

# Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany

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## ABSTRACT

**Objective:** The aim of this first phase of a cross-sectional study from Germany was to investigate whether proximity of residence to mobile phone base stations as well as risk perception is associated with health complaints.

**Methods:** The researchers conducted a population-based, multi-phase, cross-sectional study within the context of a large panel survey regularly carried out by a private research institute in Germany. In the initial phase, reported on in this paper, 30 047 persons from a total of 51 444 who took part in the nationwide survey also answered questions on how mobile phone base stations affected their health. A list of 38 health complaints was used. A multiple linear regression model was used to identify predictors of health complaints including proximity of residence to mobile phone base stations and risk perception.

**Results:** Of the 30 047 participants (response rate 58.6%), 18.7% of participants were concerned about adverse health effects of mobile phone base stations, while an additional 10.3% attributed their personal adverse health effects to the exposure from them. Participants who were concerned about or attributed adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m) reported slightly more health complaints than others.

**Conclusions:** A substantial proportion of the German population is concerned about adverse health effects caused by exposure from mobile phone base stations. The observed slightly higher prevalence of health complaints near base stations can not however be fully explained by attributions or concerns.

Two recently released reports by the European Union (EU) reveal the differences between scientific evidence and subjective perception of possible hazards in relation to mobile phone base stations. According to a scientific report by an EU expert group<sup>1</sup> there are no established adverse health effects related to exposures to radio frequency electromagnetic fields (RF-EMFs), as long as the respective guidelines for public protection are not exceeded. The expert group however noted that the database for evaluation, especially for long-term low-level exposure, remains limited. The guidelines referred to have been suggested by the International Commission on Non-Ionising Radiation Protection (ICNIRP)<sup>2</sup> and are the basis of the EU Council Recommendation of 12 July 1999 for the limitation of exposure of the general public to electromagnetic fields. On one hand,

measurements carried out in households in the vicinity of mobile phone base stations have shown that exposures from these antennas hardly reach a few per cent of the ICNIRP protection limits, even in apartments close to the stations.<sup>3</sup> On the other hand, a survey among EU citizens in 25 member states showed that 40% of respondents considered that mobile phone base stations affected their health to some extent, while 36% even considered this to be true to a large extent.<sup>4</sup> Some experimental laboratory studies have looked into a similar effect, known as the nocebo effect, an inverse of the placebo effect. The adverse symptoms experienced in the nocebo effect occur due to expectations, that is, due to concerns. Results of a systematic review of provocation studies involving electromagnetic hypersensitive (EHS) and non-electromagnetic hypersensitive individuals conducted by Rössli showed that the majority of EHS individuals were not able to detect RF-EMFs under double-blind conditions. In some of the reviewed studies, EHS individuals reported reactions during sham conditions more often than the general population.<sup>5</sup> Unfamiliarity with the technology and the involuntary nature of RF-EMF exposure from mobile phone base stations are likely to promote these concerns.

Our knowledge about such worries is also based on numerous anecdotal reports from persons attributing health complaints to various sources of electromagnetic fields. Whereas it seems to be established that many affected persons suffer severely from such health complaints,<sup>6,7</sup> the evidence that these complaints are causally linked to the RF-EMF exposure is very weak.<sup>1,8,9</sup> This assessment is however mainly based on the absence of consistent effects in human provocation and sleep studies and on the lack of a biologically plausible explanation.<sup>1,5,7,10,11</sup> Very little is known about how these health complaints relate to true RF-EMF exposure, and/or to the proximity to mobile phone base stations outside laboratory environments.<sup>1</sup>

Outside controlled conditions, exposure to RF-EMF is rather difficult to measure and varies considerably in time and space. It has been clearly demonstrated that proximity to a mobile phone base station is a very weak surrogate measurement for true RF-EMF exposure, as there is a mixture of exposures of several magnitudes some 100 m within the vicinity of the mast.<sup>12</sup> This is due to the fact that walls and other houses obstruct the emission path and act as shields within the area of

a theoretical distance–exposure relationship, which is the main beam of the antenna. Conversely, scattered fields and reflections lead to higher exposures also outside the main beam. Due to the antenna's side lobe patterns, exposure does not decline monotonously with distance. However, at a distance of more than 500 m, exposures can be assumed to be generally low, providing a crude basis for categorisation of exposure applicable for descriptive purposes in large populations. For formal investigations of associations however, measured RF-EMFs from mobile phone base stations and other relevant sources (TV and radio broadcast towers, cordless phone base stations) are essential.

