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Review

Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication—a literature review published between 2000 and 2004

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Abstract

Literature published between 2000 to 2004 concerning electromagnetic fields (EMF) of mobile communication and electromagnetic hypersensitivity (EHS) or unspecific symptoms of ill health, respectively, is reviewed. Basically, literature from established databases was systematically searched for. For each study, the design and quality were evaluated by means of a criteria list in order to judge evidence for causality of exposures on effects. Finally, 13 studies of sufficient quality were considered for this review.

In only one provocation study, individuals with self-reported electromagnetic hypersensitivity were exposed to EMF. Their perception of field status was no better than would have been expected by chance. Results of five randomised cross-over studies on impaired well-being due to mobile phone exposure were contradictory. Even though these studies would allow more reliable exposure assessment, they are limited due to short exposure period and the small study size.

No firm conclusion could be drawn from a few observational epidemiological studies finding a positive association between exposure and unspecific symptoms of ill health due to methodological limitations. Causality of exposure and effect was not derivable from these cross-sectional studies as field status and health complaints were assessed at the same time. In addition, exposure assessment has not been validated.

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In conclusion, based on the limited studies available, there is no valid evidence for an association between impaired well-being and exposure to mobile phone radiation presently. However, the limited quantity and quality of research in this area do not allow to exclude long-term health effects definitely.

Keywords: Electromagnetic hypersensitivity; Unspecific health complaints; Subjective symptoms; Mobile phone; Electromagnetic fields

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1. Introduction

Public discussion on possible health risks from electromagnetic fields even below the legal thresholds is common (Sage, 2001). As mobile communication is being increasingly established, this discussion is focussing on health impairment associated with mobile phones and base stations. Still, ongoing rapid, nationwide implementation of this technology is accompanied by its wide use in the population. The heath risk discussion focuses on carcinogenic and bioregulatory effects as well as impaired well-being, i.e., headache, sleep disturbances or problems in concentrating, sometimes referred as electromagnetic hypersensitivity (Silny et al., 2004).

The term electromagnetic hypersensitivity (EHS) relates to subjects attributing health symptoms to an exposure to electromagnetic fields. In population-based surveys, prevalence of EHS was reported to be 1.5% in Sweden (Hillert et al., 2002) and 3.2% in California (Levallois et al., 2002). In this context, EHS can be related to radio and microwave frequency fields of mobile communication, fields in the kilohertz range of display units as well as extremely low-frequency fields of domestic power supply. It should be noted that the term EHS exclusively depicts self-reported hypersensitivity. So far, objective criteria classifying these subjects as hypersensitive have not been established. In analogy to environmental patients reporting Multiple Chemical Sensitivities (MCS) or

Sick-Building–Syndrome (SBS), individuals with EHS describe multiple non-specific health complaints (David et al., 2002; Hietanen et al., 2002; Raczek et al., 2000). Many of these complaints are subjective, e.g., redness and burning sensation of the skin and face, tingling, pain and dryness of the mouth and throat, problems in concentrating, nervousness or headache. The health complaints related to EHS result in considerable psychological stress in these patients. Due to a lack of knowledge of the pathophysiology of this complex of symptoms, adequate medical treatment for these patients is difficult.

An additional phenomenon in this context is the proclaimed ability to perceive electromagnetic fields at a much lower threshold than the general population without necessarily developing health symptoms (Leitgeb and Schröttner, 2003). Therefore, the presence of considerably decreased perception threshold, on one hand, and the attribution of health symptoms to EMF exposure, on the other hand, can be considered as two independent phenomena. Nevertheless, in a survey among self-declared EHS individuals, 56% declared their ability to perceive electromagnetic fields (Röösli et al., 2004). The ability to perceive EMF at a considerably decreased threshold can be investigated by so-called provocation studies. In contrast, to investigate a possible association between symptoms and EMF exposure is methodologically more challenging, in particular effects demonstrable after long-term exposure or with some latency period only.

The aim of the presented review of the literature is to elucidate whether EHS can be considered an entity and whether subjects with higher electrosensitivity toward frequencies from mobile communications actually exist.

2. Methods

2.1. Outcome selection

Electromagnetic hypersensitivity as an entity and a considerably decreased perception threshold was considered to be outcomes of priority. In addition, the most common unspecific symptoms of ill health reported in relation to exposure to electromagnetic fields were derived from the literature and viewed as further outcomes. These were the following: fatigue/difficulties in sleeping, dizziness/nausea, headache, disturbances in concentrating and memory, pain other than headache, nervousness, depressive mood/or state, skin-related sensation, e.g., itching, tickling, redness, burning or increased temperature of the skin including warm sensation of the ear, tinnitus/ringing of the ear.

