

Is there a syndrome caused by radiofrequency electromagnetic fields?

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It is claimed that exposure to radiofrequency fields (RF) produces a ‘microwave syndrome’, characterised by ‘sleep disturbance/insomnia, headache, depression/depressive symptoms, fatigue/tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, restlessness/anxiety, nausea, skin burning/tingling/dermographism and EEG changes’.¹ There are, it is claimed, many scientific studies which support this concept; and a PubMed search today on (radiofrequencies OR electromagnetic AND symptoms) gives 133,062 hits. So how do we assess this question, and can we conclude if the ‘microwave syndrome’ is a distinct clinical condition?

Many studies have reported that various symptoms appear to be increased by exposure to RF from cell phones or other technology. Many of the earlier studies were very simple, comparing self-reported symptoms, with no confirmation or validation, with self-reported exposures, for example from recalled cell phone use or from perceived distance of residence from a cell phone transmitter. Moreover, many of the studies had no defined sample base and may have involved unrepresentative groups of people, for example those responding to media or Internet invitations to participate.

Reporting of symptoms will vary greatly. Documentation of actual RF exposure is difficult. These symptoms are related to many other health conditions. Radiofrequency exposures could produce short-term or immediate effects, or long-term effects. Those in the affected group may be the whole general population exposed, or only a subgroup who are ‘hypersensitive’ to radiofrequencies. The studies can be considered in these ways.

For this brief commentary, systematic reviews for provocation studies and for cross-sectional and retrospective studies are used, while the few main prospective studies are described more fully. A literature search up to Dec 2019 used PubMed and the EMF Portal data base run by Aachen University, Germany, which is the most comprehensive data base on EMF science (<http://www.who.int/peh-emf/research/database/en/>).

Short-term effects

Short-term effects can be tested in double-blind trials, which can be called ‘provocation studies’ in this context. Volunteers are assessed in laboratories in which radiofrequency exposures can be generated, to mimic the exposures of using a cell phone or being close to a base station. Sham exposures can be used to give single or double blind conditions. Volunteers can be chosen from the general population, or from those who consider themselves hypersensitive to RF.

In a major review, 29 such studies of subjects who reported themselves ‘hypersensitive’ to electromagnetic fields were assessed.² Of these, only five studies each reported one statistically significant result, out of several outcomes assessed, with no consistency between studies. A further review notes 10 studies that showed that the development of symptoms was related to the perception of exposures, in the absence of actual exposure.³ This clearly suggests a placebo effect, that is, symptoms occurring if the subject assumes they have been exposed to something they believe is noxious and likely to cause health problems.

Long-term effects

Prospective cohort studies

The hypothesis that exposures produce symptoms over a long-time course cannot

be tested by randomised trials. The best available study design is a prospective study with measured careful documentation of RF exposures and symptomatic outcomes over subsequent time, with due consideration of likely confounders, and sufficient size to allow detailed analysis. Some major studies have been set up and are beginning to produce results.

The most ambitious study is COSMOS, the International Cohort Study of Mobile Phone Use and Health. This was started in 2007 to 2014 in Sweden, Finland, Denmark, the UK and the Netherlands. The first results have recently been reported, from 21,049 subjects in Sweden and 3,120 in Finland, based on four years' follow-up.⁴ At baseline for each participant, data on cell phone use from operator data bases as well as self-reported phone usage behaviour and defined symptoms were obtained; and repeat questionnaires used after four years. Analyses for each symptom were restricted to subjects free of that symptom at baseline. Results on headache, tinnitus and hearing loss have been reported.⁴ Outcomes were assessed by standardised questionnaires, and the key results compared subjects in the top decile of exposure with those in the lowest 50 percent. There were no significant associations with weekly headaches (odds ratio 1.13, 95% limits 0.95–1.34), or with other frequencies of headache. Exposures to 2G Systems (GSM) and to 3G systems (UMTS) were considered separately, as RF exposures for the same call time are approximately 150 times lower in the newer 3G system. While the associations were both small and non-significant, those with the higher dose 2G exposure showed lower odds ratios. There were no significant increases in tinnitus (OR 1.04, 0.87–1.25) or in hearing loss (OR 0.89, 0.56–1.41). These results applied after controlling for demographic variables, depression, mental and physical health, and daily pain killer use at baseline. Other factors such as obesity, depression, sleep disorders, smoking, alcohol use, did not affect the results.

