

Hypersensitivity of Human Subjects to Environmental Electric and Magnetic Field Exposure: A Review of the Literature

Patrick Levallois

Unité de Recherche en Santé Publique, Centre Hospitalier Universitaire de Québec, and Institut National de Santé Publique du Québec, Beauport, Québec, Canada

Hypersensitivity to exposure to electric and magnetic fields (EMFs) has been reported for nearly 20 years; however, the literature on the subject is still very limited. Nearly all the literature published concerns a dermatological syndrome that consists of mainly subjective symptoms (itching, burning, dryness) and a few objective symptoms (redness, dryness) appearing after individuals begin working with video display units and decreasing during absence from work. Case-control studies as well as some good but limited double-blind trials have not found any clear relationship between this syndrome and exposure to EMFs. A "general syndrome" with more general symptoms has been rarely described but seems to have a worse prognosis. The symptoms often associated with skin disorders are mainly of neurasthenic type and can cover a lot of nonspecific symptoms present in other atypical syndromes such as multiple chemical sensitivity or chronic fatigue. Most of these symptoms are allegedly triggered by exposure to different sources of EMFs, but there have been no valid etiologic studies published on this more general syndrome. It appears that the so-called hypersensitivity to environmental electric and magnetic fields is an unclear health problem whose nature has yet to be determined. *Key words:* electromagnetic fields, hypersensitivity. *Environ Health Perspect* 110(suppl 4):613–618 (2002).

<http://ehpnet1.niehs.nih.gov/docs/2002/suppl-4/613-618levallois/abstract.html>

Hypersensitivity of human subjects to environmental electric and magnetic fields (EMFs) has been reported quite recently in the medical literature. Descriptions of possible allergic reactions from exposure to "electrical" environments have been published principally by European researchers, mainly from Nordic countries. But the reports and probably the cases appear to have increased so rapidly that some authors have labeled this a new environmental epidemic (1).

Although the clinical picture was mainly dermatological at the beginning and mostly associated with work on video display units (VDUs) (2), it has been extended to several health problems triggered by different kinds of exposure to EMFs. Health consequences could be so serious for some people that they lead to lengthy sick leaves and even sometimes to changes of jobs and homes (3). Studies of hypersensitive people are particularly difficult to conduct because symptoms are nonspecific and their relationships to EMFs are mainly alleged by the patients but not proved. In fact few etiologic studies have considered this health issue, and few reviews have been published on it.

This article is an overview of the scientific literature published on the subject, with a special focus on the possible causal relationship of exposure to EMFs of extremely low frequencies (ELF; 0.03–0.3 kHz). For that purpose, a MEDLINE (<http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>) search was carried out from January 1990 through September 2000, using the headings electrical, electric and magnetic fields, hypersensitivity, dermatitis, and allergy. Older reports were taken from references of

reports selected at the first stage as well as from two recent reports, one from Europe (3) and the other from the United States (4). The National Institute for Occupational Safety and Health database (NIOSH) with the Canadian Centre for Occupational Health and Safety database (OSHLIN) (http://www.ccohs.ca/education/aspl/search_hseosh.html) was also consulted, and contacts were established with European experts to obtain recent data from Europe. Only reports published in peer-reviewed journals were considered for this review.

Definition and Description of the Health Problem

Many terms are used to name hypersensitivity to EMFs. *Hypersensitivity to electricity* seems to have been first used by Knave et al. (5) to describe health problems triggered by exposure to VDUs, fluorescent lighting, or electrical devices. *Electric hypersensitivity* was also used to describe similar clinical portraits by Bergqvist and Knave (6) and Anderson et al. (7). Other synonyms used are *electrosensitivity* (8), *electromagnetic hypersensitivity* (3,4), *electrical hypersensitivity* (4,9), and *electrical sensitivity* (10). A more general term, *environmental illness*, has also been used by Arnetz et al. (11) to describe apparently the same clinical portrait.

Several definitions have been given for such diverse designations. A definition has been proposed recently that seems adequate to us:

electromagnetic hypersensitivity [is] a phenomenon where individuals experience adverse health

effects while using or being in the vicinity of devices emanating electric, magnetic or electromagnetic fields (EMFs). (3)

As implied by the title of this review, herein I use the term proposed by the California Department of Health Services: *hypersensitivity to electric and magnetic fields* (HSEMF). It seems preferable because in the ELF range where electric and magnetic fields are considered separately (12). HSEMF is then defined in this review as a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric and/or magnetic fields of extremely low frequency.

The clinical portraits are sometimes complex, but it seems that two general characteristics are associated with HSEMF (3,5,13): *a*) a group of symptoms (syndrome) usually appears or worsens during exposure to a specific source of EMFs, usually at work; *b*) these symptoms are reported to diminish when patients are away from the source and especially during absences from work (weekends, holidays, etc.).

The *dermatological syndrome* was the first to be described in the literature (2,14–16). It is mainly related to exposure to VDUs and mostly has a good prognosis. The symptoms are primarily subjective (itching, burning, stinging, etc.) and sometimes objective but nonspecific (rashes, dry and rosy skin), and are mostly localized to the face. Clinical diagnoses of VDU users with skin disorders were quite commonly facial dermatoses such as seborrheic eczema, acnea vulgaris, mild rosacea, and atopic dermatitis (16–19). Only

This article is part of the monograph *Environmental Factors in Medically Unexplained Physical Symptoms and Related Syndromes*.