We performed a comprehensive population-based, cross-sectional study in Germany with the following aims:

- ▶ To estimate the prevalence of *concerns* about mobile phone base station-related adverse health effects and *attributions* of health complaints to RF-EMFs emitted from mobile phone base stations in the general population and particularly among persons living in the proximity of them.
- ▶ To investigate whether there is an association between health complaints and the exposure to RF-EMFs as measured in the participants' residences.

The study was conducted in two phases. Phase 1 dealt with the first aim, while the second aim was dealt with in phase 2 (see page 124). This article will report on the results of the first phase.

## METHODS

### Study design

The study was embedded in a large panel study that is regularly carried out by the Taylor Nelson Sofies (TNS) Infratest/Test Panel Institute (TPI). The panel bases on a large household sample of persons who agreed to participate in future surveys. The current panel of the Institute in Germany comprises more than 73 000 households nationwide, representative for the German population aged 0–79 years. The households are selected on a voluntary basis via e-mail contacts, address publishers or snow-ball systems. The institute has information on the sex, age and income group of all persons residing in the households in their database, as well as the region in which they reside.<sup>15 14</sup> The institute's survey conducted between August 2004 and November 2004 involved 51 444 households with persons aged 14–69 years. In co-operation with the institute and using their data, one person was randomly selected from each household using a randomisation process. This was done such that in the end we had a study population representative for the general German population with regards to age, sex, income group and region of residence. The participants were informed in writing that completing the questionnaire and answering individual questions was voluntary. As is usually the case with this type of panel survey conducted by marketing research companies and in the case of social science, ethical approval was not sought.

A total of 30 161 persons responded to the request (58.6%). After the exclusion of 114 incorrectly filled-in questionnaires, a total of 30 047 questionnaires (58.4%) were available for the analyses. The mailed questionnaire included a list of 38 symptoms that have been reported in previous studies to be possibly associated with RF-EMF exposure (Frick list).<sup>15</sup> The symptoms covered in the list range from cognition problems, pain, sleeping problems, skin reactions, gastrointestinal affections, to visual problems. Each of the 38 symptoms were ranked as “not at all”, “little”, “moderate” or “strong”; hence, a higher summary score indicates poorer well-being. Participants were

also asked in two questions whether they are worried about health effects of mobile phone base stations in general (*concerns*), and whether they believe that their health is adversely affected by mobile phone base stations (*attribution*). They could answer either “yes” or “no”.

The questionnaire included questions on demographic characteristics. In addition, the subjects were asked to estimate the distance to the next mobile phone base station.

### Geo-coding

The distance between residence and mobile phone base station was additionally computed based on geo-codes of base station locations and participants' addresses. Locations of all 51 000 mobile phone base stations in Germany in 2004 provided by the respective German authority (“Bundesnetzagentur”) were geo-coded by the network operators, and household addresses by the Post Direct GmbH, a commercial service provider. The distance estimation based on geo-coding was successful for 29 805 participants (99.2%).

Distance was dichotomised into “not exposed” (>500 m) and “possibly exposed” (≤500 m).

### Data security

The study procedure guaranteed data security and anonymity of participants during analyses. The postal questionnaires were sent and collected by the holder of the TPI, which also ordered the geo-coding. All data were forwarded to the TNS Institute and further to the University of Bielefeld and Mainz as anonymous datasets. The linkage for consolidating geo-coordinates and questionnaire data were the so-called TPI-Identity numbers. All requirements of the German Data Protection Act were adhered to.