2.2. Literature selection

Literature search was based on a number of criteria. Eligible studies had to be published between 2000 and March 2004 and had to be related specifically to electromagnetic fields from mobile communication (mobile phones or base stations), i.e., analogue signals used in the past as well as digital signals (GSM, UMTS). Only original papers but not reviews were considered. Besides peer-reviewed journal contributions so-called "grey literature" was included whenever possible. These publications had to be informative enough to allow a critical quality evaluation, e.g., comprehensive study reports. Short conference abstracts were not considered to supply sufficient information. Applying this procedure was to insure that all of the relevant studies relating to the selected outcomes were assessed.

2.3. Literature search

Literature search was performed independently by two teams in order to reach a maximum completeness. Eligible literature was systematically searched for in The National Library of Medicine (Pubmed: www.ncbi.nlm.nih.gov/PubMed/). In doing so the MeSH search term "radiation, nonionizing/adverse effects" was combined with numerous single words describing the outcome of interest, e.g.: «"radiation, nonionizing/adverse effects" [MeSH] and headache» or «"EMF" [MeSH] and nausea». First triage was based on the abstract. The completeness of the search was checked with three strategies: (i) reference lists of review articles were examined with respect to papers and grey literature which fulfilled inclusion criteria; (ii) topic-specific online data bases were consulted: Research Centre Jülich (http://134.94.127.170:8087/), the University of Basle (www.elmar.unibas.ch/index.html) and the Research Center for Bioelectromagnetic Interaction in Aachen (www.femu.de/); (iii) related ar-

ticle search was used in Pubmed as well as in the online database of the Institute for Scientific Information (ISI: www.isinet.com/).

In order to identify studies that addressed subjective health complaints only marginally, as a secondary outcome, experimental studies assessing, e.g., brain physiology or cognitive functioning in relation to exposure to mobile phones or base stations were also systematically screened.

2.4. Quality evaluation

The value of studies on possible health effects and exposure is predominantly determined by their design. Evidence for causality of exposures on effects can only be obtained from studies excluding possible bias; e.g., randomised double blind trials using well-defined exposure settings. Cross-sectional studies (surveys), measuring health effects and exposure at the same time, are not able to depict the causal relationship between exposure and effects, especially if these effects are subjective complaints reported by the subjects.

For these reasons, selected literature was weighted according to study design for this review. In a second step, study quality was judged. This judgement was based on criteria for the evaluation of epidemiological studies on radiation published by the Commission for Radiation Protection (SSK, 2002). Applying a ten-page questionnaire, each study was assessed as far as wording of the aims and problems, study concept, quality assurance, evaluation as well as interpretation and discussion of results are concerned. Most important minimal quality criteria which experimental studies had to fulfil were (i) adequate sample size; (ii) blinding of the study participants; (iii) randomisation; (iv) exposure characterized. Minimal quality criteria for observational studies were (i) comprehensible study participants recruitment, (ii) allowing for possible confounding factors in the analysis (at least age and sex), (iii) approved exposure assessment with respect to a reproducible personal exposure.

This procedure allowed for deriving four categories of evaluation (Table 1).

Studies of sufficient quality with designs appropriate to examine causal relationships are able to give evidence as to whether (or not) and possibly to what extent exposure to electromagnetic fields influences occurrence of complaints. Studies of sufficient quality with a study design not appropriate for finding causal relationships are able to give indication or can be used to derive hypotheses without contributing to evidence. Studies of poor quality are not able to contribute to the evaluation (Table 1).

Table 1
Scheme of assessment for studies

	Suitable[a] study design	Unsuitable[a] study design
Sufficient quality	Evidence	Hints/Hypothesis
Quality inadequate[a]	Useless	Useless

The suitability of the study's design concerning evidence of causal effects and the study's quality are taken into consideration.
[a] Suitability and assessment of quality referred to the aim of this analysis of literature.

