ORIGINAL ARTICLE

Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations

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Background: The erection of mobile telephone base stations in inhabited areas has raised concerns about possible health effects caused by emitted microwaves.
Methods: In a cross-sectional study of randomly selected inhabitants living in urban and rural areas for more than one year near to 10 selected base stations, 365 subjects were investigated. Several cognitive tests were performed, and wellbeing and sleep quality were assessed. Field strength of high-frequency electromagnetic fields (HF-EMF) was measured in the bedrooms of 336 households.
Results: Total HF-EMF and exposure related to mobile telecommunication were far below recommended levels (max. 4.1 mW/m^2). Distance from antennae was 24–600 m in the rural area and 20–250 m in the urban area. Average power density was slightly higher in the rural area (0.05 mW/m^2) than in the urban area (0.02 mW/m^2). Despite the influence of confounding variables, including fear of adverse effects from exposure to HF-EMF from the base station, there was a significant relation of some symptoms to measured power density; this was highest for headaches. Perceptual speed increased, while accuracy decreased insignificantly with increasing exposure levels. There was no significant effect on sleep quality.
Conclusion: Despite very low exposure to HF-EMF, effects on wellbeing and performance cannot be ruled out, as shown by recently obtained experimental results; however, mechanisms of action at these low levels are unknown.

Hand-held cellular telephones were introduced in the early 1980s. Due to the relatively high microwave exposure for users while they are on the telephone, the potential health effects of mobile phones have been studied in recent years. However, exposure to the much lower emissions from mobile phone base stations has been neglected. There have been only two observational pilot investigations,[1–2] and one experimental study.[3]

The World Health Organisation (WHO)[4] has recently recommended investigating the effects of exposure to emissions from mobile phone base stations to address public concerns.

It has often been argued that if there are detrimental long term effects from high-frequency electromagnetic fields (HF-EMF) as transmitted by mobile phone base stations, then such effects should have been found near powerful radio and television transmitters. This argument is invalid as: (1) there are very few studies on effects from radio and TV transmitters, ecological and cluster studies on cancer,[5–10] and studies on sleep and other endpoints;[11–12] (2) the results of these studies are compatible with the assumption of a moderately elevated risk; and (3) emissions from base stations differ substantially from those of other sources of HF-EMF.

There are numerous reports from physicians that base stations are associated with a number of health symptoms in neighbours. However, these symptoms might be due to fear about negative effects. Nevertheless there is evidence that long term, low level exposure to HF-EMF may result in a number of symptoms (for example, headaches, fatigue, sleep disorders, memory impairments),[13] attributed as microwave sickness syndrome.[14]

This study investigated the relation between exposure from mobile telecommunication and other sources of HF-EMFs and the associations between exposure and symptoms.

METHODS

Selection of base stations

The study covers urban as well as rural areas in Austria. The city of Vienna was selected as the urban area while villages in Carinthia represented the rural areas. Two network providers were each asked to identify about five base stations within both regions that fulfilled the following requirements:

- The antenna must have been operating for at least two years
- There had been no protests by neighbours against the base station
- There was no other base station nearby (this could only be achieved in rural areas)
- Transmission was preferably only in the 900 MHz band.

Twenty one base stations were specified, from which 10 were selected for the study based on inspection of the local conditions (population density, other sources of exposure).

Selection of study area and participants

Data from the 10 selected antenna locations, including the antenna diagram, were provided by the network companies. In order to ensure a sufficient gradient of exposure, these data were used to define the study area around the selected base station. The investigation was carried out by trained students and a medical technical assistant in Carinthia and

Abbreviations: ANCOVA, analysis of covariance; BCCH, broadcast channel; CI, confidence interval; GSM, global system for mobile telecommunication; HF-EMF, high-frequency electromagnetic fields; MHz, megahertz; POR, prevalence odds ratio; SAR, specific (energy) absorption rate; SD, standard deviation; TDMA, time division multiple access; WHO, World Health Organisation

Table 1 Demographic characteristics of subjects by exposure category

	Exposure category (mW/m^2)			
	<0.1	0.1–0.5	>0.5	p value
Age	45 (SD 16)	40 (SD 14)	44 (SD 15)	0.390
Females	60%	58%	56%	0.829
Years of residence	19 (SD 16)	17 (SD 13)	20 (SD 16)	0.403
Hours at home	10 (SD 5)	10 (SD 4)	10 (SD 5)	0.413
Employed	56%	60%	61%	0.689
Urban residence	55%	42%	49%	0.171
Education > 12 y	42%	38%	40%	0.784
Mobile phone use	75%	77%	78%	0.866

p value from Kruskal–Wallis or χ^2 test.