### Statistical analysis

*Concerns* about health effects and self-reported adverse health effects attributed to mobile phone base stations (*attribution*) were combined in a newly created three-level item on risk perception, with the categories “no concern and no attribution”, “concern but no attribution”, and “attribution”. In some analyses, the last two categories were combined.

The prevalence distribution of risk perception and the quartiles of the summary score of the Frick list (38 complaints) were examined by age group, region and by gender. In a non-responder analysis, we compared the educational levels of the responders and non-responders. We also attempted to estimate the extent of any error resulting from non-response. For this purpose we analysed the responses of the participants regarding concern about possible adverse health effects from mobile phone base stations, according to the time span for response to the questionnaire. Participants were placed into three groups: early responders, moderate responders, and late responders. Our model, the delayed response model, is based on the assumption that persons who respond late to questionnaires are more similar to non-responders than early responders.

We also performed regression analyses for these variables to adjust for demographic differences (including age, gender, region and social status in the model). For risk perception we conducted logistic regression analysis with “no concern and no attribution” versus “concern or attribution” as dependent variables. A multiple linear regression model was applied using the summary score of the Frick list as dependent variable, and sex, age and rural areas as independent variables. Comparisons of the responders with population-based numbers show slight

differences in age and sex between urban and rural areas, so that additional analyses are based on weighted values. Weights are calculated based on known values of age, sex and community size distribution in the German population and the deviation in the study population. Social status was represented by two variables, namely school education and family income.<sup>16</sup>

Furthermore, we analysed the relationship between subjective and objective distance to the nearest mobile phone base station. Regression analyses of the relationship between subjective and objective distance and cognition of health risks were also performed, adjusted for demographic differences.

## RESULTS

### Descriptive analysis

Of the 30 047 participants, 27 376 filled in the questions on *concerns* and *attributions*. Eighteen point seven per cent reported that they were concerned about health effects from mobile phone base stations and 10.3% attributed adverse health effects to RF-EMFs from mobile phone base stations. Although the majority of the 2819 participants with *attributions* also reported being concerned about health effects, 154 (5.5%) reported not to be concerned about health effects.

The prevalence of *concern* and *attribution* varies by age, income, education and region, but not by gender (table 1). Participants with higher social status were more concerned than others, but had a lower prevalence of attribution. There were also regional differences with a tendency that participants from south

Germany seemed to be more worried and more affected than participants from other parts of Germany.

According to the geo-coding information, 14 503 out of 29 805 residences were 500 m or closer to the nearest mobile phone base station. Hence, the prevalence of living in the proximity of a mobile phone base station, weighted for community size (see Methods), was 51.5%. A comparison of the participants' responses to distance to the nearest mobile phone base station and information from the geo-coding showed that 12 402 (41.6%) had correctly classified the distance as less or more than 500 m, 3376 (11.3%) had correctly estimated the distance to be  $\leq 500$  m, and 9026 (30.3%) had correctly estimated the distance to be  $>500$  m. A total of 8852 participants (29.7%) wrongly estimated the distance, with 7170 (24.1%) wrongly estimating it to be up to 500 m and 1682 (5.6%) wrongly estimating it to be more than 500 m. Eight thousand three hundred and fourteen (27.9%) were not sure about the distance and 237 (0.8%) did not respond to the question.

