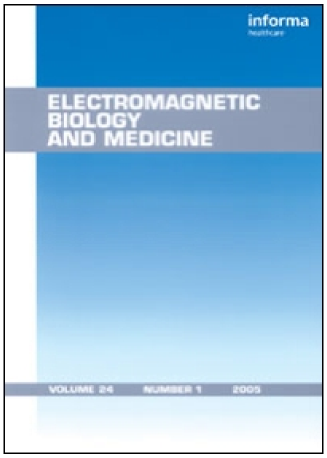

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Increased Concentrations of Certain Persistent Organic Pollutants in Subjects with Self-Reported Electromagnetic Hypersensitivity—A Pilot Study

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Electromagnetic hypersensitivity (EHS) is used for a variety of subjective symptoms related to exposure to electromagnetic fields (EMF). The aim of this pilot study was to analyze the concentrations of certain persistent organic pollutants (POPs) in subjects with self-reported EHS. In total, 13 EHS subjects and 21 controls were included, all female. The concentration of several POPs was higher in EHS subjects than in controls. Lower concentrations were found for hexachlorobenzene and two types of chlordanes. The only significantly increased odds ratios (ORs) were found for polybrominated diphenyl ether (PBDE) #47 yielding OR = 11.7, 95% confidence interval (CI) = 1.45–94.7 and the chlordane metabolite MC6 with OR = 11.2, 95% CI = 1.18–106. The results were based on low numbers and must be interpreted with caution. This hypothesis generating study indicates the necessity of a larger investigation on this issue.

Keywords Electromagnetic hypersensitivity; Persistent organic pollutants; Brominated flame-retardants; PCBs.

Introduction

A number of persons report a variety of health problems related to exposure to electromagnetic fields (EMF) or being close to electrical equipment. These symptoms have been grouped together as electromagnetic hypersensitivity (EHS). The prevalence has been reported to 5% in Switzerland (Schreier et al., 2006), 1.5% in Sweden (Hillert et al., 2002), and 3.2% in California (Levallois et al., 2002). Reactions typically include a wide range of non specific symptoms that afflicted individuals attribute to exposure to EMF. Common symptoms are often linked to nervous

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system (e.g., sleep disturbances, fatigue, neurasthenia), skin (e.g., burning sensations, rashes), eyes, or muscles, but they can also consist of non specific allergy reactions, problems in concentration, and headache.

EHS is a poorly understood condition that is being used both for a variety of medical conditions and to describe the ability of certain individuals to perceive or react to EMF at significantly lower levels than other individuals. A working group from WHO has proposed that EHS should be replaced by the term Idiopathic Environmental Intolerance (IEI), EMF attributed, since the term EHS implies that a causal link has been established between reported symptoms and EMF. While this might be appropriate, we will use EHS because most of the studies we cite use this term. However, we stress that EHS is a self-reported condition as no objective criteria to classify EHS have yet been established (Rubin et al., 2005; Seitz et al., 2005). Thus, EHS has not been recognized as a disease with an international classification disease code (ICD-number).

The underlying causes of EHS are still the subject of much debate. One hypothesis is that biophysical factors might make a minority of people particularly sensitive to EMF. However, since provocation studies have produced mainly negative results (Seitz et al., 2005), the latter has been challenged by suggestions that the condition may be more psychological in nature.

While the latter could explain the symptoms, to an extent it has been suggested that certain persistent organic pollutants (POPs), such as polybrominated diphenylether (PBDE), used as flame-retardants in, e.g., electronic devices, might be cofactors in the aetiology of EHS since such symptoms have often been related to use of video display units (Nordström, 2004). It has also been shown that alleging environmental illness or multiple chemical sensitivity diagnosed by a doctor can be a strong predictor of reporting being hypersensitive to EMF (Levallois et al., 2002).

To elucidate the potential impact of the most common types of POPs found in the Swedish population, 20 subjects with EHS that contacted one of the authors (LH) volunteered to give blood for such analyses. This was a hypothesis-generating pilot study. To compare these results with current levels in the population, controls from another study were used. This was an investigation on POPs in mothers to children aged 0–14 years with non Hodgkin lymphoma (NHL) and mothers to control children in the same age group. Only the control mothers were used for comparison since one hypothesis was that mothers to children with NHL might have increased blood concentrations of POPs. The local ethical committee approved that study.