Address correspondence to P. Levallois, Unité de Recherche en Santé Publique, Centre Hospitalier Universitaire de Québec, 2400, rue d'Estimauville, Beauport, Québec, Canada G1E 7G9. Telephone: (418) 666-7000, ext 210. Fax: (418) 666-2776. E-mail: patrick.levallois@mshp.ulaval.ca

This article is a revised version of a report prepared for the California Department of Health Services that was part of the California EMF research program. This program was mandated by the Public Utilities Commission with moneys from California utilities. This work was done by the author during a sabbatical at the California Department of Health Services, Oakland, CA, USA.

Received 3 December 2001; accepted 4 June 2002.

one case has been reported in North America, with dermatological symptoms on hands and forearms that were associated with VDU use (20).

The *general syndrome* was more recently reported and seems less defined. Patients are described with various health symptoms associated with or without skin problems: functional symptoms of the nervous system (dizziness, fatigue, headache, difficulties in concentration, memory problems, anxiety, depression, etc.), respiratory problems (difficult breathing), gastrointestinal symptoms, eye and vision symptoms, palpitations, and so on (5,13). All are present without any indication of organic lesion. These symptoms are triggered with exposure to different electrical devices and appliances (office equipment, fluorescent lights, household appliances, televisions, etc.), and often seem to worsen with time, with relatively poor prognosis (3).

Descriptive Epidemiologic Studies

Occupational Studies

Four studies have been conducted by self-administered questionnaire to assess the frequency of dermatological symptoms and

signs in relation to VDU use in different companies in Europe and Asia. The two more detailed studies in Sweden were supplemented with clinical examination of a sample of the respondents. Those four studies are summarized in Table 1 with their main results. Two were conducted in Sweden (17,18), one in Singapore (21), and one in the United Kingdom (22). Participation rate was excellent, except in the U.K. study. Facial complaints were found to be common among office workers and were more frequent for VDU users in the two Swedish studies (17,18). Operators who complained of skin problems were generally more likely to report other health problems related to VDU use: eye discomfort or irritation (17,18), musculoskeletal symptoms (17,21), and headache (17). Symptoms were associated with duration of work on VDUs but not with the type of VDU used (18).

Population Studies

No published epidemiologic study has been found on this issue. However, a group from the European Commission tried to assess the extent of electromagnetic hypersensitivity in European populations (3). Questionnaires were sent to 138 centers for occupational

medicine (COMs) and similar organizations and 15 self-aid groups (SAGs) from 15 different European countries. Response rate was 49% for the COMs and 67% for the SAGs. Questions were asked about the frequency, type, and severity of cases of electromagnetic hypersensitivity. Although it is difficult to draw statistics from such a semiquantitative survey, the report of the European Commission (3) stated that the prevalence estimated ranges

from less than a few per million (COM estimates from United Kingdom, Italy, and France) to a few tenths of a percent (SAGs in Denmark, Ireland, and Sweden) and with severe cases with generally one order of magnitude of lower occurrences.

Details of the European survey were described in the appendix of the report. It was found that the cases from Northern European countries in particular were associated mostly with work exposure, whereas cases in Germany and Ireland were associated only with sources at home. Other countries, such as France, reported mixed exposure. Nervous system and skin symptoms were more frequently reported, and ELF as well as radio frequency source exposures were reported to be associated with these symptoms.

Table 1. Descriptive studies on skin disorders in VDU users.