### Analytical analysis

Applying a logistic regression model including all relevant variables adjusted for each other, the odds ratios confirmed the findings from the univariate analysis (data not shown), implying that all these factors act independently. Persons stating that they lived in the vicinity of a mobile phone base station significantly reported more worries than other

**Table 1** Prevalence of *concerns* about adverse health effects and *attribution* of health complaints to exposures from mobile phone base stations

Category		No	Number missing	No concerns/attribution (%)	Only concerns (%)	Attribution (%)
All		30 047	2671	71.0	18.7	10.3
Gender	Male	14 399	1140	70.9	18.4	10.7
	Female	15 648	1531	71.2	18.9	9.9
Age in years	14–19	2665	228	75.6	16.0	8.4
	20–29	4074	182	74.9	17.4	7.7
	30–39	6575	285	68.5	21.7	9.8
	40–49	6039	428	68.0	20.9	11.1
	50–59	5409	599	71.7	16.1	12.2
	60–70	5285	949	71.9	16.9	11.2
Family income	Below €1000	3400	372	72.9	16.4	10.7
	€1000–€2000	10 542	1043	72.3	17.4	10.4
	€2000–€3000	8791	647	70.4	19.7	10.0
	€3000–€4000	3840	248	70.2	19.0	10.8
	More than €4000	1734	139	69.1	21.5	9.4
	Not specified	1740	222	67.4	22.2	10.4
School education‡	Low	8476	1124	72.5	16.1	11.4
	Intermediate	9858	796	71.5	18.0	10.4
	High	8610	476	68.4	22.2	9.4
	Other†	3103	275	73.3	17.1	9.6
Region	North Rhine-Westphalia West	6399	552	73.5	17.4	9.0
	North	4739	402	71.9	18.7	9.4
	Middle	3845	367	71.4	17.7	11.0
	South	7996	696	64.2	23.0	12.8
	East	7068	654	75.8	15.3	8.9
City inhabitants	<100 000	23 619	2145	70.6	19.1	10.4
Distance to nearest mast*	$\leq 500$ m	14 374	1152	71.4	18.5	10.1
	$>500$ m	15 431	1494	70.6	18.8	10.6

\*Based on 29 805 persons, only persons with geo-coded residences.

†Includes participants still going to school, who left school without a school leaving certificate, or received other degrees, that is, from foreign schools.

‡Represents the German school system: low = "Volks- und Hauptschule", intermediate = "Realschule/mittlere Reife", high = "FH-Reife/Gymnasium (Abitur)"; the school types do not necessarily reflect years of education, but low is most likely 9–10 years, intermediate 10 years, and high 12–13 years.

Attribution, participants attributed own adverse health effects to mobile phone base stations; no concerns/attribution, participants neither concerned about health effects of mobile phone base stations nor attributed own adverse health effects to mobile phone base stations; only concerns, participants concerned about health effects of mobile phone base stations, but did not attribute own adverse health effects to mobile phone base stations; region, geographical demarcation.

participants (odds ratio 1.35, 95% CI 1.25 to 1.45) (data not shown). However, taking the true distance based on geo-coding into account (two categories,  $\leq 500$  m and  $> 500$  m), the odds ratio was 1.00 (0.94 to 1.07).

The quartiles of the summary score of the Frick list of complaints showed little variation by age, region, education, income and other demographic variables, but some differences by gender (higher among women) (data not shown). Participants with *concerns* had similar quartile values as the reference group, while those who attributed health complaints to mobile phone base stations had higher values. The linear regression model confirmed the gender difference concerning the complaints and suggested little variation with increasing age up to the age of 59 years, and inverse associations with income and education (table 2). It also yielded a slightly higher level of health complaints among concerned participants. Among participants attributing health complaints to the nearby mobile phone base station the score was considerably higher. The summary score of health complaints among people living in the vicinity of mobile phone base stations ( $\leq 500$  m) was slightly higher than among those living more than 500 m away from the next mast (table 2).

### Non-responder analysis

The non-responder analyses showed only minor differences in educational level between responders and non-responders.

We observed a positive trend between time of response to questionnaire and proportion of persons concerned about adverse health effects of mobile base stations. In the early responder group, 24.7% of the participants expressed *concern*, compared with 31.9% in the late responder group (table 3). Assuming that late responders do have similar response behaviour to non-responders, 6826 (31.9% of non-responders) non-responders would be expected to have reported *concerns* about adverse health effects. Correcting for this factor would result in a marginal increase in the proportion of participants reporting *concern* from 28.5% to 29.6% (table 3).