Materials and Methods

Blood was sampled from 20 persons with EHS. Three were men and considered too few for comparison with a control group. Of the 17 women, one had given blood in 1999 and two in 2001 and they were not included in the analysis since the comparison group was recruited in 2005 and the concentration of POPs in the population changes over time. One woman was diagnosed with non Hodgkin lymphoma and was for that reason excluded. Thus, 13 women who had given blood during 2004 and 2005 remained for the analyses. The 21 control women had all given blood in 2005 and were used for comparison. Body mass index (BMI) was calculated for all subjects. Detailed questions on, e.g., year of first symptoms, attributed to exposure to EMF, change of food habits, and fish consumption were answered by the EHS persons using a questionnaire.

Plasma from each study person was frozen without personal identification number for later chemical analyses. Thus the laboratory personnel did not know if it was an EHS subject or a control that was analyzed.

Chemical Analysis

Two ml of each sample was extracted by solid phase extraction, using 200 mg solid phase extraction (SPE) columns (ENV+). In addition, one laboratory blank sample and one reference sample of each set of 6 samples were analyzed. The lipid content of each sample was determined enzymatic from a sub-sample. The samples were fortified with ^{13}C-labeled internal polychlorinated biphenyl (PCB) and PBDE and standards. Congener specific analyses and quantification of the analytes were performed by high-resolution gas chromatography coupled to high-resolution mass spectrometry (HRGC-HRMS), running in selective ion mode (SIM), using electron impact (EI) ionization. The two most abundant ions of the chlorine cluster of the molecular ion for each compound were measured, as well as the ion for the ^{13}C-labeled internal and recovery standards. A quantification standard mixture including all compounds in addition to the internal standard (IS) and recovery standard (RS) was used to calculate relative response factors (RRF). These RRFs were used to calculate the compound levels in the samples.

All results are given in ng/g lipid. Regarding PCBs, only congeners with results in both study groups were included. The results are given for the sum of 26 congeners as well as for the most abundant congener, PCB #153. Six types of chlordanes were analyzed. The brominated flame retardant analyzed was PBDE #47.

Statistical Methods

Unconditional logistic regression analysis was performed using the Stata program (Stata/SE 8.2 for Windows; StataCorp, College Station, TX) for calculation of odds ratio (OR) and 95% confidence interval (CI). In the analyses, adjustment was made for age as a continuous variable and Body Mass Index (BMI) at the time of sampling. The Stata program was also used for descriptive statistics and Wilcoxon rank sum tests for calculation of p-values.

Results

In total, 13 female persons with EHS were included in this analysis. The median age at the time of blood sampling was 53 years (range 32–73) for the EHS subjects and 45 years (range 35–53) for the 21 control subjects.

Descriptive results for female study persons are presented in Table 1 and ORs and 95% CIs are presented in Table 2. Higher concentrations of the sum of PCBs and PCB #153 were found among EHS subjects than controls. For the sum of PCBs, OR = 1.31, 95% CI = 0.25–7.01 and for PCB #153 OR = 1.57, 95% CI = 0.32–7.82 were calculated.

Lower concentration of hexachlorobenzene was found in the controls yielding OR = 0.26, 95% CI = 0.05–1.44 whereas for $p.p'$-DDE OR = 5.97, 95% CI = 0.89–40.3 was calculated. Lower concentrations of two chlordanes were found in the EHS subjects and the concentrations of the other four types were somewhat higher with significantly increased OR for MC6. However, for the sum of chlordanes, no

Table 1

Concentrations (ng/g lipid) of certain persistent organic pollutants in 13 persons with electromagnetic hypersensitivity (EHS) and 21 comparison subjects

	Number	Mean	Median	Min	Max	p^1
Sum of PCBs*						
— EHS subjects	13	373	378	156	834	0.13
— controls	21	288	298	98	648	
PCB #153						
— EHS subjects	13	109	114	45	260	0.09
— controls	21	78	76	28	177	
Hexachlorobenzene						
— EHS subjects	13	15	12	7.3	36	0.04
— controls	21	17	15	8.7	37	
p,p'-DDE						
— EHS subjects	13	227	150	48	749	0.07
— controls	21	121	87	30	563	
Cis-Heptachloroepoxide						
— EHS subjects	13	0.11	0.05	0.005	0.70	<0.0001
— controls	21	0.91	0.93	0.44	1.7	
Cis-Chlordane						
— EHS subjects	13	0.04	0.03	0.005	0.16	0.90
— controls	21	0.03	0.02	0.005	0.19	
Oxychlordane						
— EHS subjects	13	5.5	3.1	0.28	23	0.31
— controls	21	2.6	2.3	1.1	5.0	
MC6						
— EHS subjects	13	3.2	1.6	0.38	10	0.0001
— controls	21	0.65	0.60	0.10	1.6	
Trans-Nonachlordane						
— EHS subjects	13	15	8.2	2.6	58	0.02
— controls	21	5.7	5.1	2.3	9.9	
Cis-Nonachlordane						
— EHS subjects	13	0.06	0.01	0.005	0.37	<0.0001
— controls	21	0.73	0.70	0.15	1.8	
Sum of chlordanes						
— EHS subjects	13	24	12	3.3	92	0.09
— controls	21	11	11	4.1	19	
PBDE #47						
— EHS subjects	13	1.9	1.3	0.20	8.0	0.37
— controls	21	1.5	0.81	0.24	5.5	

[1]Wilcoxon.

