

## Section 12

### Symptoms Attributed to Radiofrequency Electromagnetic Fields

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## Summary

- Electromagnetic hypersensitivity or “EHS” refers to a variety of non-specific symptoms attributed to exposure to electromagnetic fields (EMF), including RF and extremely low frequency (ELF) electrical sources. Prevalence is estimated to vary from 1% to 10% of the population.
- Population health observational studies linking non-specific symptoms with exposure to radiofrequency (RF) waves from mobile phones and mobile phone base stations have shown mixed and inconsistent findings, with a major limitation being poor exposure assessment and biases in the design of the cross-sectional studies.
- In general, subjects who are self-declared with “EHS” in comparison to controls have not been found to reliably detect RF either in experimental conditions (provocation studies) or in their natural environments.
- The results from provocation studies with adequate blinding in place indicate that RF fails to trigger symptoms in self-declared EHS individuals in a reliable, reproducible and consistent way. Sham RF (no exposure) can cause symptoms in EHS persons, and sham shielding may ameliorate symptoms. This supports a possible contribution of a placebo effect (of symptoms occurring with the expectation rather than actual exposure to RF) to the etiology of EHS.
- Individuals considered to have EHS tend to score significantly higher on personality measures of somatization (conversion of mental states into bodily symptoms) and have a higher likelihood of psychiatric co-morbidity, in particular, somatoform and anxiety disorders. To what extent that these co-morbidities are due the consequences of exposure, rather than to antecedents, needs further investigation.
- The provocation studies are limited to examining short-term exposure to RF and acute symptoms. The effects of cumulative, chronic exposure to RF on human health symptoms have not been well studied.
- Research as well as clinical treatment is hampered by the lack of an accepted and validated case definition for EHS.

## 12.1 Introduction

Exposure to electromagnetic fields (EMF) has increased over the last century as a result of electricity use and the evolution of wireless technologies such as radio and TV transmitters, satellite signals, mobile phones and mobile phone base stations. EMF exposure is now ubiquitous, and with ongoing technological innovations in wireless technology, this exposure is expected to increase. Considerable public debate and concern have arisen over the potential of adverse health effects of radiofrequency fields (RF) emitted from such diverse sources as mobile phones, wireless internet, particularly in schools (WiFi), “Bluetooth” devices, and smart meters on residences.<sup>1</sup>

A number of people suffering from nonspecific symptoms of unclear origin (symptoms that do not indicate a specific disease process or involve an isolated body system) attribute their health problems to external chemical or physical sources in their environment. A common term for the attribution of symptoms to EMF is “electromagnetic hypersensitivity syndrome” (EHS). People experiencing non-specific symptoms often attribute their health effects to being hypersensitive to the suspected factor at levels well below existing exposure limits.<sup>2</sup> In the case of EMF, attribution is not usually restricted to exposure to specific frequencies but involves a large range of frequencies from extremely low frequencies (ELF) typical of power lines and electrical appliances, to the high frequencies of radiofrequency fields (RF), ranging from 10 MHz to 300 GHz.<sup>2</sup> Wherever possible, this document has focused on literature pertaining to RF, but some pertinent studies including ELF are referenced.

The purpose of this section is to present an evaluation of the scientific literature concerning the association of health symptoms with exposure to RF/EMF.

## 12.2 Methods

Due to the large volume of literature available on RF and health effects, the literature search focused on reviews of the primary literature. Reviews were identified through a search in PubMed of reviews on EMF and EHS published from 2006 through early 2012, using the MeSH terms “electromagnetic fields” and “adverse effects.” We selected reviews written in English and preference was given to systematic reviews and meta-analyses. Four published reviews satisfied our inclusion criteria.<sup>3-6</sup> The studies reviewed by Roosli et al. (2010)<sup>7</sup> overlapped with those of their 2008 and 2011 publications, and therefore this review was not included. Studies on the relationship of EMF with non-specific health symptoms comparing subjects with and without EHS were described as cross-sectional studies on non-specific symptoms in the general population. Case studies were not included because attribution of cause and effect are not possible.

Where available, the following information was extracted from each review: time frame of the review, inclusion/exclusion criteria, aim of the review, methods of exposure/outcome assessment, study design (interventional vs. observational), outcome assessment, effect size and significance.

## 12.3 Is Electromagnetic Hypersensitivity a Clinical Syndrome?

### 12.3.1 Terminology and symptoms

The term “Electromagnetic Hypersensitivity Syndrome” (EHS) is widely used in the public media and scientific literature although there are different meanings and alternative definitions. Different terms have been proposed to characterize the impairment for people who attribute their symptoms to EMF, such as “self-reported electric and magnetic field sensitivity.”<sup>8</sup> The World Health Organization (WHO) concluded that EHS resembles multiple chemical sensitivities (MCS), another symptom-based condition associated with low-level exposures to chemicals. “Idiopathic Environmental Intolerance” (IEI) was introduced as a neutral term for sensitivity to environmental factors without necessarily implying chemical causation, and now it has replaced the term MCS. The term “IEI-EMF” was proposed to capture symptoms which individuals ascribe to EMF without forming a characteristic symptom cluster;<sup>1</sup> however, use of the term “EHS” persists.