### DISCUSSION

Our study showed that 18.7% of persons aged between 14 and 69 years are concerned about health effects of mobile phone base stations and that 10.3% attribute adverse health effects to the exposure from the masts. There were prevalence differences between north and south Germany (higher in the southern part), across age groups (highest among 30–59 year olds), and across social classes by income and education (lower with increasing level). The score of a list of 38 health complaints (Frick list) showed a clear association with *concerns* and *attributions* of health effects to mobile phone base stations and a very weak association with the distance to the nearest mobile phone station.

**Table 2** Multivariate linear regression analysis\* on predictors of the summary health score (Frick list)

	No	Mean†	Regression coefficient (95% CI)
Gender	Male (reference)	12 579	48.47
	Female	13 460	53.70
Age group (years)	14–19	2369	47.69
	20–29	3740	51.74
	30–39	6002	51.14
	40–49	5320	51.27
	50–59	4435	52.35
	60–70 (reference)	4173	51.31
Income	Below €1000	2808	53.89
	€1000–€2000 (reference)	9030	51.87
	€2000–€3000	7818	50.68
	€3000–€4000	3414	49.95
	More than €4000	1555	49.00
School education§	Do not know	1414	49.38
	Low (9 years)	7011	52.22
	Intermediate 10 years (reference)	9257	51.33
	High (12–13 years)	8545	50.16
Region	Other‡	1226	51.07
	North Rhine-Westphalia/West (reference)	5547	51.21
	North	4161	50.85
	Middle	3308	51.79
	South	6998	51.34
City inhabitants	East	6025	50.82
	<100 000 (reference)	20 461	51.11
Concerns/attribution	$\geq 100 000$	5576	51.42
	Neither concerns nor attribution (reference)	17 076	50.42
	Attribution	2393	56.10
	Only concerned	4522	51.81
Distance to nearest phone mast	Not specified	2048	50.32
	>500 m (reference)	13 407	50.93
	$\leq 500$ m	12 632	51.43

\*Based on all 26 039 participants, whose residence was geo-coded and a summary health score was available.

†Crude mean.

‡Includes participants still going to school, who left school without a school leaving certificate, or received other degrees, that is, from foreign schools

§Represents the German school system: low = "Volks- und Hauptschule", intermediate = "Realschule/mittlere Reife", high = "FH-Reife/Gymnasium (Abitur)"; the school types do not necessarily reflect years of education, but low is most likely 9–10 years, intermediate 10 years, and high 12–13 years.

Our study is so far the largest one in which the possible relationship between proximity of living near a mobile phone base station, *concern*, *attribution* and health complaints was investigated. The strength of our survey was that it was not immediately obvious that the questions on health complaints and mobile phone base stations were related to each other, as they were part of a much longer panel questionnaire. Also, our study was representative for the German population and not restricted to areas where persons were already actively involved in actions against the erection of mobile phone base stations.

Nevertheless, some limitations have to be discussed. As in many postal surveys, the response rate was below 60%. Additionally, persons who had agreed to participate in the panel may have already been a selective subgroup of the general population. However, as the investigation was not only on health aspects and also not introduced as such, it can be assumed that neither attitude towards mobile telecommunication nor specific health problems influenced the response rates. A small group of participants, 5.5%, attributed health effects to mobile base stations but did not report any *concerns* about health effects. This could imply that some participants had interpreted the *attribution* item to mean that base stations may cause health problems in general, although they were not affected themselves.

The crude exposure categorisation, namely defining a 500m circle around the nearest mobile phone base station as the exposure area and neglecting exposure from other RF-EMF sources, allows only a descriptive statistical approach. The amount of exposure misclassification introduced by this method is presumably large<sup>12</sup> and the resulting bias has to be expected to underestimate possible associations, if there were any.<sup>17</sup>

In general, cross-sectional studies are limited as exposure and outcome are assessed at the same time, making it difficult to draw conclusions on the temporal relation of cause and effect. In our survey however, the situation concerning proximity to mobile phone base stations and health was expected to be more or less stable for the vast majority of participants, such that many of the investigated complaints were not occurring or vanishing within a short period of time.