3. Results

3.1. Selection of Studies

A total of 20 papers and two reports from the grey literature were considered relevant and preselected. Thereof, 5 papers were excluded due to double publication of the same material. Additional four papers were excluded as they did not meet quality criteria: the studies of Navarro et al. (2003) and Santini et al. (2002, 2003a,b) did not state the applied methods of subject recruitment, and the exposure assessment based on distance was judged to be inadequate; as well possible confounding factors were not allowed for in the analysis (e.g., age and sex). Hietanen et al. (2002) did not allocate actual and sham exposure in a random counterbalanced way. Therefore, effects resulting from exposure versus from sequence cannot be differentiated. Ozturan et al. (2002) reported non-blinded experimental results.

Overall, 11 papers and two reports remained for this review. Thereof, seven publications were observational studies (Table 2). These non-experimental studies were not considered adequate for examining causal relationship. They are only able to build the basis for generating hypotheses and indications concerning associations. Four papers and two reports described experimental studies allowing to draw conclusions on causality of unspecific health complaints and exposure to electromagnetic fields of mobile

Table 2
Observational studies

Reference	Study design	Collectives	Sample size	Country/ City	Outcome	Exposure	Exposure assessment method
Chia et al., 2000	Cross-sectional	Random population sample	808	Singapore	Headache, tingling, burning, sense of warmth, tiredness, loss of memory, difficulty in concentration dizziness, visual disturbance	Mobile phone	Questionnaire
Hillert et al., 2001	Cohort	Self-declared EHS	14	Norway	Fatigue	None	–
Sandström et al., 2001[a]	Cross-sectional	Employee of companies with mobile telephone subscription	Norway: 2,828 Sweden: 7,803	Norway and Sweden	Dizziness, discomfort, concentration, memory loss, fatigue, headaches, warmth behind/on ear, burning skin, tingling	Mobile phone	Questionnaire
Santini et al., 2001	Cross-sectional	Students and employee of an engineer school	161	France	Headaches, concentration, memory loss, fatigue, sleep disturbance, discomfort, sense of warmth or burning, tingle	Mobile phone	Questionnaire
Frick et al., 2002	Cross-sectional	Random population sample	340	Germany/ Regensburg	Numerous health complaints	None	–
Hutter et al., 2002	Cross-sectional	Residents of a mobile phone base station	365	Austria	Sleep quality, cognitive performance, complaints related to exhaustion, digestive tract and cardiovascular system	Base station	Measurements
Röösli et al., 2004	Cross-sectional	Self-declared EHS	394	Switzerland	Various health complaints	Mobile phone and base station	Questionnaire

[a] Several publications of the same study: Oftedal et al., 2000; Sandström et al., 2001; Wilen et al., 2003.

communication (Table 3). From these, three studied health complaints as primary outcomes, the remaining as secondary outcome. From the latter, only sparse data about EHS or well-being can be obtained.

3.2. Perception of electromagnetic fields

A first group of studies consisted of blinded provocation studies. In theses studies, volunteers had to state whether a source was actually emitting electromagnetic radiation or not. Therefore, they were appropriate to give evidence for the ability of electromagnetic field perception at a low threshold.

Within one of the provocation studies 16 subjects with self-reported EHS were individually, and as a group, not able to perceive the field status more often than expected by chance (Raczek et al., 2000). According to the methods of one further double-blinded cross-over study, exposure status was assessed but results not given (Tahvanainen et al., 2004).

3.3. Electromagnetic hypersensitivity

A second group of studies assessed exposure effects on health status in general, not on specific complaints. These studies, performed on subjects with and without reported EHS, were able to test the hypotheses of individually different health complaints in association to exposure. In one Australian study were changes reported in the neural response during exposure to GSM 900 mobile phones, which were correlated with the self-reported health status. The health status was assessed by a symptom check list (activation–deacti-

Table 3
Experimental studies

Reference	Study design	Collective	*n* per experiment	Outcome	Exposure	Exposure duration	Intensity	Blinding
Huber et al., 2000	Cross-over	16 male, right handed (20–25 years)	16	Subjective sleep quality[a]	Mobile phone	30 min	SAR=1 W/kg	Double
Raczek et al., 2000	Cross-over	Self-declared EHS: 9 female, 7 male (31–76 years)	16	Field perception	Mobile phone	21 tests with 3 min exposure	Incident field: 16 V/m	Double
Koivisto et al., 2001	Cross-over	48 male and 48 female (18–49 years)	48	Headaches, dizziness, fatigue, tingling, redness on skin, sense of warmth	Mobile phone	Experiment 1: 60 min experiment 2: 30 min	Power: 0.25 W	Single
Croft et al., 2002	Cross-over	16 male and 8 women (19–48 years)	24	Mood[a]	Mobile phone	20 min	SAR=0.0034W/kg	Single
Zwamborn et al., 2003	Cross-over	Self-declared EHS: 11 male 25 female (31–74 years) reference group: 22 male 14 female (18–72 years)	36	Well-being (sum score)	Base station	30 min	Incident field: 1 V/m	Double
Tahvanainen et al., 2004	Cross-over	16 male and 16 female (average age: 38.8)	16	Field perception subjective symptoms (not specified)[a]	Mobile phone	35 min	SAR=1.6 W/kg (GSM 900) SAR=0.7 W/kg (GSM1800)	Double