EHS can be loosely defined as a collection of non-specific symptoms of varying degrees of severity that is attributed to environmental electromagnetic fields. Reported symptoms thought by some to be EMF-associated are broad, encompassing neurological, psychiatric, vegetative and dermatological symptoms (Table 1).<sup>2</sup> Symptoms vary between individuals, and so it is difficult to create a uniform case definition.<sup>9,10</sup> Studying individuals who self-identify as persons with EHS is the typical approach used. An early attempt involving 18 European countries failed to identify a specific symptom cluster characterizing a syndrome based on an inquiry.<sup>11</sup>

There is currently no established or accepted clinical diagnosis of EHS supported by the majority of the medical community. The World Health Organization (WHO) states:

*EHS is characterized by a variety of nonspecific symptoms that differ from individual to individual. The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMF exposure. Further, EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem.*<sup>12</sup>

EHS is classified as a functional impairment in Sweden, and Spain has recognized EHS as a permanent disability.<sup>13</sup> According to the Canadian Human Rights Commission, national, provincial and municipal governments all have recognized conditions related to environmental sensitivities, although not necessarily specific to EHS.<sup>14</sup>

Table 1. Reported symptoms ascribed by some individuals to be associated with exposures to EMF

*In alphabetical order, obtained from Leitgeb (2009)<sup>2</sup>*

Abdominal pain	Headache	Numb limbs
Anxiety	Head pressure	Phosphenes
Appetite loss	Heart beat irregularity	Rash
Arousal decreased	Heart palpitation	Restlessness
Blood pressure increase	Hormonal disorder	Skin burning
Breathlessness	Hypersensitivity to medication	Skin redness
Chest pain	Hypersensitivity to noise	Skin tingling
Concentration difficulties	Intestinal trouble	Sleep disturbance
Crankiness	Irregular bowel movement	Stress
Daytime sleepiness	Irritation	Sweating
Digestive problems	Itching skin	Swollen eyes
Dizziness	Limb pain	Swollen joints
Dry skin	Metabolic disorder	Tachycardia
Exhaustion	Mood changes	Tenseness
Faintness	Mood depression	Tiredness
Fatigue	Muscle cramps	Toothache
Fear	Muscle pain	Trembling
Feebleness	Nausea	Unfeelingness
Feeling hot	Neck pain	Vision blurring
Forgetfulness	Neuralgia	Vomiting
Hair loss	Neurasthenia	Weariness

### ***12.3.2 Differential diagnosis and prevalence***

Since EHS is not a recognized clinical diagnosis, the discussion of a differential diagnosis is problematic. It has been suggested that IEI and EHS fall under the broader category of “symptom-based conditions,” or “functional somatic syndromes” which includes other disorders such as sick building syndrome, chronic fatigue syndrome, and Gulf War syndrome. These are not considered to be diseases but descriptions of multisystem symptoms with an associated low threshold of pain or discomfort without corroborating medical signs or pathophysiology.<sup>15</sup> According to Hyams (1998):

*Although various clinical observations and precipitating events are used for diagnosis, postulated etiologic factors have not been consistently associated with symptom-based conditions. In addition, potential risk factors have not been demonstrated to produce the kinds of organic pathology hypothesized to underlie these conditions...Without verified risk factors, symptom-based conditions are generally thought to have similar multifactorial etiologies and not a single cause. In addition, causal criteria can lead to errors in diagnosis because of reporting bias when a potential cause has been previously emphasized.”<sup>16</sup>*

Attempts to define the demographics and/or prevalence of EHS in the few population-based studies that do exist are inherently hampered by subjectivity and the lack of a case definition. The wording of questions asking about EHS strongly influences the assessed prevalence numbers.<sup>2</sup> Patient self-identification is typically used in lieu of a diagnosis.