For the observed association between *attribution* of health effects to the mobile phone base stations and the actual occurrence of health effects, it is difficult to say whether persons with persisting health complaints attribute these symptoms to the mobile phone base station in an effort to identify a cause, or whether high levels of anxiety, depression, and stress together with regarding the mast as a hazard promotes health complaints, or a mixture of both. Furthermore, as the *attribution* item inherently assumes the existence of health complaints, the relationship between attribution and the health score from the Frick list was to

**Table 3** Non-response analysis based on the delayed response model

		Total		Concerned
		No	No	%
Early responders	1st tertile of respondents' time	10 095	2493	24.7
Moderate responders	2nd tertile of respondents' time	9378	2560	27.3
Late responders	3rd tertile of respondents' time	10 574	3373	31.9
Non-responders		21 397	6826*	31.9*
Total		51 544	15 252	

\*Estimated.

## Main messages

- ▶ There is no scientific evidence that radio frequency electromagnetic fields emitted from mobile phone base station antennas are associated with the occurrence of adverse health effects.
- ▶ There is considerable public concern that living in the vicinity of a mobile phone base station has adverse effects on health.
- ▶ Until now no large-scale field study addressing this topic has been conducted.

## Policy implications

A substantial proportion (about 27%) of the German population is concerned about possible adverse health effects when living in the vicinity of a mobile phone base station and every tenth German attributes health complaints to exposures from these masts. Fifty-one point five per cent of the study population lived in the proximity of mobile phone base stations ( $\leq 500$  m distance). *Concern* about and *attribution* of adverse health effects to mobile phone base stations are associated with health complaints. The observed slightly higher prevalence of health complaints near base stations can however not be fully explained by attributions or concerns.

be expected. Of more interest is thus the group of participants who reported concerns, but no attributions. This group had a significant regression coefficient of 1.45, lending support to the idea of a general psychological construct, leading to an increased awareness of environmental hazards and a higher likelihood of expression of health complaints.

It can be argued that the investigation of adverse health effects caused by exposure to mobile phone base stations requires a different study design,<sup>5</sup> such as a case-control study as used for investigating cancer risk in relation to RF-EMF exposure,<sup>18</sup> or a cross-over design.

## CONCLUSIONS

This comprehensive nationwide, cross-sectional study in Germany shows that a substantial proportion of the population is concerned about possible adverse health effects in relation to mobile phone base stations, and almost every tenth German attributes health complaints to the RF-EMF exposure from nearby masts. More than half of the study population lived in the proximity of mobile phone base stations ( $\leq 500$  m distance). Our finding that *concern* about and *attribution* of adverse health effects to mobile phone base stations are associated with health complaints supports the findings of the survey carried out among EU citizens.<sup>4</sup>

The weak association we found between mobile phone base stations  $< 500$  m and adverse health effects confirmed the relevance of the second phase of our study, in which actual RF measurements were conducted (see page 124). The observed slightly higher prevalence of health complaints near base stations cannot be explained by attributions or concerns alone.

In conclusion, we believe that the worries and health complaints of people living close to mobile phone base stations need to be taken seriously. Improved risk communication with concerned persons is required.

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We declare that we participated in the study and have seen and approved the final version. MB, GB-B, BS, PP and JS conceptualised the study and developed the study protocol. MB and GB-B were responsible for the conduction of the study. PP was responsible for the survey, which was managed by UR. PP and UR analysed the survey data. GB-B, BK and JB were responsible for data management and, together with SS, for the analysis. JS and MB prepared the manuscript which was jointly finalised by all authors. MB is the guarantor of the work.

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