Authors	Study population	Methods	Prevalence	Factors associated with symptoms
Lidén and Wahlberg 1985 (17) Sweden	400 VDU operators and 150 other office employees not working with VDU from three enterprises in the Stockholm region.	Survey by self-administered questionnaire (response rate 97.4%). Questions on past and present symptoms. Dermatologic examination on 63% (61) of those who reported to have current symptoms on face, cheek, hands, or arms (46 exposed and 15 reference subjects).	18.7% of VDU operators reported presence of skin lesions on face, neck, hands, or arms compared with 15.6% for nonoperators ($p > 0.05$). Higher frequency of seborrheic dermatitis, acne, rosacea, and perioral dermatitis among the exposed ($p > 0.05$).	Subjects reporting skin lesions had complained more of eye discomfort, muscular skeletal symptoms, and headache ($p < 0.05$). 18.9% of the subjects with objective lesions suspected that these have been worsened by their work.
Koh et al. 1990 (21) Singapore	694 VDU operators in two statutory boards. 40% used PDS; 60% used CRTs.	Self-administered questionnaire survey on past or present skin symptoms, 96.8% response rate.	13.4% of PDS users had skin disorders in the last year, 11.4% for the CRT users ($p > 0.05$). 7.1% of PDS users reported having skin disorders at present, 7.7% in CRT users ($p > 0.05$). Skin rashes present at the time of the study located mainly on hands, forearms, head, and neck.	53% of PDS users reporting skin disorders in the last year felt that their symptoms were improved during weekends and while off duty; 30.4% for those working on CRT ($p > 0.05$). Operators who complained of skin problems were more likely to have musculoskeletal symptoms of shoulder, low back, and complaints about the work environment.
Berg et al. 1990 (18) Sweden	3,877 randomly selected employees from 36 companies in four Swedish cities.	Self-administered questionnaire on rashes and symptoms of skin disorders with indication of the site of symptoms within the last 2 years, response rate 96.6%. 809 persons randomly selected for clinical examination, response rate 92%.	Facial skin problems in the last 2 years: 18.8% in the group without exposure to VDU, 34.7% in the group of VDU users ($p < 0.0001$). There was a tendency for an increase of symptoms with increasing use of VDUs: RR = 1.96 (1.74–2.21) for those with at least 20 hr of VDU use per week. At the examination, nonspecific skin symptoms were found more frequently in the most exposed group (RR = 2.98; 1.25–7.07).	No difference observed among workers using different VDUs with larger static and magnetic fields. Eye irritations more common in the group of VDU users with at least 20 hr/week.
Carmichael and Roberts 1992 (22) United Kingdom	3,500 public office workers in Swansea; half considered VDU operators (working >2 hr/day at VDU).	Self-administered questionnaires on skin problems, response rate 41%.	14% of VDU users volunteered a facial complaint at the time of the survey or within 6 months, 11% among nonusers ($p > 0.05$).	None were studied.

Abbreviations: CRT, cathode ray tube; PDS, plasma display screen.

We recently reported the results of a population study of HSEMF done by telephone survey in California. The details of this study are presented in this issue (23). Out of a sample of 2,037 Californians, about 3% reported HSEMF, and 0.5% had to change jobs because of it. But no validation of the answers of the respondents was provided. Compared with power lines and distribution lines, hair dryer use was found to be the source of EMFs the most strongly associated with self-reported HSEMF.

Etiological Epidemiologic Studies

Most of the etiological studies conducted on HSEMF and published in peer-reviewed journals have focused on skin symptoms and VDU use. Case-control and experimental studies (provocation studies) have tried to assess the role of exposure to EMFs as well as other environmental factors.

Case-Control Studies

Three case-control studies, focusing on skin disorders in relationship to VDUs, have been published. All were conducted in Sweden and are summarized in Table 2.

One (24) was rather limited regarding the assessment of cases, sample size, and environmental evaluation. Despite their statistical significance, the results of hormonal changes are difficult to interpret. They might be normal variation or due to factors not controlled in the experiment. The two other studies (19,25)

have higher quality, with dermatological assessment of skin lesion, environmental assessment with EMF measurements, and organizational and psychological evaluation by questionnaire. These two studies found association of nonspecific skin disorders with VDU use and also with workload. One found association with exposure to background electric field intensity but no direct relation with magnetic fields emitted by the VDUs (25). These three studies observed some type of relationship of health status with the VDU use, but no direct link was found with EMF exposure from VDUs.

Experimental Studies

Five "provocation" studies on subjects with skin disorders associated with VDU use and whose results were published in peer-reviewed journals were found. Two are from Norway (26,27) and three from Sweden (7,28,29); they are summarized in Table 3. The five used a double-blind crossover design and only one used a control group (29). In three studies (26–28), exposure was produced by real VDUs during a working session on either VDUs with modification of exposure by screen filter (26,27) or a different type of VDU (28). The other two studies (7,29) used the VDUs ("on" or "off") only as a source of EMFs without having the subjects work with them. All assessed real exposure from EMFs [ELF or very low frequency (VLF; 3–100 kHz)] at a distance of 30–50 cm from the VDUs. All used standardized questionnaires

for symptom evaluation; two used dermatologists for clinical evaluation (26,28), and two used blood sampling for hormone evaluation (7,29). The quality of the methodology in these experimental studies is considered good, but sample sizes are limited (16–35), and simple statistical analyses are provided by the authors. All the studies were negative except one, which gave an equivocal result (26) but were not reproduced in a more robust study in terms of number of subjects and duration of the experiment (27). Globally, all these studies confirm that skin disorders alleged to be associated with VDU use are not related to EMF emission from VDUs. No study found that reaction of subjects was related to field intensity. But skin disorders were associated with perception that the source emission (7,29) was "on" and with duration of work (26) and low humidity (28).

Very few studies were done on subjects with a more general syndrome. Rea et al. (30) presented the results of a study that they labeled preliminary. One hundred patients treated for some type of environmental sensitivity (the authors briefly mentioned they had been previously evaluated and treated for biological inhalant, food, and chemical sensitivities) and who complained of being EMF sensitive were evaluated in a single-blind screening. They were challenged for 3 min at different frequencies from 0.5 Hz to 5 MHz. The mean intensity of the fields was presented as approximately 2,900 nT at floor level and 350 nT at the level of the chair in

Table 2. Case-control studies of skin disorders and VDU exposure.