Considering these limitations, the proportion of the population self-reporting clusters of symptoms such as those listed for “EHS” has been estimated to fall anywhere between 1 and 10% depending upon the location, the age group and definition of EHS used.<sup>13</sup> A population-based cross-sectional questionnaire survey in Sweden of 10,670 adults with a high (75%) response rate reported 1.5% of respondents as being hypersensitive or allergic to electricity.<sup>9</sup> A telephone interview-based study in California of 2,072 adults found 3.2% stating that they were allergic or very sensitive to being near electric appliances, computers or power lines.<sup>17</sup> A similar Swiss study found that 5% of 2,048 people had self-reported EHS.<sup>18</sup> A German population-based cross-sectional study reported that 10.1% of the study sample attributed their adverse health experience (based on a higher summary score from the “Frick” list of 38 health complaints) to mobile phone stations and were possibly exposed, with their residence being 500 m or less away; yet a similar percentage (10.6%) with complaints attributed to mobile phone stations were unexposed, living greater than 500 m away.<sup>19</sup>

In a Swiss study, 71% of individuals with self-reported EHS had symptoms for less than three years, and only 7% experienced symptoms for longer than 10 years; 53% of these individuals reported “very severe” or “severe” physical impairment from their symptoms.<sup>10</sup> In the Californian cross-sectional study (reported above), over one-half of the 3.2% of respondents who indicated that they were allergic or sensitive to common EMF sources reported sensitivities to both EMF and chemicals.<sup>8</sup> In the Swedish study, individuals with self-declared EHS were more likely to report a variety of environmental allergies, including pollen, animal fur, dust mites, and mould, and 31% reported intolerance of dental amalgam.<sup>9</sup> In view of the possible overlap between diverse environmental sensitivities, it is questionable whether EHS constitutes a unique condition or should be considered as part of a broader syndrome.

With respect to the demographics of EHS, these studies suffer from selection bias due to their reliance on self-identification. In general, women and persons with high tendency to somatization (conversion of mental states into bodily symptoms) tend to report more frequent and more severe EMF-associated symptoms.<sup>20</sup>

An association between psychiatric illness and EHS has been observed, but not well-understood. Hypotheses suggest that EHS is either a purely psychiatric somatisation disorder or that psychiatric conditions act as predisposing factors for developing EHS. In terms of personality traits, persons who report symptoms in response to EMF have higher trait anxiety, somatization, and somatosensory amplification scores.<sup>21</sup> Alternatively, there may be neurological and psychological consequences associated with EHS. Signs of mental distress have repeatedly been observed in persons with EMF-related symptoms, e.g., elevated levels of perceived stress, stress susceptibility, anxiety, and depression.<sup>22</sup>

## 12.4 Electrosensibility and EHS

*Sensibility* addresses the ability to perceive exposures without necessarily developing health symptoms. *Sensitivity* addresses the development of health symptoms associated with exposures, while for *hypersensitivity*, exposures are at much lower levels than required for the general population.<sup>2</sup>

### 12.4.1 Electrosensibility in the general population

Leitgeb and Schröttner (2003)<sup>23</sup> tested the ability of a cross-section of the population to detect EMF. The researchers recruited volunteers from a random selection of 200 households in a regional electric utility clients' list (70% response rate) and from visitors of public trade fairs. Volunteers were exposed to electric currents administered via electrodes on their forearms. The currents were increased until the volunteer pushed a button to indicate their perception of current flow. The analysis was performed on 708 adults, aged 17 to 60, including 349 men and 359 women. Women had significantly lower thresholds than men. The relationship between current strength and perception followed a log normal distribution overlapped by a second normal distribution at the sensitive end of low perception thresholds, attributable to EHS cases, with a mean that is 6.7 times lower than the population mean.<sup>23</sup> However, hypersensitive reactions to environmental EMF, characteristics typical for EHS, were expected to be several orders of magnitude (at least one thousand times) below exposure limits, which was not supported by the relatively small difference between population perception thresholds.<sup>2</sup>

### 12.4.2 Electrosensibility among subjects self-declared as EHS

Central to the postulated diagnosis of hypersensitivity to RF is that individuals self-declared as having EHS are able to discern subthreshold levels of EMF better than the general population. Schrottner and colleagues (2007)<sup>24</sup> studied the electric current perception threshold in three different groups of self-declared EHS patients recruited by different means: (1) an EHS self-help group; (2) a newspaper advertisement; and (3) subjects with health symptoms actively seeking help for perceived RF-induced sleep problems. The results were compared to normal population values. All groups exhibited results overlapping the normal range, with some individuals exhibiting lower-than-normal thresholds in each group. As a whole, the pooled EHS data showed a lowered threshold compared to the population; however, the self-help group showed no

difference from the general population.<sup>24</sup> These results indicated that electrosensitivity is a real phenomenon in a proportion of self-declared EHS subjects. However, it remains unknown if these data could be extrapolated to even lower current densities that would reflect more accurately a “hypersensitive” condition. According to Leitgeb (2009)<sup>2</sup> the results demonstrating electrosensitivity do not support the hypothesis of “electrohypersensitivity” since the span of results for EHS subjects did not extend beyond the lowest thresholds of the general population. Another consideration is that it was the response to ELF electric currents, and not to RF, that was evaluated.