*Included PCB congeners: #52, #47/48, #74, #66, #99/113, #118, #114, #105, #153, #138, #128/167, #178, #182/187, #174, #172/192, #180/193, #170/190, #189, #206.

significant difference was found. PBDE #47 yielded significantly increased OR = 11.7, 95% CI = 1.45–94.7.

Table 2

Odds ratio (OR) and 95% confidence interval (CI) for certain persistent organic pollutants. Number of electromagnetic hypersensitivity (EHS) subjects and controls with concentration > median concentration in the controls is given. Logistic regression analysis adjusted for age at the time of blood sampling and body mass index was performed

	EHS subjects/controls	OR	95% CI
Sum of PCBs*	9/10	1.31	0.25–7.01
PCB #153	9/10	1.57	0.32–7.82
Hexachlorobenzene	3/10	0.26	0.05–1.44
p,p′-DDE	11/10	5.97	0.89–40.3
Cis-Heptachloroepoxide	0/10	–	–
Cis-Chlordane	7/7	3.47	0.67–18.1
Oxychlordane	8/10	1.32	0.28–6.14
MC6	12/10	11.2	1.18–106
Trans-Nonachlordane	10/10	2.74	0.53–14.1
Cis-Nonachlordane	0/10	–	–
Sum of chlordanes	8/10	1.62	0.36–7.38
PBDE #47	11/10	11.7	1.45–94.7

*Included PCB congeners: #52, #47/48, #74, #66, #99/113, #118, #114, #105, #153, #138, #128/167, #178, #182/187, #174, #172/192, #180/193, #170/190, #189, #206.

Since blood concentrations of POPs may correlate with age, we excluded EHS subjects > 55 years of age in one analysis. That analysis included 8 EHS persons and 21 comparison subjects. The mean age of the EHS subjects was 44 years and of the controls was 45 years in that analysis. The results were similar as in the whole series. However, OR was not any longer significantly increased for MC6; OR = 6.87, 95% CI = 0.70–67.6. For PBDE #47 the median concentration was in the EHS subjects 2.1 ng/g lipid (range 0.84–8.0) and in the controls 0.81 (range 0.24–5.5), $p = 0.11$. Thus, OR could not be calculated since the concentration of PBDE #47 was higher in all EHS subjects than the median concentration in the controls.

Discussion

This is the first study to assess concentrations of POPs in EHS subjects. It consisted of 20 subjects with EHS who volunteered for blood sampling for analysis of certain POPs, the most common types found in the Swedish population. The comparison group consisted of women in a study on risk factors for NHL in children. Only subjects with blood drawn during a similar time period were included in the final analysis. This consisted of 13 females with EHS and 21 subjects in the comparison group. In one analysis we excluded the oldest EHS persons since there was an age difference between the two study groups and POPs may correlate with age (Hardell et al., 2001). However, the results were similar in both analyses.

The results must be interpreted with caution and may be regarded as hypothesis generating for larger prospective studies. One limitation was that all EHS subjects volunteered for the study and contacted the research group for participation. Thus, selection bias might have occurred. However, there was no geographical bias since they lived in different places in Sweden without any geographical selection. Also, the control group was recruited from the whole country using the national population registry. Three male EHS subjects were included in the study. Their results were similar as male controls in another study (Hardell et al., 2006a), but these male EHS subjects were too few to make any conclusions, so the results are not further discussed here.

Another disadvantage of the study was that we could not use a clinical diagnosis of EHS since this has not yet been established. We tried to get an assumption of time for onset of symptoms. This was self-reported to be mean 10 years and median 11 years (range 1–19 years) before blood sampling. Most of the EHS subjects reported that their symptoms started during video display work and/or using fluorescent tubes lighting.

Ideally, a prospective study should be done with blood sampling at the time of the onset of EHS symptoms as well as careful monitoring of the work and home conditions. A problem with a retrospective study like this is that the EHS subjects might have changed food habits over time in an attempt to cure themselves. However, no person was vegetarian. That is of importance since POPs bioaccumulate, and fatty fish is an important source of exposure (Svensson et al., 1995), and PBDEs bioaccumulate, which has been shown in the Baltic sea (Haglund et al., 1997). For PBDE as well as for other POPs, human exposure is mainly through food such as fish and dairy products (Darnerud et al., 2001; Schecter et al., 2004).