The other prospective studies are smaller and less detailed. A Swiss study with 1,375 subjects with one year follow-up also showed no significant relationships between exposure measures or changes in these measures and headache, somatic

complaints score or tinnitus.⁵ In the Netherlands, the Occupational and Environmental Health Cohort Study (AMIGO) was established in 2011–12 with subjects aged 31–65 years, and subgroups followed in 2013 and 2014 (total n=3,968).^{6,7} Validated scales were used for 16 defined symptoms and for sleep disturbances; no significant associations were seen with either perceived or estimated RF exposures. At baseline, in cross-sectional analysis, both symptoms and sleep measures showed significant positive associations with perceived exposure, but no significant association with modelled RF exposure. The authors concluded that perceived exposures, but not actual RF exposures, were related to non-specific symptoms and sleep disturbances.

In a Swiss prospective study⁸ of 425 adolescents (ages 12–17), analyses assessed if various measures of phone use over one year were related to development of new symptoms. Headache, tiredness and other measures were associated with the number of texts sent per day, but associations with measures likely to be more closely related to RF dose were generally weaker. The authors conclude that aspects of extensive media use other than RF exposure may be related to symptoms. There are several other prospective studies, but generally small, with more limitations.

Meta analyses of field studies

The cohort studies noted above are major undertakings. The majority of studies on this topic are cross-sectional studies, which in general is a much weaker design and most studies have substantial limitations. There are too many for each to be reviewed here; but there have been several meta-analyses of these studies. These also contrast the results with those of experimental short-term studies, as noted above.

Klaps et al⁹ assessed papers published in English up to July 2014, identifying 17 studies assessing exposures from cell phone base stations and a range of general health states, including various symptoms, quality of life, anxiety, mood states, sleep quality and stress measurements. Eight studies were classified as blinded experiments, and none showed any significant associations. In two unblinded experimental studies, effects were seen only with open rather than hidden exposure; with open

exposure, fatigue, discomfort, and anxiety and tension showed positive significant associations. Nine studies were classified as field studies, in which subjects reported on both their own symptoms and their own assumed exposures; six of the nine studies showed positive associations, with headache, impaired memory, anxiety, fatigue, depression, lack of concentration, dizziness or vertigo, and irritability being increased with perceived higher exposures. The authors of the review summarise it by concluding that no effects were seen in blinded experiments, but were seen in open, less controlled, field studies; and some studies showed effects related to open exposures but not to concealed exposures.

Roosli et al¹⁰ presented a review of studies of health effects of cell phone base stations published up to March 2009, assessing risk of bias by the GRADE approach, and including 17 studies, five randomised trials and 12 epidemiological studies, examining non-specific symptoms. The randomised trials did not detect any association with estimated radiation exposure and the development of symptoms during or shortly after exposure. Of the epidemiological studies, six assessed headache and three showed significant positive associations; seven assessed sleep measures in various ways with one study showing a positive significant association with sleep disturbances, but others showing no significant associations. Three epidemiological studies used quality of life questionnaires, with none showing significant associations. The authors note that the more sophisticated the exposure measurement, the less likely it was that an effect would be reported.

A review of cell phone use and the risk of headache¹¹ assessed studies published up to May 2017, identifying seven cross-sectional studies. The meta-analysis showed a significant increased risk of headache in cell phone users compared with non-users, OR 1.38 (1.18–1.61), and the headache risk increased with longer call duration and greater call frequency. Most studies had control for age and sex, and some for residential and occupational variables. Three other studies not included in the meta-analysis showed consistent effects. No assessment of the RF exposures of the subjects were made. This review, even in

supplementary tables, gives no information on how cell phone exposure or headache were ascertained.

Other major reviews

Studies of health effects of radiofrequencies have been reviewed in detail by expert, multidisciplinary groups in many countries.¹² A specific report on electromagnetic-related symptoms and on hypersensitivity was commissioned by French authorities.¹³ The work involved 16 independent experts from many disciplines over three years, and reviewed studies from 2009 to 2016, and over 500 responses from public consultation. They concluded that there are no validated diagnostic criteria, so hypersensitivity can be defined only by self-report, and the experimental evidence does not show any causal relationship between symptoms experienced and electromagnetic exposures. The latest New Zealand report¹⁴ notes the lack of effects in controlled experimental studies, several community-based studies from 2010 to 2017 which show no effects, and agrees with the French report. It lists many other expert reviews.

Are the symptoms increased?