Vienna. Based on power calculations, the projected number was 36 subjects for each of the 10 locations.

In Vienna, households were randomly selected from telephone register entries. Subjects were contacted by telephone. If after three attempts no contact could be achieved, the next entry in the telephone list was chosen. Subjects were told that the relationship between environmental factors and health would be investigated. They had to be older than 18 years, have been living in their present house for at least one year, and been staying there for a minimum of eight hours a day on average. Refusal was slightly above 40% and mainly due to time constraints. On acceptance of participation an appointment was made for a visit. In Carinthia the procedure was different because no clear relation of address to study area could be ensured (houses are not always numbered consecutively). Therefore a random selection of houses based on the site plan was performed. Investigators contacted subjects directly in their homes. In the case of acceptance, either an appointment for the investigation was made or it was carried out immediately. Rate of refusal was somewhat lower than in the urban area (32%). On contact, gender, age, and duration of residence in their present house (eligibility criteria) were registered. Non-participants were insignificantly more frequently males (47% *v* 41%) and significantly younger (40 *v* 44 years), and had a significantly shorter time living in their present house (13 *v* 16 years).

Data collection and measurements

All investigations were done in the homes of the subjects using a laptop computer. Performance tests as well as questionnaires were presented along with instructions on the screen. Handling was so simple that after a short introduction all subjects were able to fulfil the tasks without further assistance by the investigators. The investigation consisted of the following:

- 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 have on the health of the subjects. Among the items listed were traffic noise, particulate matter, and mobile phone base station. Assumed impact was rated on a five point scale from 0 = not at all, to 4 = very strong impact.
- Subjective scaling of symptoms (Zerssen scale).[15] Symptoms were rated on a four point scale from 0 = not at all, to 3 = strong. Symptoms of special interest were headaches, symptoms of exhaustion, and circulatory symptoms (see table 4). For analysis, ratings were dichotomised (0/1–3).
- Investigation of sleeping problems (Pittsburgh sleeping scale).[16] Problems falling asleep and staying asleep were rated by the participants on a frequency scale ranging from never to more than 3 days a week. The global index is

Table 2 Exposure categories and results of analysis of covariance for tests of cognitive performance

	Exposure category (mW/m^2)			
Test	<0.1	0.1–0.5	>0.5	p value
Memory				
Immediate memory*	6.2 (1.4)	5.6 (1.4)	5.9 (1.5)	0.166
Short term memory (1 min)†	29.1 (4.3)	29.5 (4.1)	29.3 (3.9)	0.354
Short term memory (5 min)†	33.9 (2.9)	33.1 (3.1)	34.0 (1.9)	0.761
Short term memory (15 min)†	33.4 (2.9)	33.6 (2.4)	33.7 (2.0)	0.883
d′ (1 min)‡	0.87 (0.48)	0.88 (0.42)	0.86 (0.41)	0.737
d′ (5 min)‡	1.54 (0.39)	1.48 (0.62)	1.53 (0.32)	0.579
d′ (15 min)‡	1.56 (0.39)	1.54 (0.32)	1.62 (0.27)	0.198
ln β (1 min)§	−0.34 (0.45)	−0.19 (0.32)	−0.29 (0.30)	0.235
ln β (5 min)§	−1.09 (0.58)	−1.11 (0.72)	−1.04 (0.54)	0.605
ln β (15 min)§	−1.36 (0.53)	−1.21 (0.52)	−1.47 (0.53)	0.095
Perceptual speed				
Speed score (sec)	4.3 (0.9)	4.0 (1.1)	3.8 (1.0)	0.061
Items solved (max. 8)	4.6 (2.4)	4.1 (2.3)	4.1 (2.5)	0.147
Choice reaction task				
Reaction time (msec)	582 (217)	511 (139)	585 (244)	0.485

Results expressed as mean (SD).
p values for exposure factor are shown.
*Highest number of correctly reproduced digits.
†Number of correctly identified items (sum of correct detections (from 20) and correct rejections (from 20 distraction items)).
‡d-prime from signal detection analysis.
§Natural logarithm of detection bias beta.

computed as the sum of seven sub-scales (see table 5) with each component scored 0 to 3 (higher score indicates greater problems).