Authors	Subjects	Methods	Results
Berg et al. 1992 (24) Sweden	19 cases and 28 controls randomly selected among 809 office workers using VDU at least 20 hr/week. Cases defined as subjects reporting facial skin symptoms.	Study carried out on a typical workday and a day of leisure. Itching behavior registered by a nurse, psychological measurements, blood and urinary samples for various hormones.	More associated eye complaints among subjects with skin complaints ($p < 0.001$). Prolactin and thyroxin elevated and testosterone decreased in those with symptoms during the workday ($p < 0.05$). Registered itching and mental strain more important among subjects with symptoms ($p < 0.05$).
Bergqvist and Wahlberg 1994 (19) Sweden	Cases and controls defined after clinical examination of 299 subjects volunteered among 323 respondents to a questionnaire of 353 office workers. 76 cases with any dermatologic diagnosis (22 cases of seborrheic eczema, 19 cases of acne, 5 cases of rosacea, 14 cases of lentigo) and 17 cases with signs of nonspecific erythema. The 223 noncases were used as controls.	VDU use, individual and organisational variables assessed by questionnaire. Environmental assessment: wall-to-wall carpets, room size, relative humidity measured daily 1 week before the dermatologic exam, static charge, electrostatic field and low frequency EMF from the VDU measured. Potential confounders considered: age, gender, perceived lack of influence, limited rest break opportunity, stomach-related stress reactions.	Nonsignificant increase of OR among VDU users for seborrheic eczema, erythema, and symptoms, without any relationship with duration of use. OR increased for erythema among those who perceived their work pace as high and especially in VDU users with limited rest break (OR = 7.86; 95% CI: 0.90–69). Low relative humidity (30%) associated with seborrheic eczema similar in VDU users and nonusers. No association with EMF measurements.
Sternberg et al. 1995 (25) Sweden	Cases and controls selected among 4,943 office workers. Case: an employee reporting itching, stinging, tight or burning sensation in facial skin and facial erythema or dry facial skin every week during the last 3 months. Referents matched for age, gender and geographic area. 85 cases chosen randomly among cases and the same number of controls.	Clinical dermatologic examination for cases and controls. Psychological, organizational, and general environmental evaluation done with questionnaire. Measurements of electrostatic and frequency EMF at the work stations.	Facial erythema and rosacea more prevalent in cases. Factors significantly associated with case status in multivariate analysis were: workload/support index (OR = 3.7, 95% CI: 1.3–10.3), VDT work for at least 4 hr/day (OR = 2.6; 95% CI: 1.0–6.5), background electric field >30 V/m (OR = 3.2; 95% CI: 1.0–10.2).

Abbreviations: CI, confidence interval; OR, odds ratio.

Table 3. Experimental studies on subjects with skin disorders associated with VDU use.