## 12.5 Evidence Regarding Electromagnetic Hypersensitivity

### 12.5.1 Provocation studies

Provocation studies are experimental human studies where subjects are exposed to an agent that is claimed to provoke a response (e.g., mobile phone RF triggering EHS symptoms) and to a sham agent that should provoke no response. Physiological reactions or symptoms occurring during exposure or shortly after provocation (20 minutes to 24 hours) are the endpoints.<sup>6</sup> The degree to which the exposure and testing environment is controlled varies among the different study designs, which in turn, influences the potential for bias and confounding. At one end of the spectrum are the minority of studies which carefully control exposure to RF by using real and sham shielding against EMF in either laboratory or home settings, or by exposing participants to real and sham EMF fields in shielded rooms. Alternatively, many of the laboratory provocation studies create exposures to real and sham mobile-phone-like signals but do not control the background EMF exposure, although they may report or measure this component of exposure.

Experimental provocation study designs have been used to test the ability of individuals to perceive low level RF compared to sham exposure (either directly or via shielding) in order to determine whether individuals with self-reported EHS can perceive EMF. Roosli and colleagues (2008)<sup>3</sup> performed a meta-analysis to evaluate the ability of “EHS” individuals to detect RF emitted from mobile phones or mobile phone base stations. Seven studies met their inclusion criteria encompassing 182 individuals with self-declared EHS and 332 non-EHS individuals. The pooled relative difference between observed and expected correct choices was not statistically significant from zero (averaging 4.2% 95% CI: -2.1 to 10.5).<sup>3</sup> There was no evidence that persons self-reporting as EHS could detect the presence or absence of RF better than persons not considered EHS, that could not be attributed to chance findings. The meta-regression did not show any significant relationship between the ability to detect EMF and EHS status, type of exposure (mobile phone vs. mobile phone base station) or duration of exposure.

Experimental studies have been consistent in demonstrating that acute exposure to RF does not trigger symptoms in individuals with self-reported EHS if they are adequately blinded. Rubin et al. (2010)<sup>25</sup> updated a previous systematic review on provocation studies comparing individuals with and without EHS under blinded conditions.<sup>5</sup> The original meta-analysis of 31 provocation studies reported no robust evidence to

support the existence of EHS. The 2010 update used the same inclusion criteria: subjects had to be exposed to at least two different levels of EMF, the experiment had to be performed under blind or double-blind conditions, and the outcome had to be either self-reported symptoms or the ability to perceive EMF. The review excluded studies that only tested “healthy” participants (i.e., those who did not report EHS).

A total of 46 provocation studies were identified and 16 of these were reviewed in the update. Of the studies selected for the update, seven tested exposure to a mobile phone type signal, four tested exposure to mobile phone base station type signals, four tested exposure to magnetic fields, and one tested the effectiveness of a protective cage over beds of participants reported to have EHS. Subjects were exposed to RF in the 800–900 MHz range with exposures lasting five seconds to 50 minutes. The near-field exposure of the mobile phones all had peak SARs less than 2 W/Kg. For the base station exposures, the whole body exposure to RF was created to have a maximal strength of 10 V/m. For example, in the cited study of Furubayashi et al. in 2009,<sup>26</sup> the subject was exposed to a 2.14 GHz W-CDMA down-link signal at an intensity of about 10 V/m, which corresponds to an incident power density of 0.265 W/m.<sup>2</sup> The result of the meta-analysis was that there was little evidence to suggest that EHS individuals could detect EMF, or EMF triggered acute symptoms. An alternative explanation was the existence of a “nocebo effect” of symptoms occurring with the expectation rather than actual exposure to RF.

These results are in agreement with most other reviews of this area.<sup>3,27,28</sup> The few studies that did report some effects of exposure on participants with self-reported EHS were considered to have methodological flaws due to either type 1 error associated with multiple testing (performing many tests in one study will increase the chance of at least one being incorrectly found to be statistically significant),<sup>29,30</sup> an effect caused by the order of exposure (the order should be given randomly to avoid learning effects)<sup>31</sup> or un-blinding of the study by the participants (who were able to discern shielding from RF exposure and therefore influence the results).<sup>32</sup>

The systematic review by Roosli and colleagues (2008) evaluated whether typical daily levels of exposure to RF are associated with symptoms in self-reported EHS and non-EHS subjects.<sup>3</sup> They selected peer-reviewed studies published prior to 2007 which had non-specific symptoms of ill health as the primary outcome. The exposure had to be in the RF range (300 kHz–3 GHz) and below the International Commission on Non-ionizing Radiation (ICNIRP) guidelines. Studies were excluded if both exposure and outcome assessment were by self-report alone. In total, 194 “EHS” and 346 non-EHS individuals were included from eight studies. The majority of studies used double blinding and exposure duration was between 30 and 60 minutes. Most often a GSM 900 MHz mobile phone exposure was used, although some studies applied MPBS signals. None of the individual studies found an association between symptoms, and RF exposure and symptoms also tended to occur during the sham exposure.