[a] Secondary outcome (main outcome of the study was not well-being related).

vation check list by Thaya: individual health status is judged with a four-point scale using 20 opposite pairs of words). The mode of correlation is not given in the paper (Croft et al., 2002). In the Dutch TNO study weak exposure to UMTS was statistically significantly correlated with changes in health status in 36 subjects with and 36 without electromagnetic hypersensitivity. In this study, health status was assessed by a sum index of a symptom questionnaire. On the contrary, exposure to GSM did not influence well-being (Zwamborn et al., 2003). In an experimental double-blinded cross-over study giving no methodological details about health complaint measurement, no differences in complaints for actual and sham exposure were reported (Tahvanainen et al., 2004).

One cross-sectional study assessed health status in association with measured field levels at home from base stations of mobile communication in 365 individuals (Hutter et al., 2002). Reported health was grouped in complaints related to exhaustion, digestive tract and cardiovascular system according to the complaint list of Zerssen. After controlling for possible confounding factors (age, sex, use of mobile phones and health concerns), complaints related to the cardiovascular system, but not the other groups of complaints were significantly associated with measured field levels from base stations.

Further studies addressed the question whether physiological and laboratory parameters were different in patients with EHS and reference groups without complaints. To determine this, 14 patients with EHS who reported excessive fatigue were examined. Excessive fatigue was not associated with changes in cholinesterase (Hillert et al., 2001). Thus, it was not possible to objectify this subjective complaint by a laboratory parameter.

One further physiological parameter applied to objectify heightened sensitivity to metal compounds

in EHS patients is the lymphocyte transformation test (LTT). In a study aiming to show electrosensitivity towards reactions to the German D-net, various metal compounds were found and thereby a possible elevated reaction towards electromagnetic fields was derived (Raczek et al., 2000). It should be stressed, however, that a specific LTT is able to demonstrate sensitising but not the effector reaction, i.e., previous contact to an antigen but not clinical manifestation of sensitivity is shown. Clinical relevance of the LTT in terms of diagnoses of environmental illnesses has not been established and is still an issue for future research (RKI 2002).

3.4. Sleep quality

In German-speaking countries, fatigue and disturbances in sleep quality belong to the most frequent complaints related to EMF (Röösli et al., 2004). While a number of experimental studies have investigated electromagnetic field effects on EEG during sleep, effects on subjective rating of the sleep quality have not been studied thoroughly. Huber et al. (2000) did not find that exposure to EMF from mobile phones changed the reported quality of sleep in 16 young male subjects. Likewise exposure to a GSM mobile phone for 60 min did not affect daytime fatigue in two further experimental studies each with 24 individuals (Koivisto et al., 2001). Contradictory results have been reported from observational studies on associations of daytime fatigue and quantity of mobile phone use (Chia et al., 2000; Sandström et al., 2001; Santini et al., 2001). Potential confounding factors taken into account in the Singapore study (Chia et al., 2000) were age, sex, occupation and extent of onscreen work; in the Scandinavian study (Sandström et al., 2001), extent of onscreen work was considered, and in the French study (Santini et al., 2001), no confounder was taken into account. A cross-sectional study from Austria (Hutter et al., 2002) did not find an association between reported quality of sleep and exposure to base stations of mobile communication.

3.5. Dizziness

Concerning dizziness, one randomised cross-over study in 48 subjects did not find an association to mobile phone handset exposure in two experiments (Koivisto et al., 2001). Results of observational studies on mobile phone users were contradictory: while one Norwegian study in 2800 individuals described an association, studies from Sweden ($n=7800$), Singapore ($n=808$) and a French University ($n=161$) were not able to confirm this (Chia et al., 2000; Sandström et al., 2001; Santini et al., 2001).