Authors	Subjects	Methods	Results
Swanbeck and Bleeker (1989) (28) Sweden	30 patients referred to dermatologists for skin problems felt to be caused by VDU use. Half of them had one of the following skin problems before starting to work on VDU: eczema, seborrhea, dryness, psoriasis, rosacea, or icthyosis	Double-blind crossover design: Two PCs (A and B) with different emissions were used successively. Magnetic field (1–300 kHz) intensity at 30 cm in front of the VDU: 50 nT (A) and 800 nT (B) electrostatic field: 0.2 kV/m (A) and 30 kV/m (B). Three hours work randomly assigned on A or B on 2 consecutive days. Patients filled out questionnaires about symptoms. Dermatologist evaluation 20 min and 4–20 hr after the exposure.	Most of the patients experienced their usual skin problems (mostly heat or reddening, itching, stinging) when working with VDU but no difference between exposure to computer A or B: 22 reacted to computer A and 23 to computer B. Symptoms remarkably reduced when relative humidity was increased from 25 to 60% with no difference regarding the type of VDU. Of the 13 reacting at high humidity, 11 reacted when exposed to a VDU switched off and covered with a cloth. Only slight redness was found on some of the patients with complaints, but one patient had a Quincke's edema.
Oftedal et al. (1995) (26) Norway	20 subjects with skin symptoms associated with work on VDU. 5 subjects had already a facial skin disorder (acne, seborrheic dermatitis, and atopic dermatitis). 12 subjects had already experienced fewer symptoms after using a screen filter.	Double-blind crossover design: Subjects working with VDU during 6 weeks at their own workstation: 2 weeks without screen filter, 2 weeks with one filter, 2 weeks with another filter. Exposure to each filter was randomly selected: one supposed to be active and the other inactive. The two filters reduced significantly the electrostatic field but active filters reduced more effectively ELF and VLF electric fields. No reduction of magnetic field (ELF or VLF) was provided by the filters. Symptoms evaluated by questionnaire each day and signs evaluated by dermatologist at the end of each exposure period.	Symptoms were less frequent when filters were used and the reduction was stronger for the first filter used. Tingling, pricking or itching were significantly less pronounced when active filters were used but not other symptoms. Dermatologic evaluation: no difference between active and passive filter. Symptoms more pronounced on days with long duration of work with VDU.
Andersson et al. (1996) (7) Sweden	16 patients referred by occupational physicians and dermatologic clinics. Inclusion criteria: clear subjective reactions in the skin of the face with exposed to environments with electricity for at least 6 months and reacting within 30 minutes to test equipment. All reacted to VDU and sometimes to other electric sources. 14 subjects had made adjustments at work because of their hypersensitivity, and two were on full-time sick leave.	Double-blind crossover design: After a rest period of 15 min, patient seated for 30 min in front of a personal computer (PC) at a 50- to 60-cm distance. Each subject tested 4 times (twice with PC on and twice off). Magnetic fields intensity at 50 cm of the VDU: 245 nT (ELF) and 19 nT (VLF). Electric field: 7 V/m (ELF) and 10 V/m (VLF). Questionnaire compared symptoms before and after each test. Blood samples for prolactin, testosterone, dehydroepiandrosterone, and cortisol taken before and after each test.	Subjects could not discriminate between the two exposure conditions ("on" or "off"). No relationship between subjective symptoms ratings and the actual presence of the field. Symptoms were significantly more intense when subjects felt that the PC was on. No relationship between levels of hormone and exposure status.
Oftedal et al. (1999) (27) Norway	35 subjects selected by questionnaire distributed to office workers, telephone interview, and electric field measurements in front of the worker's VDU. Inclusion criteria: at least one facial symptom reported in connection with VDU and reduction by a filter of ELF or VLF electric field by 40% or more.	Double-blind crossover design: First week VDU work without filter, then two periods of 3 months of work with active or passive filter chosen at random. Average reduction between active and passive filter at 60 cm of the VDU: 4.3 V/m for ELF and 0.23 V/m for VLF. Questionnaire on severity of skin symptoms as well as eye discomfort and nervous system symptoms at the end of each day and a questionnaire on physical and psychological factors at the end of each exposure period.	Severity of symptoms not different between periods with active or passive filters. Statistical significant reduction of symptoms compared with period without filter for: skin symptoms (heat, burning sensation or stinging; tingling, pricking or itching, sensation of tightness or dryness; redness or flushing), eye discomfort (stinging or dryness, pain, redness, tiredness, and light sensitivity), nervous system (headaches, tiredness, or fatigue). Symptoms were constant during exposure period regardless of the order of the filter or the intensity of the reduction of the electric fields by the filter.
Lonne-Rahm et al. (2000) (29) Sweden	24 patients recruited by advertisements in newspapers or referred by dermatologists. Inclusion criteria: minimum of 6 months of skin symptoms, reported to appear within 30 minutes of exposure to EMF. 12 controls matched to cases for age, gender, and pigmentation ability.	Two double-blind experiments with 12 cases and 12 controls: Both groups exposed to 30-min periods of high or low stress, with and without exposure to electromagnetic fields from a VDU. Matched controls were tested twice with similar exposure but with the fields turned on every time. Stress induced by requiring participants to act with random sequence of flashing lights while solving mathematical problems. Magnetic fields intensity measured at 50 cm from the VDU: 198 nT (ELF), 18 nT (VLF). Electric field intensity: 12V/m (ELF) and 10 V/m (VLF). Blood samples for adrenocorticotropic hormone, prolactin, growth hormone, melatonin. Skin biopsies analyzed for the occurrence of mast cells.	Patients reported increased skin symptoms when they believed that electromagnetic field was turned on. No differences were found between "on" and "off" blind exposure. Inflammatory mediators and mast cells in the skin were not affected by the stress exposure or by exposure to EMFs. No effect of the fields on hormone levels and no difference between cases and controls for blood hormones.

Abbreviations: PC, personal computer.

which the patient sat while being exposed. The imprecision of the exposure measurements and the adequacy of the exposure settings were settled in a letter to the editor from Bergqvist and Franzén (31). Of the 100 patients first challenged, 25 reacted positively to exposure, with only one reaction to exposure to a placebo. These 25 were compared with 25 healthy volunteers for a double-blind

challenge. No detail was given on those volunteers or on the double-blind setting. Of the 25 hypersensitive patients, 16 (64%) reacted positively, the majority (53%) reacting to exposure compared with a few (7.5%) who reacted to a blank challenge. In fact, most of the results presented are incomplete, and it was stated that no reaction to any challenge, active or placebo, was found in the volunteer

group. The major symptoms reported by the patients tested were mainly neurological, cardiological, and respiratory. In fact, many of the data are imprecise; therefore, it is difficult to give credence to these results. The same group tried to reproduce these results with an improved design but without success (3,32).

Results of other types of experimental studies have been published recently.

Sandström et al. (9) presented a report of a challenge with flickering light in 10 patients with HSEMF symptoms and 10 controls. Patients were found to react more intensely than controls to the exposure, as assessed by visual evoked potentials. The authors concluded that the patients labeled as HSEMF are hyperreactive to environmental stimulation such as flickering. Because of its sample size, this study should be considered preliminary, and no relation was evident between the findings and the symptoms reported by HSEMF patients.

More recently, Trimmel and Schweiger (33) reported the results of a double-blind trial to evaluate the effect of a 1-hr exposure to ELF (50 Hz, 1 mT) on concentration and memory. They found that among 66 volunteers, subjects self-rating themselves as sensitive to EMFs tended to perform less well than others when exposed to noise and EMFs. Exposure to noise only had no effect, but the effect of EMFs only was not evaluated, and few details are given on the exposure setting.