A study example is the double-blind provocation study by Eltiti et al. (2007)<sup>31</sup> where 56 self-reported “sensitive” subjects and 120 controls were exposed to mobile phone base station-like signals during three exposure conditions (GSM, UMTS and sham). The combined power flux density for each experimental signal was a realistic level of 10 mW/m<sup>2</sup> to the participant. Although the sensitive group reported more symptoms overall, there were no differences between active and sham exposures in the number of symptoms and symptom score for either group. However, during open provocation, when subjects were aware of being exposed or not, the sensitive group did report more symptoms when exposed to either signal compared with sham. The sensitive group had higher skin conductance overall. Judging whether the exposure was “on” or “off” was correctly done by only a few sensitive and control subjects and overall, the judgments by each group did not differ from chance.

Unlike laboratory provocation studies, field studies involve turning EMF sources, such as a mobile phone base station, on/off while participants are in their homes or offices. An example of such a field experiment is the planned shut-down of a short-wave radio transmitter in a Swiss study which determined the effects of RF exposure on salivary melatonin levels and sleep quality of residents living in the vicinity of the transmitter.<sup>33</sup>

The investigators recruited 54 volunteers to take part in two four-day periods of assessment, each of which took place one week before the shut-down of the transmitter (baseline) and one week after. The researchers grouped subjects into low and high exposure on the basis of estimated average 24-hour exposure for each participant’s home as determined by the relative position of the residence to the centre of the antenna and exposure measurements at baseline, which took place in 1992, 1993, and 1996. The transmitter operated at frequencies of 6.1 to 21.8 MHz, and after shut down there were no other exposures in this frequency range. Volunteers collected two samples of their own saliva at five different times during the day and filled out a sleep diary every morning, reporting morning tiredness, sleep quality, duration of sleep and the time that they fell asleep.

After controlling for age and gender, and taking into account baseline measurements in a regression analysis, subjects rated their morning freshness as 1.74 units better for each mA/m reduction in magnetic field exposure, which was statistically significant (with a 95% CI of 0.11 to 3.36 which does not include zero, or no difference). Melatonin excretion tended to be increased (although not statistically significant) by 15% (95% CI: -3 to 36%). Blinding of the subjects to the exposure source was not possible in this study. Furthermore, there is the potential for biased results in the sleep diary since this study was developed from an investigation that was initiated by residents’ symptomatic complaints.

Roosli and colleagues (2011) updated their 2008 review to evaluate studies published between 2007 and 2011. Nine experimental studies investigated exposures close to body sources (using GSM 900 mobile phones, tetra handsets and UMTS phones) and

six experimental studies determined the effects of far-field sources either in the laboratory or under everyday environments. Almost all of the nine experimental studies of RF exposures from phones and handsets showed no increase in any symptom during exposure and most of the six experimental far-field studies were also negative. It was concluded that the 15 randomized trials showed little evidence that short-term RF exposure causes non-specific symptoms.

### ***12.5.2 Limitations of provocation studies***

Provocation studies allow greater control over confounding variables and exposures and therefore the possibility of biased results is minimized. Although this design provides the temporal association that is necessary for causal inference, it only allows for assessment of the acute effects of short-term exposure. In a recent review of study criteria used to define IEI-EMF by Baliatsas et al. (2012), a major inclusion criteria for identifying EHS was the experience of symptoms during or soon after the perception or presence of an EMF exposure source (from 20 minutes to 24 hours after).<sup>6</sup> Yet symptoms associated with exposure to RF can be chronic, developing over time with low levels of exposure. Furthermore, individuals may react to a specific EMF frequency from a source that is not being tested in the experimental protocol<sup>13</sup> or to multiple sources of RF simultaneously.

An additional drawback to this experimental study design is the small sample size, which therefore leads to low statistical power, and limited ability to detect relatively rare effects. The laboratory setting itself may provoke anxiety in participants and may introduce noise into the study, masking any subtle induced symptoms. In addition, it is possible that by controlling for all background exposure through use of shielded exposure rooms, some unknown synergistic elements of EMF may also be removed. An alternative is conducting experiments in “real-life” settings such as residences or workplaces. However, the level of control over the extent of exposure and confounding variables is even more difficult to achieve than in laboratory experiments.

### ***12.5.3 Observational studies***

There is a large body of observational research that explores the relationship between EMF and non-specific health effects. The prospective cohort design (subjects who are initially free of disease are followed forward in time) is considered to be stronger than cross-sectional designs in determining causal relationships. There are currently no reports of prospective cohort studies evaluating the relationship of exposure to RF to the development of non-specific symptoms characteristic of EHS.

The cross-sectional design is the most frequently used for evaluating symptomatic responses to exposure to RF. Information about a wide range of health outcomes is collected by questionnaire, with standardized instruments available to assess symptoms. Most studies were population-based rather than focusing on “EHS” subjects.