- Cognitive performance.
  - Memory tasks consisted of a short term memory test using 1–10 digit numbers that had to be reproduced immediately after presentation. The score was defined as the highest number of digits correctly reproduced. The assessment of medium term memory was based on 20 simple everyday objects in silhouette drawings presented together for 30 seconds on the screen. After 1, 5, and 15 minutes these items together with 20 distraction items (different for the three tests) were presented in random sequence, one at a time, and the subjects had to decide whether or not the picture was among those presented. Each response was followed by immediate feedback. After each test all objects were again presented for 15 seconds. The score was defined as the number of correct responses. In addition, d-prime and response bias (beta) from signal detection analysis were computed (d-prime is the normalised distance between the signal and noise answer distributions, the higher the d-prime, the less likely is confusion between target and distraction items; beta measures the bias to respond ''yes'' whether it is a target or distraction item).
  - The choice reaction task consisted of a random sequence of squares of three different colours (red, green, and yellow) appearing at random locations on the screen. Subjects had to react as fast as possible by pressing a specified button for each colour. The score was defined as the average correct reaction time across 25 trials.
  - Perceptual speed was tested by presenting two series of 10 letters (''meaningless words'') that differed at exactly one position. Eight of these double series were presented in random sequence. Subjects had to find the differing letter under time constraints (maximum 6 seconds) and place a cursor below it. These position varied between the 3rd and 7th letters. Score was defined as the average time to achieve the correct solution. In addition, the number of items solved within the time window was computed.

After completion of the questionnaires and tests, dates were arranged for exposure measurements. Measurements of high frequency EMFs were done by a specialist from a certified centre in Vienna (TGM). A biconic field probe (PBA 10200, ARC Seibersdorf) was used connected to a spectrum analyser (FSP, Rhode & Schwarz). Measurements were performed in the bedroom (this being typically the only place in the house where people consistently spend many hours a day). As exposure may vary at this location, in addition to the sum of power densities across all mobile phone frequencies, the maximum exposure from the base station was computed based on measurements of broadcast channels. Broadcast channels (BCCH) operate all the time at maximum power with all time slots occupied. Hence multiplication of measurements of BCCH by the ratio of the sum of the power of all channels to that of the BCCH results in maximum possible exposure level, while the sum of BCCH measurements gives the minimum. The former is the result of all channels operating at maximum power with all time slots occupied, while the latter occurs if no traffic channel is active.

Distance from the antenna was calculated based on the coordinates of the measurement location and the base station. It ranged between 24 m and 600 m in rural areas and between 20 m and 250 m in urban areas. The smaller range in the latter was due to the vicinity of other base stations and the shadowing effect of high buildings.

Subjects

In total, 365 subjects were investigated (185 in Vienna and 180 in Carinthia). In some cases EMF measurements were not possible due to the absence of the inhabitants at the arranged date. Therefore, only data from 336 subjects could finally be evaluated.

Subjects were between 18 and 91 years of age (mean 44, SD 16 years). Fifty nine per cent were female. Average duration of residence in the house was 19 (SD 16) years, and subjects stayed for 10 (SD 5) hours a day in the immediate neighbourhood. Overall, six subjects occupied the place only after erection of the base station. All subjects slept normally at home.

Statistical analysis

Statistical evaluation of exposure from the base stations was done by analysis of covariance (ANCOVA) for components of the Pittsburgh Sleeping Scale and performance measurements, and by logistic regression analysis for subjective symptoms based on the following procedure. First the maximal power density estimates from base station frequencies were classified into three groups: $\leqslant 0.1$ mW/m^2 (approximately up to median), 0.1–0.5 mW/m^2 (between median and 3rd quartile), and >0.5 mW/m^2. Originally it was planned to define four exposure categories based on quartiles. However, it turned out that the level of exposure was too low for the two lowest exposure categories to be meaningfully discriminated and consequently these categories were combined. Average exposure levels were 0.04 mW/m^2, 0.23 mW/m^2, and 1.3 mW/m^2, respectively. Exposure level, area (rural *v* urban), and interaction were included as fixed factors, age, sex, regular use of a mobile telephone, and the subjective rating of negative consequences of the base station on health were used as covariables. Normality was assessed by Kolmogorov–Smirnov tests using Lilliefors p values, homogeneity of variance by Levene's tests. For all analyses the model with separate slopes was first tested. If none of the interactions with fix factors were significant at the 10% level, the model with homogenous slopes was computed. In addition, homogeneity of variance–covariance matrices of covariables and dependent variables across groups was tested by Box M tests. Unconditional logistic regression was performed using the same covariables. For all tests a p value below 0.05 was considered significant. No correction for multiple testing was applied.