There is little consistency in how symptoms are described or classified. In supporting the ‘microwave syndrome’, one review¹ cites 22 studies showing “similar patterns of neuropsychiatric effects”, and lists how many of these report each symptom. In a Swiss study, 394 adults who considered they had EMF-related symptoms were surveyed, and the frequencies of specific symptoms in this group recorded.¹⁵ In Table 1, the data from these studies are compared to the results of a general population survey in New Zealand, asking about symptoms experienced in the previous seven days;¹⁶ in this sample (n=1,000) the median number of symptoms reported was five and only 10.6 percent reported no symptoms. The symptoms reported as being most often linked to radiofrequency exposures in the review and in the Swiss study are all common, with the most common symptoms also being reported by more than 20 percent of the New Zealand random sample in the past week. The comparison is very approximate, as symptom definitions and the age distribution vary; but as most studies of radiofrequency related symptoms do not have any time definition,

Table 1: Symptoms described as part of the ‘microwave syndrome’, and frequency of symptoms in one week in a general population survey in New Zealand.

Symptom	Symptoms self-reported as related to EMF		Population survey
	Number of studies reporting symptom, total 22. From ¹	Percent reporting symptom, of all reporting EMF related symptoms (n=394). From ¹⁵	% of respondents (n=1,000) reporting symptom in the last week. From ¹⁶
sleep disturbance/insomnia	17	58	28.6
headache	14	41	35.4
fatigue/tiredness	11	18	35.5
depression/depressive symptoms	10	5	13.8
dysesthesia (vision/hearing/olefactory dysfunction) ^a	10	20	11.7
concentration/attention dysfunction,	10	16	15.2
dizziness /vertigo	9	11	8.6
memory changes	8	Not recorded	12.1
restlessness/tension/anxiety/stress/agitation/feeling of discomfort ^b	8	19	17.4
irritability, ^b	7	Not recorded	17.4
loss of appetite/body weight, ^c	6	Not recorded	8.9
skin burning/tingling/inflammation/dermographism ^d	6	6	16.0
nausea	5	4	8.4

Notes: for population survey, % given may be low as other classifications are used:

a. ear or hearing problems 11.7%; eye or vision problems 10.4%;

b. irritability or nervousness 17.4%; anxiety or fearfulness 14.1%; agitation 12.7%

c. reduced appetite

d. skin rash or itching.

the frequencies reported in one week in the survey will likely underestimate the frequency over an undefined period. In another study of a representative group of patients in general practice in Norway (n=909, response rate 89%), 40 percent of patients considered they had one or more unexplained conditions, including electromagnetic hypersensitivity and several other syndromes, and having any such condition was positively associated with the number of symptoms reported.¹⁷

Discussion

Some general themes emerge from these studies. Positive associations between estimates of cell phone use or exposure to base stations or other radiofrequency sources

are frequently seen in cross-sectional studies in which the subjects report both the symptoms and their exposure. These positive associations may be strong and significant, and a wide range of symptoms has been reported. In contrast, prospective cohort studies in which RF exposures are assessed at baseline, using objective measures such as operator data in addition to questionnaire information, and then these exposures are related to the later occurrence of symptoms, or to changes in symptoms over time, show no clear associations. These prospective cohort studies are relatively few at present and have only short follow-up, but they do avoid the major limitations of cross-sectional studies. In addition, assessments of short-term effects

under experimental conditions, where sham exposures are used as well as actual RF exposures, and subjects can be kept unaware of their real exposure, have shown no associations with symptoms.

This strongly suggests that associations with symptoms are not due to actual RF exposure. They may be due to other aspects of cell phone usage, such as time spent on calls, texting or games, or the psychological factors associated with this media use. They may also be due to perceived RF exposure, where this perceived exposure is seen as detrimental to health, through a nocebo effect. That is due to the individual's negative expectations about getting symptoms or health effects following exposure, but not actual RF exposure. There is strong evidence for this in experimental studies showing associations of symptoms with perceived RF exposures even with no actual RF exposures, and observational studies in which perceived exposures showed stronger associations with symptoms than did objectively assessed exposures.²

The symptoms reported as increased in relation to radiofrequencies are often common in the general population. They are also commonly increased in relationship to other environmental exposures which are perceived as hazardous. These include a range of very diverse exposures, including power lines, various facilities such as incinerators, waste dumps, factories and 'sick buildings',¹⁸ multiple chemical hypersensitivity¹⁹ and wind turbines. The range of symptoms is also very similar to the putative syndrome of ASIA, claimed to be caused by autoimmune reactions to common exposures.²⁰ Thus in a general population survey of 3,406 adults in Sweden,²¹ four types of intolerance were considered: multiple chemical sensitivity, sick building syndrome, electrosensitivity and noise sensitivity. In this sample 22 percent reported themselves as having at least one of four intolerances, and 6.3 percent had been diagnosed by a physician as having at least one. The intolerances occurred together; of persons with electromagnetic sensitivity, 58 percent reported at least one of the other three intolerances, 28 percent reported two, and seven percent reported all of them. The co-occurrence of each of the other syndromes with electrosensitivity was statistically more common than would be expected.