Although a limited number of studies have addressed the effects of near-exposure RF (close-to-body), e.g., mobile or cordless phone use, the majority of researchers have attempted to evaluate the effects of far-field RF exposure. The exposure type and methods of exposure ascertainment in these studies vary greatly. Exposure sources include a single mobile phone base station (MPBS), all MPBS in the vicinity of a residence, and the sum of EMF from MPBS stations and WiFi. Exposure assessment is usually based on distance from the residence to the exposure source (typically an MPBS), spot measurements in bedrooms and offices, or personal dosimetry of total RF over the course of a waking day or a 24-hour period.

All of these methods for exposure assessment have limitations which affect accuracy of the measurement of RF (see Section 5). While, the exposure levels generally decrease substantially with increasing distance (inverse square law) in the far field of base stations, the exposure levels are affected by reflections from buildings and other obstacles. A better predictor of exposure than distance is line-of-sight to the base station. The representativeness of personal dosimetry of RF is complicated by the low levels found and variability due to changing multiple sources of exposure and the dominant contributions of mobile phone technology.

Roosli (2008)<sup>3</sup> reviewed the findings of observational population-based studies and found that results differed from those of the provocation studies. A statistically significant positive association was reported for the association of exposure with symptoms for each of four cross-sectional observational studies, although the type of exposures, exposure assessment and health outcomes considered varied greatly. For instance, a Swiss cross-sectional survey queried 400 adults living at various distances from a short-wave broadcast transmitter about their sleep and other somatic symptoms. Exposure assessment was based on 2,621 measurements of magnetic field strength in 56 locations. The study found a significant relationship for difficulty in falling asleep, maintaining sleep, tiredness, nervousness and restlessness in the more exposed.<sup>34</sup> However, the authors do report that this series of studies was instigated by similar symptomatic complaints by residents living near the broadcast transmitter and the subjects could not be blinded to their exposure. An Austrian study surveyed 365 randomly selected individuals living near a MPBS about subjective symptoms, sleep, and cognitive performance. Exposure measurements were based on spot measurements of high frequency EMF taken in the bedrooms of the participants after completion of the questionnaire. The symptoms of headache, cold hands or feet and concentration difficulties were significantly associated with exposure levels, even after their response of fear of negative effects was taken into account.<sup>12</sup> Exposure levels were generally low (95% were below 1 mW/m<sup>2</sup>) for frequencies ranging from 80 MHz to 2 GHz and the contribution was mostly from mobile communications. Concerns about negative health effects associated with living near a MPBS were highly related to overall sleep quality.

The 2011 narrative review by Roosli and colleagues,<sup>4</sup> an update of the 2008 review,<sup>3</sup> explored the effects of RF exposure encountered in everyday life on self-reported non-

specific symptoms and well-being, as was also covered extensively by Roosli et al. (2010).<sup>7</sup> They included eight studies published from 2007 to 2010 with RF-exposure frequencies ranging from a few MHz up to 10 GHz and excluded studies based on self-reported exposure.

Only three of the eight studies reported statistically significant associations. The authors noted a lack of association of exposure to RF and symptoms found in the majority of recent observational studies, contradicting the findings of their earlier (2008) review.<sup>3</sup> As well, cross-sectional epidemiological studies with crude exposure assessments based on distance from an RF source often showed health effects, whereas studies based on more sophisticated exposure measurements rarely indicated any association.<sup>7</sup> Whether there are unknown confounders related to socioeconomic or other conditions which are related to residence near a base station that may explain the increase in symptoms is not known. Alternatively, there may be characteristics of RF relevant to health not captured by measurement of power density.

An example of a large cross-sectional study is the investigation the relationship between MPBSs and self-reported health and well-being in a representative population of German residents.<sup>19</sup> In the first phase of this study, 26,039 subjects aged 14 to 69 completed a questionnaire about a variety of health symptoms. Exposure to RF was based on the distance between a participant's address and the nearest mobile phone base station, where a distance of  $\leq 500$  m was considered possible exposure and a distance  $> 500$  m was considered non-exposure. In this study, 18.7% were concerned about health effects from MPBSs and 10% attributed their health effects to MPBSs. Multivariate linear regression analysis was conducted for a 38 item symptom list adjusted for gender, age, income, education, region of residence, urban vs. rural, concern about MPBSs, attribution of health effects to MPBSs and distance to the nearest MPBS. Participants who had possible exposure to RF by living closer to an MPBS scored slightly higher on the Frick Summary Symptom Score (indicating greater severity) than less exposed residents.