In summary, most of the experimental literature is concerned with VDU skin disorders. At present there is no scientific evidence for a link of these disorders with exposure to EMFs, either ELF or VLF. The general syndrome of HSEMF has not been seriously evaluated by researchers. Two recent preliminary studies found that patients labeled as HSEMF reacted differently to different environmental exposures (flickering light, noise plus EMFs) from non-HSEMF patients.

Discussion

The result of the literature review is rather meager. Few studies have been published on the subject of HSEMF in peer-reviewed journals. Most of the studies published on HSEMF come from Nordic countries and are concerned with nonspecific skin disorders related to VDUs. Few studies have been conducted in other countries and almost nothing comes from North America. The evidence of the existence of a more general syndrome associated with HSEMF (including such different nonspecific symptoms of the nervous system as fatigue, dizziness, headache, and depression) is still very weak.

No evidence exists of a link between VDU skin disorders and exposure to EMFs, but there is some evidence of a link with organizational factors and possibly physical factors such as humidity. Moreover, the provocation studies aimed at evaluating the effect of EMF exposure in a double-blind setting failed to reproduce the symptoms of labeled HSEMF patients, and several indicators demonstrated the important psychological factors in the emergence of such a health problem.

Globally, the largest amount of the evidence pleads against a role of EMFs in the reported symptoms and, moreover, its existence in North America has yet to be demonstrated. But the quality of the research on this subject is limited. No good descriptive study is available on the burden of the health problem at a population level, and most of the etiological research on HSEMF has concentrated on VDU exposure. Methodological problems are also an issue.

First, most if not all the cases reported are of subjects who diagnosed themselves as HSEMF cases. No clear case definition exists, and no recognizable criteria are available to confirm this diagnosis. Presentation of symptoms and the alleged causes for the symptoms vary greatly from one country to another, and there is doubt about the specificity of the cases reported. Developing a case definition for such a symptom-based condition is not a simple task, but it is a necessity to improve study quality (34). Some authors have speculated on the possible relation to multiple chemical sensitivity and other related clinical portraits (24). This relationship certainly should be clarified to evaluate the specificity of the HSEMF syndrome.

Most studies on HSEMF are also limited by the data available on the exposures reported by subjects or evaluated in studies. The descriptions of the exposure triggering the symptoms is usually rather vague. In general, the exposure reported refers to sources such as VDUs, which are not usually recognized as important sources of high-intensity exposure to EMFs (35,36). However, the importance of computer use on personal exposure to 60-Hz magnetic fields when considering 24-hr exposure was recently demonstrated (37). Most of the controlled studies did not evaluate the effect of different kinds of exposure to EMFs (e.g., varying frequency, intensity and time course of exposure) but instead focused on a simple exposure setting corresponding to what was usually reported by patients. Usually, no data on quality control of the exposure setting were provided.

Because of the absence of a good case definition and the limited methodology of the studies on HSEMF, it is difficult to determine completely the nature of this possible health problem. The fact that SAGs seem to attract a large number of people who claim that they suffer from HSEMF is rather intriguing (38). More studies are certainly needed to clarify the nature of the health problem labeled HSEMF.

To my knowledge, few expert groups have reviewed the literature on this topic. In 1991, the International Radiation Protection Association, via its Non-Ionizing Radiation Committee, issued a statement regarding the "alleged radiation

risks from visual display units" (39). It concluded its review: "Based on current knowledge, there are no health hazards associated with radiation or fields from VDUs." Further research on the possibility that skin disorders may be related to VDU work was recommended.

In 1994 an advisory group of the National Radiological Protection Board of the United Kingdom published a report on health effects related to the use of VDUs (40). The report focused mainly on reproductive outcomes, but a section was devoted to skin problems. It concluded,

Skin diseases do not appear to be caused by the electric fields from VDU, although there is anecdotal evidence unsupported by epidemiology that in conditions of low humidity the associated electrostatic fields may aggravate existing skin problems.

In 1997, the European Commission presented a report on the "possible health implications of subjective symptoms and electromagnetic fields" (3). It concluded, "The review was unable to establish a relationship between low or high frequency fields and electromagnetic hypersensitivity." They recommended adequate handling of seriously afflicted individuals. Because of "the inability to clearly describe the syndrome and causation of electromagnetic hypersensitivity," further research was also recommended.

Finally, in its Working Group report on EMF health effects, the National Institute of Environmental Health Sciences presented a brief review of the topic of electromagnetic hypersensitivity (4). This section concluded:

Some individuals have subjective symptoms apparently related to [VDU] use in the office environment. The evidence is inadequate to relate such symptoms to the EMF associated with that use. . . . No high-quality double-blind challenge studies have been conducted that conclusively establish the existence of sensitivity to EMF.