The overlap between symptomatology reported in relationship to very different environmental exposures suggests a general phenomenon, which has been referred to as idiopathic environmental intolerance (IEI), or enhanced responsivity.²² Van der Bergh et al²² postulate that effects can be triggered by the acquired meaning or expectation of exposures; thus "the symptoms of IEI result from a nocebo process driven by expectation and beliefs about the effects of particular environmental stimuli".

The best available scientific evidence does not support the concept that exposures to radiofrequency fields or other electromagnetic fields, from cell phones, base stations and other sources, cause increases in disease or increases in symptoms. Studies which do report such effects are usually weak studies in which there are major issues with the selection of participants and the documentation of both the exposures and the symptoms. Studies with stronger methods show generally no effects.

Despite this many people assume there are such effects. Some people believe that they are particularly susceptible or hypersensitive to radiofrequencies and therefore suffer these effects.

Helping the individual affected people, and dealing with the general issue, raises different questions.

The therapeutic approach to individuals who perceive themselves as seriously affected by radiofrequencies, or indeed other environmental influences, is beyond the scope of this paper. The health complaints expressed are a reality of life. Petrie and Rief²³ give a valuable overview of psychobiological mechanisms and principles of interventions. Various devices are marketed as reducing exposures from cell phones and other EMF sources, but tests of nine such devices showed no effectiveness.²⁴ The general issue is that the stories of ill effects, and the studies showing ill effects even if they are of very low quality, tend to receive the greatest attention. Thus media coverage could contribute to physical symptoms. An experimental study showed that watching a television documentary on the possible health effects of radiofrequencies increases the likelihood of symptoms following a sham radiofrequency exposure.²⁵ A content analysis of British

newspaper reports on idiopathic environmental intolerance (IEI) attributed to electromagnetic fields assessed 241 articles published from 2006 and 2011.²⁶ The authors concluded that the majority of news reports supported the idea of IEI being produced by electromagnetic fields, 40 percent suggested beneficial effects of reducing fields and 20 percent beneficial effects from complementary or alternative treatments or from electromagnetic screening. They conclude that such reports may “encourage more people to misattribute their symptoms to electromagnetic fields”. It is an example of public concern over difficult issues where the scientific evidence cannot prove a negative: even if no consistent evidence of a harm exists, the potential of a harm from the environmental exposures cannot be dismissed: the situation has been called post-normal science.²⁷ This has been specifically discussed in terms of electromagnetic fields by Wood,²⁸ whose recommendations include a commitment to open science, with wider participation of stakeholders in studies, more use of quality measures and sensitivity analyses, and preregistration of protocols.

This can also be considered an example of medical misinformation, defined as “a health-related claim of fact that is currently false due to a lack of scientific evidence” and is seen as a growing problem in medicine in general.²⁹ Armstrong and Naylor argue

that this is already having adverse effects on global health, through distrust of effective medical interventions such as immunisation and fluoridation and promotion of ineffective therapies, and requires a “robust and coordinated response from health professionals, organisations, institutions and midstream media”, with a particular responsibility for medical journals.

Conclusions

There is insufficient scientific evidence to support the idea that exposures to radiofrequency fields cause a specific syndrome of ill health, characterised by psychological and physical symptoms. The symptoms reported are generally common, and generally similar to those reported with other perceived environmental hazards. The more detailed studies suggest the symptoms are related more closely to the perception of harm rather than actual exposures to radiofrequency fields, suggesting other aspects of phone or computer use or a placebo effect are relevant. Irrespective of their causation, the symptoms experienced are real and affected individuals may have substantial ill-health and need appropriate supportive management. Public perceptions of a potential hazard are affected by the information given, and encouraging better understanding of relevant science is important in this as in many other health issues.

Competing interests:

The author has been involved in discussions of this topic with government and commercial organisations, including review groups, advisory groups on guidelines and standards, and reports on specific situations. The views given in this article are the author's own, and do not represent any other organisation or group.

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