3.6. Headache

One randomised cross-over study could not confirm an association between exposure to mobile phones and headache (Koivisto et al., 2001). The same applied also for headache resulting from an experimental study on different electromagnetic fields (GSM 900, GSM 1800, UMTS) from a base station for mobile communication (Zwamborn et al., 2003). On the other hand, two experimental studies found significant associations between reports of headache and use of mobile phones (Chia et al., 2000; Sandström et al., 2001). These results were consistent for number of phone calls, time of use and type of telephone (more symptoms when using analog phones with higher output power than GSM). In a French cross-sectional study, however, headache was not reported more often by subjects using mobile phones than those not using mobile phones (Santini et al., 2001).

3.7. Skin problems

"Itchiness, tingling and redness of skin" have only been studied once using a randomised cross-over study (Koivisto et al., 2001). No increase in skin problems was reported when using a GSM 900 mobile phone for 60 min at a distance of 4 cm from the ear compared to sham exposure. However, associations were found in cross-sectional studies investigating, e.g., "tingling" with use of mobile phones. In a Scandinavian study (Sandström et al., 2001), these associations reached significance, while in Singapore, only a tendency was reported (Chia et al., 2000) and no association was found in a study from France (Santini et al., 2001).

For increased temperature of the skin (burning and warm ear) controlled experimental studies found no associations (Koivisto et al., 2001). However, again, in observational studies, associations were found.

Even if mobile phone users did not report more frequent feeling of warmness than non-users, these complaints were reported significantly more often in the subgroup of mobile phone users that phoned for more than 2 min/day (Santini et al., 2001). Again in the Scandinavian study, a consistent increase in warmness was found with increasing exposure to mobile phones (Sandström et al., 2001), while in Singapore, no difference was found for mobile phone users compared to non-users (Chia et al., 2000).

3.8. Problems in concentration and memory loss

A number of experimental studies examined the effect of mobile phone exposure on cognitive functioning leading to contradictory results. However, several times, an improvement (or acceleration) of cognitive functioning was reported (Hamblin and Wood, 2002). Tests of cognitive functioning depend among others on power of concentration and memory. The evaluation of the presented study only refers to "problems in concentration" and "disturbances in memory," as they affect everyday life and can be reported by the subjects. These complaints have not been the object of controlled exposure studies even though EHS patients report these complaints frequently (Röösli et al., 2004). In the cross-sectional study from Singapore, no significant differences were found in reported difficulties in concentration when mobile phone users were compared to non-users (Chia et al., 2000). In the Scandinavian study, an indication for disturbances in concentration was observed for those reporting more than four calls per day. In contrast, memory loss was not associated with use of mobile phones. In the French cross-sectional study, users of mobile phones were not more likely to report problems in concentration and memory than non-users. Among those using mobile phones, 1800 MHz phone users were more likely to state disturbances in concentration than GSM 900 users. Likewise, more complaints were reported by subjects using mobile as well as stationary phones compared to those only using mobile phones (Santini et al., 2001).

3.9. Nervousness

Incidence of nervousness during controlled exposure was only studied for the TNO report and was reported more frequently during UMTS exposure than GSM exposure (Zwamborn et al., 2003).

3.10. Other unspecific symptoms of ill health

Other outcomes, e.g., depressive state and mood as well as pain other than headaches and tinnitus, have not been the focus of controlled exposure studies.

4. Discussion

The presented review of the literature comprising the years 2000 through 2004 yielded a total of 13 studies with sufficient quality focussing on electromagnetic fields of mobile communication systems and impaired well-being, i.e., health complaints or electromagnetic hypersensitivity (EHS). The evaluation depicted six randomised cross-over studies appropriate to address causal associations of exposure to EMF and well-being. Three of them focussed on impaired well-being as primary outcome, the others as secondary outcome. A further seven observational studies fulfilled the quality standards but were not designed to evaluate causality but only statistical associations. Altogether, there was little evidence for a particular population subgroup who is able to perceive electromagnetic fields in an experimental double blind setting at a much lower threshold than the general population. No specific symptom or symptom cluster was found to be caused by exposure to mobile phone radiation. On the other hand, based on the contradictory results of three randomised cross-over studies, it cannot completely be ruled out that exposure to EMF can lead to an impaired well-being. If so, the studies to date would indicate an individually different response and not a typical "EMF-symptom cluster".