In other respects, I consider that the issue of hypersensitivity should not be limited to the HSEMF studies reviewed in this article. In a broader sense, hypersensitivity could mean the greater susceptibility of an individual to EMF effects. This could potentially be found for different outcomes possibly related to EMF exposure. For instance, some studies found that certain subjects might be more sensitive to the effect of EMFs on melatonin secretion (41,42). Although this is still preliminary evidence and not synonymous with adverse health effects, it seems to support the possibility of individual susceptibility to EMF exposure. Research on such a topic should focus not only on the rather nonspecific symptoms of hypersensitivity described in HSEMF reports but also on well-diagnosed illness.

Individual variations to electric field perception have been described previously

but at higher intensities than those usually found in the environment and without reference to symptoms of HSEMF (4). As a matter of fact, the field intensities used in the controlled studies reviewed were not perceived by the patients suffering from HSEMF. Recently, Leitgeb (32) described variability in the perception of induced currents in 606 subjects. Although 2% of the sample seemed particularly sensitive to the currents, no individual reported symptoms of HSEMF. Although the issue of hypersensitivity is still open, it seems clear that there are variations of perception of EMF exposure, but this does not appear to be related to HSEMF symptoms.

Conclusion

To date, the literature on hypersensitivity to EMFs is rather meager and suffers from methodological problems. Most of the published studies were done in the Scandinavian countries and focused on dermatological disorders. The other clinical portraits are rarely well described. Globally, case definition is unclear, and few population studies have evaluated the prevalence of this disorder. The most-studied clinical portraits (dermatological problems associated with VDU work) were evaluated in case-control and in controlled studies, and no consistent relationship was found with EMF exposure.

In conclusion, I found no substantial grounds on which to build a framework for helping a risk assessor to take into account the alleged "HSEMF syndrome." Our knowledge of the nature of the problem seems too vague to integrate it into an EMF risk assessment protocol. But there are certainly grounds for further research to assess more carefully its nature and its possible burden in North America.