All results were adjusted for BMI since POPs are stored in adipose tissue. Loss of weight might increase the lipid-adjusted concentrations (Hardell et al., 2006b). In one calculation we adjusted for BMI among EHS subjects five years before blood sampling. However, the results were not significantly changed thereby. Thus, PBDE #47 yielded OR = 11.8, 95% CI = 1.46–95.7 in this calculation.

An interaction between POPs, e.g., brominated flame-retardants, and EMF has been postulated to be of etiologic significance (Nordström, 2004). The concentrations of most POPs were in this study higher in EHS subjects than in the comparison group. Lower concentrations were found for hexachlorobenzene and two types of chlordanes. However, the sum of chlordanes was somewhat higher in the EHS subjects. It should be noted that the results were based on low numbers with broad CIs.

Of special interest was the significantly increased OR for PBDE #47. An increased concentration of PBDE has been reported in electronic dismantling environment indicating a potential for such exposure in the work environment (Karlsson, 2006). PBDEs have been identified in household air and dust (Karlsson et al., 2007). An interaction between PBDE and EMF is an interesting hypothesis that needs further studies in depth.

In summary, this was a hypothesis generating pilot study on a potential association between POPs and EHS. Of special interest was the finding of increased concentration of the brominated flame retardant PBDE #47 among EHS subjects since the symptoms have often been related to work with electronic devices, e.g., computers. However, the results must be interpreted with caution due to methodological limits in the study.

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References

Darnerud, P., Eriksen, G., et al. (2001). Polybrominated diphenyl ethers: occurrence, dietary exposure, and toxicology. *Environ. Health Perspect.* 10(Suppl.):49–68.

Haglund, P., Zook, D., et al. (1997). Identification and quantification of polybrominated diphenyl ethers and methoxy-olybrominated diphenyl ethers in Balitc biota. *Environ. Sci. Tech.* 31:3281–3287.

Hardell, L., Björnfoth, H., et al. (2006a). Concentrations of organohalogen compounds and titers of antibodies to Epstein-Barr virus antingens and the risk for non-Hodgkin lymphoma. *Organohalogen Compounds* 68:2535–2538.

Hardell, L., Eriksson, M., et al. (2001). Case-control study on concentrations of organohalogen compounds and titers of antibodies to Epstein-Barr virus antigens in the etiology of non-Hodgkin lymphoma. *Leukemia & Lymphoma* 42:619–629.

Hardell, L., Lindström, G., et al. (2006b). High concentrations of organochlorines in a patient with kidney cancer and anorexia-cachexia syndrome. *Med. Chem.* 2(6):607–610.

Hillert, L., Berglind, N., et al. (2002). Prevalence of self-reported hypersensitivity to electric or magnetic fields in a population-based questionnaire survey. *Scand. J. Work Environ. Health* 28:33–41.

Karlsson, M. (2006). Levels of brominated flame retardants in humans and their environment—occupational and home exposure. Doctoral Dissertation, Örebro Studies in Chemistry 7, Örebro University. Örebro, Sweden.

Karlsson, M., Julander, A., et al. (2007). Levels of brominated flame retardants in blood in relation to levels in household air and dust. *Environ. Int.* 33(1):62–69.

Levallois, P., Neutra, R., et al. (2002). Study of self-reported hypersensitivity to electromagnetic fields in California. *Environ. Health Perspect.* 110(Suppl. 4):619–623.

Nordström, G. (2004). *The Invisible Disease*. Winchester, UK; New York, O'Books.

Rubin, G. J., Munshi, J. D., Wessely, S. (2005). Electromagnetic hypersensitivity: a systematic review of provocation studies. *Psychosomatic Med.* 67:224–232.

Schecter, A., Päpke, O., et al. (2004). Polybrominated diphenyl ethers contamination of United States food. *Environ. Sci. Technol.* 38:5306–5311.

Schreier, N., Huss, A., Roosli, M. (2006). The prevalence of symptoms attributed to electromagnetic field exposure: a cross-sectional representative survey in Switzerland. *Soz. Preventivmed.* 51(4):202–209.

Seitz, H., Stinner, D., et al. (2005). Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile communication—a literature review published between 2000 and 2004. *Sci. Total Environ.* 349:45–55.

Svensson, B. G., Nilsson, A., et al. (1995). Fish consumption and exposure to persitent organochlorine compounds, mercury, selenium and methylamines among Swedish fishermen. *Scand. J. Work Environ. Health* 21:96–105.