RESULTS

Table 1 gives an overview of features of participants across exposure categories. Although none of the variables reached statistical significance, the somewhat higher proportion of subjects from the urban area in the lowest exposure category should be noted.

Exposure to high frequency EMFs was generally low and ranged from 0.0002 to 1.4 mW/m^2 for all frequencies between 80 MHz and 2 GHz; the greater portion of that exposure was from mobile telecommunications (geometric mean 73%), which was between 0.00001 and 1.4 mW/m^2. Maximum levels were between 0.00002 and 4.1 mW/m^2. Overall 5% of the estimated maximum exposure levels were above 1 mW/m^2. Average exposure levels were slightly higher in the rural area (0.05*/7.6 mW/m^2) than in the urban area (0.02*/7.1 mW/m^2).

Most subjects expressed no strong concerns about adverse health effects of the base station. In the urban and rural test areas, 65% and 61% respectively stated no concerns at all.

Table 3 Detailed results of analysis of covariance for speed score of perceptual speed as a dependent variable

Source of variation		df	MSQ	F value	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 exposure	2	7.869	2.823	0.061
Interaction		2	0.036	0.001	0.999

Factors and covariables are shown in the column ''source of variation''.
df, degrees of freedom; MSQ, mean sum of squares.

Table 2 gives an overview of results from ANCOVA on the different tests of cognitive performance for the exposure factor only; table 3 shows the full results for the test of perceptual speed. For perceptual speed a tendency for faster reaction in the higher exposure category was found. Omitting the three insignificant covariates from analysis resulted in a significant ($p = 0.009$) main effect for exposure. Logistic regression with the median chosen as a cut-off point was statistically significant. The estimated risk of a value below the median speed score relative to the lowest exposure category was 0.73 (95% CI 0.33 to 1.58) for the second and 0.42 (95% CI 0.18 to 0.98) for the third exposure categories. Accuracy of perceptual speed indicated by number of correct reactions showed the opposite effect, although not

Table 4 Relative risk estimates of subjective symptoms of primary interest for categories of exposure to microwaves from base stations in the bedroom against lowest exposure category

Symptom	Exposure category (mW/m^2)	% with symptom	Relative risk*	95% CI	p value
Headaches	⩽0.1†	61	1.00		0.017
	0.1–0.5	66	1.36	0.62–2.99	
	>0.5	79	3.06	1.22–7.67	
Vertigo	⩽0.1 †	17	1.00		0.306
	0.1–0.5	27	1.27	0.50–3.22	
	>0.5	32	1.54	0.68–3.50	
Palpitations	⩽0.1†	26	1.00		0.444
	0.1–0.5	32	1.06	0.45–2.47	
	>0.5	38	1.37	0.61–3.11	
Tremor	⩽0.1†	12	1.00		0.062
	0.1–0.5	9	0.68	0.19–2.41	
	>0.5	26	2.37	0.96–5.87	
Hot flushes	⩽0.1†	32	1.00		0.739
	0.1–0.5	26	0.90	0.39–2.09	
	>0.5	26	0.87	0.37–2.01	
Sweating	⩽0.1 †	34	1.00		0.455
	0.1–0.5	38	1.05	0.47–2.32	
	>0.5	40	1.35	0.61–2.97	
Cold hands or feet	⩽0.1†	40	1.00		0.019
	0.1–0.5	46	1.03	0.40–2.63	
	>0.5	62	2.57	1.16–5.67	
Loss of appetite	⩽0.1†	13	1.00		0.069
	0.1–0.5	17	1.23	0.42–3.57	
	>0.5	24	2.40	0.93–6.18	
Loss of energy	⩽0.1†	63	1.00		0.886
	0.1–0.5	63	1.32	0.61–2.84	
	>0.5	58	1.06	0.49–2.27	
Exhaustion	⩽0.1†	44	1.00		0.098
	0.1–0.5	41	0.77	0.30–2.02	
	>0.5	51	2.07	0.87–4.89	
Tiredness	⩽0.1†	64	1.00		0.258
	0.1–0.5	89	1.97	0.64–6.10	
	>0.5	88	1.92	0.62–5.96	
Difficulties to concentrate	⩽0.1†	60	1.00		0.035
	0.1–0.5	64	1.32	0.61–2.86	
	>0.5	76	2.55	1.07–6.08	
Feeling strained	⩽0.1†	44	1.00		0.450
	0.1–0.5	51	1.67	0.76–3.65	
	>0.5	40	0.74	0.33–1.63	
Urge for sleep	⩽0.1†	47	1.00		0.630
	0.1–0.5	54	1.21	0.56–2.61	
	>0.5	51	1.17	0.53–2.54	

p values for exposure factor are shown.
*Adjusted for age, sex, region, regular use of mobile telephone, and fear of adverse effects of the base station.
†Reference category.