This review is based on a systematic compilation and evaluation of possible effects of radiation from mobile communication on well-being or unspecific symptoms of ill health. Detailed evaluation of up-to-date literature, including grey literature, became possible due to the additional focus on specific health complaints and a limited number of years of publication. At the same time, this implies a clear restriction. Older studies and other health effects such as carcinogenic or bioregulatory effects were not considered.

It should be noted that only a sparse amount of literature focussed on health effects of mobile communication before the year 2000. Likewise, papers on EMF not related to exposure from mobile communication were not considered.

In the following, it will be discussed why there are only relatively few and contradictory studies on this topic although public interest and concern are obvious. Furthermore, the relevance of public health concern is justified as the number of those exposed is considerable.

It should be stressed that restrictions in well-being, i.e., health complaints, are frequent in the general population and individual reports of complaints depend on a number of individual variables (e.g., age, gender, social status, anxiety, accompanying disease and personality traits) and individual factors of exposure in everyday life. This clearly shows that only well-designed studies allow to attribute health complaints to one specific cause, i.e., exposure to radiation from electromagnetic field from mobile communication.

In particular, observational studies on the phenomenon EHS have two main restrictions: valid exposure assessment and lack of objective criteria for assessment of outcome, i.e., reported health complaints. Reports of symptoms, complaints and well-being are of subjective quality and are not or not necessarily correlated with the clinical status (Michel, 2004). Judgement of personal well-being depends on individual characteristics (e.g., hypochondria), present mood (Michel, 2004) as well as context of questioning (Frick et al., 2002). Subjectivity poses a problem for between subject comparisons and in particular, if long-term effects after a latency period are addressed; both of which is stated by some of those presuming to suffer of EHS. It would be of utmost relevance to assess long-term health effects. Cross-sectionals studies are often understood to detect long-term effects. However, due to severe methodological limitations, no firm conclusion can be drawn from the few published studies on mobile phone radiation exposure. In cross-sectional studies, exposure and effect are measured at the same time. Thus cause and effect cannot be differentiated. Furthermore, in published studies, exposure assessment was based on a subjective statement which has not been validated (use of mobile phone) or on one single spot measurement (base station). Co-exposures to other possible risk factors were not taken into account, and only a few, if any at all, potential confounding factors had been considered in the analysis. It is conceivable, e.g., that the number of phone calls made is related to the individual stress level which is in turn associated with health complaints (Herr et al., in press). None of the published studies made an attempt to take this aspect into account. It is not surprising that so far only experimental, randomised, cross-over designed studies with short exposure duration are able to give evidence for or against causality of health status in relation to exposure to mobile communication systems. However, experimental studies leave open a number of unresolved issues even if the results had been consistent across studies. Due to their design, these experimental studies are only able to give evidence for acute immediate effects. Long-term effects cannot be studied or evaluated. A drawback of experimental studies compared to epidemiological studies is their small sample size. Thus, their power to detect rare or subtle effects is small. Unfortunately, published studies in which no effect was found did not state the effect size that could have been detected with the respective study. Considering this, the interpretation of results is difficult.

In addition, the investigation of EHS individuals by means of laboratory studies is hampered by the fact that many patients reporting EHS have psychological impairments and in part paranoid fears about EMF (Härmä, 2000). For this reason, many of the patients do not agree to participate in studies of unknown laboratory environment. The reasons given for non-participation are fear of effects of the experimental exposure or lack of objectivity within the study.

An open issue remains the question whether potential effects occur above a high, localised threshold or whether cumulative total body exposure possibly including a latency period is most relevant. Latter is often suggested from EHS persons and would suggest that beside exposure due to mobile phones themselves, mobile phone base station exposure may be relevant. Following the concept of a highly localised threshold would mean that only exposure to mobile phones themselves could be considered relevant for triggering health complaints.

5. Conclusion

Only a restricted number of studies has been published on well-being (i.e., health complaints) and exposure to electromagnetic fields from mobile communication between 2000 and March of 2004. The results are contradictory and the greater part of these studies is not able to address the issue of causality between exposure and outcome. Therefore, an effect of exposure to electromagnetic fields from mobile communication on well-being cannot be derived based on these limited studies. In order to obtain more insights in the phenomenon EHS an interdisciplinary research effort is needed, including psychological, pathophysical, laboratory and epidemiological disciplines as well as the improvement of personal dosimetry.

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