distance as a proxy for concerns from the antennas, the reversed distance might show up as a variable with a certain amount of explanation of the model. In two out of 16 symptoms the reversed distance showed a significant contribution to the model in addition to the sex and age adjusted model. The variables being "sleeping disorders" with OR 1.47 (95%-CI 1.01 – 2.15) and "dizziness" with OR 1.71 (95%-CI 1.17 – 2.51). In comparison with the explanation of the measured E-field, the contribution is very small. See table 5, where the symptom "sleeping disorder" was associated with the measured E-field OR 10.39 (95%-CI 2.43 – 44.42) and OR 10.61 (95%-CI 2.88 – 39.19) and "dizziness" OR 2.98 (95%-CI 0.62 – 14.20) and OR 8.36 (95%-CI 1.95 – 35.82). A relevant influence of the reversed distance would result in a substantially alteration of the odds ratios associated with the E-field, which is not the case.

We also calculated logistic regression models including other variables like living closer than 100 m to high voltage power lines or 10 m to a transformer, living closer than 4 km to a radio / TV station, use of a computer > 2h/day or a cell phone > 20 minutes/day. For some of the above mentioned variables we found a significant contribution to the explanation of the model (data not shown) for few of the symptom variables which did not alter the overall associations of the models presented in this paper. For future studies we advice that the exposure to high voltage power lines and transformers as well as to radio / TV stations should be measured on an individual level in order to reduce exposure misclassification.

In 13 out of the 16 health related symptoms significant exposure-response relationships and very high and significant odds ratios for the measured electric fields were found which is one of the main findings of this study. An other important finding is that 10 out of 16 symptoms showed significantly elevated OR between the reference exposure category (0.02 – 0.04 V/m) and even the intermediate exposure category (0.05 – 0.22 V/m). In order to derive guideline values for the protection of public health from electromagnetic fields from mobile phone base stations GSM 900/1800 MHz, one should take into account that epidemiological studies usually underestimate individual risks, as well as the uncertainty with respect to the reference exposure category, which could be at a sufficiently low level but that is not known in this study and an open question in this issue as well. In order to take this arguments into account a provisional reference level of about 0,02 V/m for the sum total of electric fields from mobile phone base stations GSM 900/1800 MHz is recommended and is in line with the level recommended in 2002 by the Public Health Office of the Government of Salzburg, based on empirical evidence.

Table 3 shows the raw logistic regression model. Table 4 shows the sex and age adjusted model. Table 5 shows the sex, age and distance adjusted model.

Table 3: Raw Model

0.05 – 0.22 V/m (6 – 128 μW/m^2)

OR 95%-CI p

Health Outcome

Fatigue

Irritability

Headaches

Nausea

Loss of Appetite Sleeping Disorder Depressive Tendency Feeling of Discomfort Difficulty in Concentration Loss of Memory Skin Disorder Visual Disorder Hearing Disorder Dizziness

Gait Difficulties Cardiovascular Problems

23.46 3.71 7.46 7.62 5.82 7.67 32.00 4.80 8.46 1.65 4.50 1.65 2.72 5.29 0.74 9.60

2.77 – 198.82 0.0038

1.19 – 11.55 0.0234

2.10 – 26.55 0.0019

0.83 – 69.89 0.0726

0.61 – 55.61 0.1263

2.36 – 24.86 0.0007

3.79 – 270.21 0.0015

1.41 – 16.33 0.0121

2.31 – 31.00 0.0013

0.53 – 5.14 0.3844

0.82 – 24.55 0.0825

0.53 – 5.14 0.3844

0.87 – 8.52 0.0852

1.26 – 22.25 0.0229

0.21 – 2.62 0.6454

1.07 – 85.72 0.0429

0.25 – 1.29 V/m (165 – 4400 μW/m^2) OR 95%-CI p

33.88 4.16 – 276.04 0.0010

10.73 3.48 – 33.13 0.0000

6.56 2.14 – 20.05 0.0010

14.67 1.77 – 121.49 0.0128

24.00 2.94 – 195.94 0.0030

6.64 2.30 – 19.20 0.0005

42.66 5.23 – 348.33 0.0005

12.21 3.72 – 40.12 0.0000

18.12 5.05 – 64.99 0.0000

4.69 1.65 – 13.32 0.0037

5.19 1.08 – 26.21 0.0463

3.31 1.17 – 9.32 0.0236

1.10 0.35 – 3.47 0.8702

9.44 2.43 – 36.77 0.0012

1.08 0.36 – 3.25 0.8886

14.67 1.77 – 121.49 0.0128

p for the trend 0.0044 0.0002 0.0005 0.0382 0.0028 0.0003 0.0021 0.0002 0.0000 0.0108 0.1278 0.0707 0.1534 0.0053 0.8321 0.0442

Table 4: Age and Sex adjusted model

Table 5: Age, Sex and distance adjusted model

Health Outcome

Fatigue

Irritability

Headaches

Nausea

Loss of Appetite Sleeping Disorder Depressive Tendency Feeling of Discomfort Difficulty in Concentration Loss of Memory Skin Disorder Visual Disorder Hearing Disorder Dizziness

Gait Difficulties Cardiovascular Problems

25.79 2.94 – 225.85

3.36 1.06 – 10.66

8.06 2.14 – 30.31

7.53 0.80 – 70.75

6.03 0.60 – 60.19

13.982 3.50 – 55.85

44.87 4.85 – 414.69

4.34 1.25 – 15.03

9.40 2.44 – 36.21

2.40 0.70 – 8.26

6.25 1.05 – 37.13

2.57 0.74 – 9.08

4.45 1.23 – 16.13

5.37 1.24 – 23.16

1.09 0.28 – 4.24

12.56 1.32 – 118.99

p

0.0033 0.0395 0.0020 0.0774 0.1260 0.0002 0.0008 0.0207 0.0011 0.1642 0.0437 0.1380 0.0231 0.0243 0.8970 0.0274