In the second phase of the study, a subset of individuals who participated in Phase I of the study also had dosimetry performed in their homes.<sup>35</sup> Five standardized health questionnaires were used to measure sleep disturbances, headaches, health complaints, mental health and physical health. Exposure information was obtained through combining dosimetric measurements of five minutes each in four different positions on the beds of participants. In each location, 75 measurements were taken for 12 different frequency ranges, encompassing frequencies from 88 MHz to 2.5 GHz. Uplink frequencies used for communication between mobile phones and mobile phone base stations were excluded from the calculation of the "mean total field value," as the study focus was background RF. A person living in a residence with a mean total field  $> 0.1$  V/m ( $0.029$  mW/m<sup>2</sup>) was considered exposed.

Of 1,326 participants with valid RF measurements, 27.1% were concerned about MPBS and 8.8% attributed their health problems to EMF. Exposures were generally found to

be low; 65.8% of the households had a total mean field value below 0.05 V/m (limit of detection) and the highest value was 1.14 V/m. No differences in the medians of the five health scores were observed for the comparison of exposed versus non-exposed, whether based on RF from mobile telecommunication frequencies or total RF including exposures from TV and radio broadcast towers, cordless phone base stations and WiFi. The authors concluded that measured RF (analyzed only as a binary variable) emitted from mobile phone base stations was not associated with adverse health effects. However, the researchers noted that subjects attributing adverse health effects to MPBSs had more sleep disturbances and health complaints.

Baliatsas and colleagues (2012)<sup>6</sup> conducted a formal systematic review of observational studies published between 2000 and 2011 regarding symptoms attributed to actual and perceived exposure to EMF among the general population. Of the 22 studies included as having adequate reporting quality (of 41 eligible articles), 13 studies provided data on actual exposure to EMF based on field strength spot measurements, use of personal dosimeters during waking hours, exposure predictor modeling or geo-coded distance to base stations, with eight studies using standardized instruments to assess non-specific physical symptoms (NSPS). The results of nine of the 13 studies showed an association with at least one symptom. The number of studies where there was a significant effect of actual exposure on NSPS (versus the negative studies) was as follows: fatigue (n=1 vs. 4); concentration difficulties (n=1 vs. 3); headache (n=4 vs. 3); sleep problems (n=4 vs. 5); and dizziness (n=3 vs. 3).

Methodological quality was determined to be an important component for the strength of the associations, since studies with questionable exposure assessment and/or sample selection reported more significant associations. More recent studies using advanced exposure characterization methods did not suggest a significant effect. Although there were only two to four studies contributing to the analysis of each symptom group, there were between 919 and 1897 study participants included in each analysis. Meta-analyses were conducted to quantify the association, after excluding five studies due to high risk of bias and lack of comparability. No significant effect of higher exposure levels was determined for any of the symptoms analyzed according to severity (acute) and frequency (chronic). The investigators concluded that there were no indications for an association between higher levels of actual EMF exposure and frequency and severity of NSPS in the general population. It was recognized that the meta-analysis was limited by the small number of available high quality comparable studies.

Twelve studies reported on the association between perceived exposure and NSPS, based on daily use (duration and/or number of calls) of mobile phones. Seven studies assessed symptoms with standardized instruments. Comparison of the number of studies showing a significant effect of perceived exposure on NSPS (versus negative studies) were: concentration problems (n=4 vs. 2); headache (n=5 vs. 3); fatigue (n=4 vs. 3); burning sensation (n=2 vs. 2); sleep problems (n=1 vs. 4); and dizziness (n=2 vs. 5). Due to the considerable heterogeneity between studies, meta-analysis could not be

performed. It was concluded that, unlike the studies measuring EMF exposure, there may be an association of symptoms with perceived exposure, although more evidence is needed due to the lack of comparable methods and instruments to assess perceived exposure and outcomes between studies.

#### ***12.5.4 Limitations of observational studies***

There have been a large number of cross-sectional studies conducted on RF and non-specific health effects. Cross-sectional studies are regarded as a relatively weak epidemiological design as they are subject to bias related to design and confounder effects, as well as misclassification of exposure and effects. Overall, cross-sectional studies have reported more positive associations between EMF exposure and EHS symptoms than other types of studies, particularly for perceived exposure, but the findings are frequently mixed. For example, a statistically significant association was found between “skin tingling” and mobile phone use in a Scandinavian study,<sup>36</sup> while only a trend was identified in a Singaporean study,<sup>37</sup> and no association at all was found in a French study.<sup>37,38</sup> Cross-sectional studies have the potential to assess the effects of long-term exposures, but the temporal relationship is difficult to establish, and it is generally not possible to blind participants, leading to considerable risk of information bias.

Exposure classification is challenging for most observational studies, given the many different sources of RF exposure in the environment. These exposures vary significantly with time and are heterogeneous. Hence, non-differential misclassification is a problem for observational studies, which biases study outcomes towards the null. In older cross-sectional studies, the exposure assessment was frequently based on distance from transmitters, but dosimetry subsequently revealed that distance did not correlate well with actual levels of exposure. In addition, exposure to RF is low overall, leading to low variability and lack of an exposure gradient, which makes finding an effect, if there is one, more difficult.