REFERENCES AND NOTES

- Lidén S. "Sensitivity to electricity"—a new environmental epidemic. *Allergy* 51:519–524 (1996).
- Lidén C, Wahlberg JE. Does visual display terminal work provoke rosacea. *Contact Dermat* 13:235–241 (1985).
- European Commission. Possible Health Implications of Subjective Symptoms and Electromagnetic Fields. A Report Prepared by a European Group of Experts for the European Commission, DG V. Solna, Sweden:National Institute for Working Life, 1997.
- Portier CJ, Wolfe MS. Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. Working Group Report. Research Triangle Park, NC:National Institute of Environmental Health Sciences, 1998.
- Knave B, Bergqvist U, Wibom R. "Hypersensitivity to electricity"—a workplace phenomenon related to low frequency electric and magnetic fields. In: *Worldwide Achievement in Public and Occupational Health Protection Against Radiation, Vol. II*. Montreal, Canada: Eighth International Congress of the International Radiation Protection Association, 1992;1121–1124.
- Bergqvist U, Knave B. Work with visual display units. Do exposure to electromagnetic radiations or fields influence the occurrence of adverse health reactions? In: *Non-ionizing Radiation. Proceedings of the Second International Non-ionizing Radiation Workshop* (Greene MW, ed). Vancouver BC, CN:International Radiation Protection Association, 1992;445–464.
- Andersson B, Berg M, Arnetz BB, Melin L, Langlet I, Lidén S. A cognitive-behavioral treatment of patients suffering from "electric hypersensitivity." *J Occup Environ Med* 38:752–758 (1996).
- Bergqvist U. Review of neurasthenic and other symptom-based effects and electromagnetic fields—methods and results. In: *Non-thermal Effects of RF Electromagnetic Fields* (Bernhardt JH, Matthes R, Rapacholi MH, eds). Munich:ICNIRP, 1997;173–189.
- Sandström M, Lyskov W, Berglund A, Medvedev S, Hansson K. Neurophysiological effects of flickering light in patients with perceived electrical hypersensitivity. *J Occup Environ Med* 39:15–22 (1997).
- Grant L. *The Electrical Sensitivity Handbook: How Electromagnetic Fields (EMFs) Are Making People Sick*. Prescott, AZ:Lucinda Grant, Weldon Publishing, 1995.
- Arnetz BB, Berg M, Andersen I, Landenberg T, Haker E. A nonconventional approach to the treatment of "environmental illness." *J Occup Environ Med* 37:838–844 (1995).
- Levallois P, Gauvin D, Lajoie P, Saint-Laurent J. Review of exposure guidelines for electromagnetic fields (0–300 GHz) and ultraviolet radiation. Bilan de connaissance—B-051. Montreal, CN:Institut de Recherche en Santé et en Sécurité du Travail du Québec, 1997.
- Bergdahl J. Psychological aspects of patients with symptoms presumed to be caused by electricity or visual display units. *Acta Otolol Scand* 53:304–310 (1995).
- Lidén V. Video computer terminals and occupational dermatitis. *Scand J Work Environ Health* 7:62–67 (1981).
- Nielsen A. Facial rash in visual display unit operators. *Contact Dermat* 8:25–28 (1982).
- Berg M. Skin problems in workers using visual display terminals. *Contact Dermat* 19:335–341 (1988).
- Lidén C, Wahlberg JE. Work with video display terminals among office employees. V. Dermatologic factors. *Scand J Work Environ Health* 11:489–493 (1985).
- Berg M, Lidén S, Axelson O. Facial complaints and work at visual display units. *J Am Acad Dermatol* 22:621–625 (1990).
- Bergqvist U, Wahlberg JE. Skin symptoms and disease during work with visual display terminals. *Contact Dermat* 30:197–204 (1994).
- Feldman LR, Eaglstein WH, Johnson RB. Terminal illness. *J Am Acad Dermatol* 12:366 (1985).
- Koh D, Goh CL, Jerayaratnam, Ong CN. Dermatological symptoms among visual display unit operators using plasma display and cathode ray tube screens. *Ann Acad Med* 19:617–620 (1990).
- Carmichael AJ, Roberts DL. Visual display units and facial rashes. *Contact Dermat* 26:63–64 (1992).
- Levallois P, Neutra R, Lee G, Hristova L. Study of self-perceived hypersensitivity to electromagnetic fields in California. *Environ Health Perspect* 110(suppl 4):619–623 (2002).
- Berg M, Arnetz BB, Lidén S, Eneroth P, Kallner A. Technostress. A psychophysiological study of employees with VDU-associated skin complaints. *J Occup Environ Med* 34:698–701 (1992).
- Stenberg B, Eriksson N, Hansson Mild K, Höög J, Sandström M, Sundell J, Wall S. Facial skin symptoms in visual display terminal (VDT) workers. A case-referent study of personal psychosocial, building-and VDT-related risk indicators. *Int J Epidemiol* 24:796–803 (1995).
- Oftedal G, Vistnes A, Rygge K. Skin symptoms after the reduction of electric fields from visual display units. *Scand J Work Environ Health* 21:335–344 (1995).
- Oftedal G, Nyvang A, Moen BE. Long term effects on symptoms by reducing electric fields from visual display units. *Scand J Work Environ Health* 25:415–421 (1999).
- Swanbeck G, Bleeker T. Skin problems from visual display units. *Acta Derm Venereol* (Stockholm) 69:46–51 (1989).
- Lonne-Rahm S, Andersson B, Melin L, Schultzberg M, Arnetz B, Berg M. Provocation with stress and electricity of patients with "sensitivity to electricity." *J Occup Environ Med* 42:512–516 (2000).
- Rea WJ, Pan Y, Fenyves EJ, Sujisawa I, Samadi N, Ross GH. Electromagnetic field sensitivity. *J Bioelectr* 10:241–256 (1991).
- Bergqvist U, Franzén O. Electromagnetic field sensitivity [Letter]. *Electro Magnetobiol* 12:v–vii (1993).
- Leitgeb N. Electromagnetic hypersensitivity. In: *Proceedings, International Workshop on Electromagnetic Fields and Non-specific Health Symptoms* (Leitgeb N, ed). Graz, Austria:European Cooperation in the Field of Science and Technical Research, 1998;8–16.
- Trimmel M, Schweiger E. Effects of an ELF (50 Hz, 1 mT) electromagnetic field (EMF) on concentration in visual attention, perception and memory including effects of EMF sensitivity. *Toxicol Lett* 96/97:377–382 (1998).
- Hyams KC. Developing case definitions for symptom-based conditions: the problem of specificity. *Epidemiol Rev* 20:148–156 (1998).
- Kavet R, Tell RA. VDTs: field levels, epidemiology, and laboratory studies. *Health Physics* 61:47–57 (1991).
- Gauvin D, Levallois P, Leclerc J-M, Gingras S. Champs électromagnétiques émis par les terminaux à écrans cathodiques. In: *Actes du Vingtième Congrès de l'Association Québécoise pour l'Hygiène, la Santé et la Sécurité du travail*, Montreal, 1998:58–67.
- Mezei G, Kheiffets LI, Nelson LM, Mills KM, Iriye R, Kelsey JL. Household appliance use and residential exposure to 60-Hz magnetic fields. *J Expos Anal Environ Epidemiol* 11:41–49 (2001).
- Electrical Sensitivity Network. Welcome to the Electrical Sensitivity Network. Available: <http://www.northlink.com/~lgrant/> [accessed 15 February 2002].
- International Radiation Protection Association. IRPA Guidelines on Protection against Non-ionizing Radiation. The collected publications of The IRPA Non-ionizing Radiation Committee (Duchêne AS, Lakey JRA, Repacholi MH, eds). Oxford, UK:Pergamon Press, 1991.
- NRPB. Health Effects Related to the Use of Visual Display Units. Report from an Advisory Group on Non-Ionizing Radiation. Documents of the NRPB. Oxon, UK:National Radiological Protection Board, 1994;5(2).
- Wilson BW, Wright CW, Morris JE, Buschbom RL, Brown DP, Miller DL, Sommers-Flannigan R, Anderson LE. Evidence for an effect of ELF electromagnetic fields on human pineal gland function. *J Pineal Res* 9:259–269 (1990).
- Wood AW, Armstrong SM, Sait ML, Devine L, Martin MJ. Changes in human plasma melatonin profiles in response to 50 Hz magnetic field exposure. *J Pineal Res* 25:116–127 (1998).