0.25 – 1.29 V/m (165 – 4400 µW/m^2) OR 95%-CI

37.72 4.42 – 321.49

9.60 3.05 – 30.26

7.29 2.22 – 23.94

14.33 1.68 – 122.55

25.84 2.98 – 223.80

12.39 3.47 – 44.26

64.28 7.05 – 586.27

10.97 3.27 – 36.77

20.55 5.35 – 79.00

7.91 2.37 – 26.35

7.67 1.36 – 43.44

5.88 1.75 – 19.74

1.75 0.49 – 6.24

9.70 2.39 – 39.33

1.86 0.54 – 6.41

20.43 2.26 – 184.95

p

0.0009 0.0001 0.0011 0.0150 0.0032 0.0001 0.0002 0.0001 0.0000 0.0008 0.0212 0.0041 0.3859 0.0015 0.3235 0.0073

p for the trend 0.0040 0.0006 0.0007 0.0445 0.0031 0.0001 0.0011 0.0005 0.0001 0.0027 0.0647 0.0158 0.0643 0.0063 0.5629 0.0267

0.05 – 0.22 V/m (6 – 128 μW/m^2) OR 95%-CI

Health Outcome

Fatigue

Irritability

Headaches

Nausea

Loss of Appetite Sleeping Disorder Depressive Tendency Feeling of

Discomfort Difficulty in Concentration Loss of Memory Skin Disorder Visual Disorder Hearing Disorder Dizziness

Gait Difficulties Cardiovascular Problems

0.05 – 0.22 V/m (6 – 128 μW/m^2) OR 95%-CI

28.53 3.03 – 268.78

3.12 0.91 – 10.68

5.99 1.50 – 23.93

5.92 0.60 – 58.68

6.66 0.62 – 71.52

10.39 2.43 – 44.42

39.41 4.02 – 386.40

4.29 1.14 – 16.15

8.27 2.01 – 34.01

2.35 0.62 – 8.89

7.04 1.06 – 46.62

2.48 0.65 – 9.44

3.89 0.99 – 15.21

2.98 0.62 – 14.20

1.32 0.30 – 5.84

9.42 0.93 – 95.07

p

0.0034 0.0704 0.0113 0.1288 0.1175 0.0016 0.0016 0.0314 0.0034 0.2090 0.0429 0.1830 0.0510 0.1712 0.7114 0.0572

0.25 – 1.29 V/m (165 – 4400 μW/m^2) OR 95%-CI

40.11 4.56 – 352.44

9.22 2.86 – 29.67

6.10 1.80 – 20.65

12.80 1.48 – 110.64

27.53 3,07 – 247.03

10.61 2.88 – 39.19

59.39 6.41 – 550.11

10.90 3.16 – 37.56

19.17 4.91 – 74.77

7.81 2.27 – 26.82

8.22 1.39 – 48.51

5.75 1.68 – 19.75

1.63 0.45 – 5.95

8.36 1.95 – 35.82

2.07 0.57 – 7.50

17.87 1.96 – 162.76

p

0.0009 0.0002 0.0037 0.0205 0.0031 0.0004 0.0003 0.0002 0.0000 0.0011 0.0201 0.0054 0.4572 0.0042 0.2690 0.0105

p for the trend 0.0039 0.0009 0.0050 0.0499 0.0030 0.0008 0.0016 0.0007 0.0001 0.0031 0.0628 0.0186 0.1285 0.0117 0.5211 0.0333

Summary

Frequency selective measurements done in July 2004 (n=6) showed that the main contribution and the main variability of the broad band signal measured in February and March 2001 is due to GSM 900/1800 signals (n=97). This is further supported by the fact that the dipol antenna used in 2001 is quite insensitive to frequencies below 400 MHz which is related to FM (80 – 110 MHz) and that the TV channels were quite weak in comparison to the GSM signals. However we would prefer to have frequency selective personal exposure values for all important signals of the electromagnetic spectrum in future studies.

For the logistic regression we divided the broad band measurements of the electric field in three exposure groups, the low exposure group served as the reference category. We calculated the odds ratios and 95% CI for the raw model, an age and sex adjusted model and an age, sex and distance adjusted model. All models showed statistical significant associations between the measured electric field (~ 400 MHz – 3 GHz) and 13 out of 16 health related symptoms. The strongest five associations found are depressive tendency, fatigue, sleeping disorder, difficulty in concentration and cardiovascular problems. The symptoms associated are in line with the symptoms reported in the literature as "Microwave Syndrome". The odds ratios are quite high having small p-values. Some kind of selection bias cannot be ruled out, because of the way the questionnaires were distributed, but that would affect more or less all cases and therefore affect the odds ratios not substantially. The introduction of the reversed distance to the nearest base station, which might serve as a surrogate for the sometimes claimed "concerns explanation" for health related symptoms attributed to mobile phone base stations, did not alter the odds ratios substantially and the OR associated with the measured electric fields remained at their high level. It should be noted that the findings of this study might be of great importance for Public Health and should be taken seriously. Further epidemiological studies are warranted but do not preclude measures to reduce microwave exposures from GSM 900/1800 base stations now. Based on the data of this study the advice would be to strive for levels not higher than 0.02 V/m for the sum total, which is equal to a power density of 0.0001 $\mu W/cm^2$ or 1 $\mu W/m^2$, which is the indoor exposure value for GSM base stations proposed on empirical evidence by the Public Health Office of the Government of Salzburg in 2002 [14].

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