### **12.6 Nocebo Effect**

With adequate study blinding, subjects considered to have EHS generally are not able to perceive levels of RF, or even the presence of RF. In the placebo-controlled studies that used sham exposure or sham shielding, symptoms were elicited by both the active and the sham conditions (reviewed in Rubin et al. (2010)<sup>5</sup>). The observation that sham conditions are able to provoke symptoms supports the role of nocebo effects in the etiology of EHS. Nocebo is an undesirable effect resulting from the suggestion or belief that something is harmful, when it is not. It has been noted that symptom scores in provocation studies are related to the beliefs about the actual presence or intensity of EMF.<sup>39</sup> The role of negative expectations in triggering symptoms is supported by a recent study in which 40 college students were asked to rate their symptoms during “sham,” “weak,” and “strong” RF exposure. In reality, there was no exposure at all, i.e., all sessions were “sham.” Suggestions of stronger EMF exposure resulted in higher symptom scores and enhanced EMF-perception.<sup>40</sup>

Roosli et al. (2010, 2011)<sup>4,7</sup> observed that cross-sectional studies which used crude exposure measurements based on distance tended to show health effects, while studies which used more sophisticated measures of exposure, such as dosimetry, rarely found an association. In the 2011 review evidence suggestive of a placebo effect was discussed.<sup>4</sup> In a double-blind, randomized, cross-over control study using exposure to Universal Mobile Telecommunication System (UMTS) signals, a significant association was observed between symptom score and perceived field intensity in both “EHS” and non-EHS individuals even though perceived fields were not associated with exposure levels.<sup>41</sup> Likewise a strong correlation between symptom score and perceived operating status was observed in the field trial of the UMTS base station ( $p < 0.0001$ ).<sup>42</sup> In another laboratory study, both individuals with and without reporting of EHS felt worse and had more severe symptoms during exposure to a TETRA mobile phone base station during open provocation compared to sham, with a greater effect seen in individuals considered to have EHS. The effect disappeared in subsequent double-blind testing where no differences were found between exposure and sham conditions for symptomatic or physiological measures.<sup>43</sup> These results support the observation that a placebo effect may be apparent for symptoms associated with EHS and should be considered in study designs.

## 12.7 Discussion

Research in this area is hampered by issues of internal and external validity of the studies, which limit the inferences that can be made. For example, the existence of a placebo effect, associated with the expectation of reacting negatively to exposure, highlights the importance of using blinding techniques in provocation studies.

There is much heterogeneity of exposure measurement regarding the EMF frequencies used, their pulsing characteristics, on-off behavior and the variable contributions of ELF and RF. In provocation studies, exposures range greatly in terms of type, strength and duration. There is uncertainty about the characteristics of RF exposure which are important for health. The observation that dosimetric measurement of exposure is usually not associated with health effects (unlike crude distance measurements) may be related both to the variability (and subsequent misclassification) of personal exposure measurements as well as the role of perception of exposure on symptoms. Multiple sources of exposure to RF are an important consideration in studies of “real-life” exposures.

Studies utilize a variety of symptom lists for non-specific health symptoms and include a diverse array of outcomes such as cognitive effects, sleep disturbance, headaches, neurological disorders and somatic complaints. This reflects the wide range of health symptoms in individuals who report that they have EHS. There is a lack of an accepted and validated case definition for EHS. Applying broad criteria not only dilutes the power of studies to determine an outcome for self-reported EHS subjects, but there is also a greater potential for misclassification and inability to detect legitimate subjects considered to have EHS.

While EHS may not have an accepted clinical definition, subjects who self-identify as EHS can be severely debilitated by their symptoms. The prominent contribution of the nocebo effect in the generation of the symptoms of EHS should not be ignored, nor should it be used as a means to disregard symptoms. Rather, it should be seen as a disease-causing mechanism in itself, termed the “psychogenic” model of EHS.<sup>15</sup>

Grouping symptom-based illnesses together, including illnesses such as MCS, chronic fatigue syndrome and fibromyalgia could benefit from similar—although individually tailored—approaches to multidisciplinary management. In this regard, there are small studies of EHS patients responding well to sleep hygiene, avoidance/reduction of triggers,<sup>13</sup> cognitive behavioral therapy,<sup>44</sup> and anxiolytics.

The decades of research regarding symptoms in the general population attributed to exposure to EMF have been hampered by a lack of clear definition of what constitutes a diagnosis of “EHS.” Cross-sectional and provocation studies generally rely on self-report of EHS, which introduces problems of misclassification and affects the strength of any association found.

Further research is needed to define what types of EMF exposure may be of relevance, what biological mechanisms may be involved and the role of chronic exposure to EMF on symptoms and reporting of EHS. Since most studies have been conducted on adults, the symptomatic effects of exposure to RF on children and other potentially vulnerable groups are not clear.

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