Table 5 Results of analysis of covariance for components and global score of the Pittsburgh Sleep Quality Index and logistic regression for "poor sleepers" (global score >5)

Component	Exposure category (mW/m^2)			p value
	<0.1	0.1–0.5	>0.5	
Subjective sleep quality	0.71 (0.79)	0.60 (0.77)	1.00 (0.89)	0.240
Sleep latency	0.76 (0.93)	0.74 (0.95)	0.94 (0.98)	0.295
Sleep duration	1.06 (0.98)	1.14 (1.03)	1.21 (1.09)	0.504
Habitual sleep efficiency	0.54 (0.92)	0.70 (0.98)	0.74 (1.15)	0.061
Sleep disturbances	0.92 (0.58)	0.91 (0.66)	0.91 (0.62)	0.338
Daytime dysfunction	0.66 (0.75)	0.54 (0.70)	0.82 (0.90)	0.099
Sleep medication	0.10 (0.46)	0.17 (0.71)	0.21 (0.73)	0.216
Global score	4.74 (3.52)	4.78 (3.86)	5.87 (4.21)	0.282
Poor sleepers (%)	35%	31%	41%	0.225

Results expressed as mean (SD).
p values for exposure factor are shown.

to a significant extent. Hence there is some speed–accuracy trade-off.

For subjective symptoms of primary interest, effects of exposure from the base station are shown in table 4. Many symptoms were more frequent at higher exposure levels; headaches, cold hands or feet, and difficulties in concentrating, and to a lesser degree, tremor, loss of appetite, and feelings of exhaustion showed increased prevalence after correction for confounding factors.

Results for sleep quality are shown in table 5. Two subscales (sleep efficiency and daytime dysfunction) showed indications of poorer sleep at higher exposure categories. A highly significant effect of concerns about negative health implications of the base station was found for overall sleep quality (global score), with poorer quality in those concerned. As expected, age also had a significant influence. Without considering the influence of the subjects' concerns about the base station, the effect of exposure would have been statistically significant. Logistic regression analysis with the median score as a cut-off point showed no pronounced effect of exposure ($p = 0.131$).

DISCUSSION

Mobile phone base stations easily comply with current guidelines (for example, ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines).[17] Our measurements show that exposure of the public in the vicinity of base stations is indeed low. However, considering all HF-EMF exposures above 80 MHz, mobile telecommunication is responsible for an average of 73% of these exposures. This is consistent with representative measurements in Sweden[18] and the UK.[19]

The present study was conducted to provide answers to intriguing methodological problems of the epidemiological investigation of base stations.

How is it possible to attribute effects to a specific source of HF-EMF? In study areas, exposure from other sources of HF-EMFs was from distant transmitters and therefore more or less constant. Effects from these exposures will therefore not confound the effects of base stations. As study areas were selected to guarantee a gradient of exposures from base stations, the only relevant contribution to the variance of HF-EMF exposure was from base stations (93% of variance).

Another problem is the time variation of exposure, depending on the number of connected calls (due to the TDMA (time division multiple access) mode of the GSM system). Of course the best approach would be a long term measurement of exposure, or to use personal "dosimeters". However, there are no such dosimeters available and long term measurements are not feasible due to economic restrictions as well as problems of compliance. A possible solution is to conduct a short term measurement at a location where subjects are assumed to spend considerable periods of time (we chose the bedroom), analyse the spectrum of exposure, and select the broadcast channels that are operating at constant maximum power. Based on these measurements a range of exposures can be computed. We analysed data based on broad categories so that this categorisation leads to almost equal allocation whether "average", minimum, or maximum exposure estimation is used. A broad categorisation was used because of other sources of variance of exposure (like movements of subjects) that cannot be accounted for.

A further problem is the dynamic development of telecommunication networks. For the present study, we selected base stations emitting with unchanged features for

Table 6 Results of analysis of covariance (ANCOVA) for global score of the Pittsburgh Sleep Quality Index as dependent variable

Source of variation		df	MSQ	F value	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 Exposure	2	34.959	1.272	0.282
Interaction		2	58.404	2.126	0.121

Factors and covariables are shown in the column "source of variation".
df, degrees of freedom; MSQ, mean sum of squares.

Main messages

- Exposure from mobile phone base stations is orders of magnitude below current guideline levels.
- Self-reported symptoms like headache and difficulties in concentrating show an association with microwave exposure from base stations, not attributable to subjects' fear of health effects from these sources.
- Other symptoms, like sleeping problems, seem to be more due to fear of adverse health effects than actual exposure.

Policy implications

- Despite very low emissions from mobile phone base stations, more research concerning the effects of radiofrequency radiation from base stations is indicated.
- As a precautionary measure, siting of base stations should be such as to minimise exposure of neighbours.

at least two years. Furthermore, it was important that no other base station was nearby (which, however, could only be achieved in rural areas).

Because of the much higher exposure during telephoning compared to exposure from base stations, it is hardly conceivable that such small additional exposure could have an effect. However, these exposures have fundamentally different features. Exposure from the base station will be at low, but more or less constant levels for many hours a day, especially during the night. Comparing these levels is inappropriate if long term effects actually exist. If, for example, a subject is using a GSM mobile with a specific energy absorption rate (SAR) of 0.04 W/kg[20] for 10 minutes, this would be roughly equivalent to a 15 day exposure from a base station at an exposure level of 1 mW/m^2 if the principle of time–dose reciprocity is valid. However, it is not known whether this principle holds for exposure to HF-EMFs.

There is no a priori argument why the much lower levels from base stations should have no effect in the presence of widespread use of mobile telephones. Possible confounding by using a mobile has been considered in this study.

Generally, ratings were higher for most symptoms in subjects expressing concerns about health effects from the base station. Subjects who experience health problems might search for an explanation in their environment and blame the base station; another explanation would be that subjects with concerns are more anxious and also tend to give a more negative view of their body functions, or that some people generally give quite negative answers. Irrespective of these explanations there seem to be effects of exposure that occur independently of the fear of the subjects about the base station affecting their health. This is the case for headaches, cold hands or feet, and difficulties in concentrating, for example. These effects were robust with respect to additional potential confounders (for example, for headaches, inclusion of an indicator of socioeconomic status—years of education and type of occupation—slightly increased the risk estimator for exposure and decreased the p value from 0.017 to 0.016; inclusion of years of living in the present home and overall rating of environmental quality slightly increased the p value to 0.019; inclusion of hours staying at home did not change effect estimates at all). Interestingly these symptoms as well as some others that tended to be increased at higher exposure levels belong to those attributed to the microwave sickness syndrome. However, no clear relationship has been found for sleeping problems that are often mentioned in the public debate. The effect on sleep is dominated by concerns of the subjects of negative health effects of the base station. Many factors are known to influence sleep quality. Only a few could be considered in this study. Since some aspects of sleep quality, like sleep efficiency, showed a tendency for being affected by exposure, future studies should attempt to eliminate additional confounders.

Concerning symptom reporting there are a number of personality factors for which an association has been established. Among these are state anxiety, depression, and negative affectivity. The main question concerning this range of factors is whether they might act as confounders. In discussions of the microwave sickness syndrome, depression has also been mentioned among the possible effects of exposure; confounding is therefore conceivable. Sleep quality, unspecific symptoms, depression, affectivity, and other personality characteristics are connected with each other in a network of relationships such that a clear understanding of the possible long term effects of exposure may only be determined by longitudinal studies.

No influence of the subjects' fear about negative effects of the base station was found for cognitive performance. There was a small but significant reduction of reaction time for perceptional speed at increased exposure levels. It is interesting to note that such facilitating effects have also been reported during short term experimental exposures[20 22] and a study in teenagers using mobile phones.[21] On the other hand, a study[12] in children chronically exposed to emissions from a radio tower reported increased reaction times and reduced performance in cognitive tasks. We found a reduction of reaction time in adults, but an insignificant decrease of accuracy. Recognition in the medium term memory task showed a reasonable and increasing differentiation between target and distraction items and a decreasing response bias over repeated tests, but there was no indication of an influence of exposure from the base station. Furthermore, cognitive performance varies with factors that have not been controlled or considered in this study. Indices of socioeconomic status, however, were tested and did not modify effect size of base station exposure.

The results of this study indicate that effects of very low but long lasting exposures to emissions from mobile telephone base stations on wellbeing and health cannot be ruled out. Whether the observed association with subjective symptoms after prolonged exposure leads to manifest illness remains to be studied.

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