

Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity

Amanda Johansson^{a,*}, Steven Nordin^{b,c}, Marina Heiden^d, Monica Sandström^a

^aDepartment of Public Health and Clinical Medicine, Umeå University, Umeå, Sweden

^bDepartment of Psychology, Umeå University, Umeå, Sweden

^cDepartment of Occupational and Environmental Medicine, Örebro University Hospital, Örebro, Sweden

^dCentre for Musculoskeletal Research, University of Gävle, Umeå, Sweden

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Abstract

Objective: Some people report symptoms that they associate with electromagnetic field (EMF) exposure. These symptoms may be related to specific EMF sources or to electrical equipment in general (perceived electromagnetic hypersensitivity, EHS). Research and clinical observations suggest a difference between mobile phone (MP)-related symptoms and EHS with respect to symptom prevalence, psychological factors, and health prognosis. This study assessed prevalence of EMF-related and EMF-nonrelated symptoms, anxiety, depression, somatization, exhaustion, and stress in people with MP-related symptoms or EHS versus a population-based sample and a control sample without EMF-related symptoms. **Methods:** Forty-five participants with MP-related symptoms and 71 with EHS were compared with a population-based sample ($n=106$) and a control group ($n=63$) using self-report questionnaires. **Results:** The EHS group reported more

symptoms than the MP group, both EMF-related and EMF-nonrelated. The MP group reported a high prevalence of somatosensory symptoms, whereas the EHS group reported more neurasthenic symptoms. As to self-reported personality traits and stress, the case groups differed only on somatization and listlessness in a direct comparison. In comparison with the reference groups, the MP group showed increased levels of exhaustion and depression but not of anxiety, somatization, and stress; the EHS group showed increased levels for all of the conditions except for stress. **Conclusion:** The findings support the idea of a difference between people with symptoms related to specific EMF sources and people with general EHS with respect to symptoms and anxiety, depression, somatization, exhaustion, and stress. The differences are likely to be important in the management of patients.

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Introduction

Symptoms attributed to exposure to electromagnetic fields (EMF) have been reported at least since the 1970s [1–5]. Epidemiological studies suggest a prevalence of 1.5–4% in the general population [6–8]. People with EMF-related symptoms commonly report skin symptoms, neurasthenic symptoms (e.g., dizziness, fatigue, headache), sleep-

ing disorders, and cognitive disturbances [9,10]. However, no causal relationship between EMF exposure and symptoms has been established, nor are there indications that individuals with EMF-related symptoms would detect EMF at lower levels than most people [11]. There is to date no widely accepted explanation model for the development of EMF-related symptoms.

Apart from those who experience symptoms attributed to electrical equipment in general (referred to as perceived electromagnetic hypersensitivity, EHS), there are people who report symptoms that they attribute to specific EMF sources, mainly mobile phones (MP) or visual display terminals (VDT). Previous studies have shown that

* Corresponding author. Department of Public Health and Clinical Medicine, Occupational and Environmental Medicine, Umeå University, SE-901 87 Umeå, Sweden. Tel.: +46 0 90 785 27 89; fax: +46 0 90 77 96 30.
E-mail address: amanda.johansson@envmed.umu.se (A. Johansson).

individuals with EHS generally report a higher number of symptoms than do those with VDT-related symptoms. They are also often more disabled by their symptoms with respect to both working capability and everyday life and do not improve with time to the same extent as individuals with VDT-related symptoms [10,12–14]. VDT-related symptoms have been observed to precede general EHS in several cases, but it is uncertain why the symptoms generalize in some individuals and not in others [10,15].

Signs of mental distress have repeatedly been observed in people with EMF-related symptoms, e.g., elevated levels of perceived stress, stress susceptibility, anxiety, and depression [12,16–18]. Comparisons of individuals with EHS and those with VDT-related symptoms indicate higher levels of distress among individuals with EHS, and it has been proposed that this difference may contribute to the observed differences in degree of disability and prognosis [10,12]. Attempts to treat EMF-related symptoms, e.g., with cognitive behavior therapy, have in many cases proven to be effective, but the results from intervention studies are inconclusive [19]. The heterogeneity of the study groups has been mentioned as one of the reasons for this inconclusiveness, and a case-by-case approach has been recommended for the practical management of patients [20,21].

Since MP-related symptoms are of more recent date they are less well described than VDT-related symptoms and EHS, but the clinical impression is that people with MP-related symptoms differ from those with EHS with respect to symptom picture as well as to attitudes and behavior in relation to exposure sources and may constitute another subgroup. This is supported by recent results [17,22].

One objective of the present study was to compare individuals with EHS and individuals with MP-related symptoms with respect to prevalence of EMF-related and EMF-nonrelated symptoms, and to compare both groups with a population-based sample. A second objective was to compare individuals with MP-related symptoms and EHS with respect to levels of anxiety; depression; and somatization, exhaustion, and stress, as well as to compare both groups with a population-based sample and with a healthy control group. It was hypothesized that the mentioned conditions would be more pronounced in the groups with EMF-related symptoms compared with the reference group and in the EHS group in particular.

Methods

Participants

Individuals who reported symptoms that they associated with the use of MP, VDT, or electrical equipment in general were invited to participate through advertisements in eight Swedish newspapers. Those who responded to the advertisements were sent a set of questionnaires. For each person with EMF-attributed symptoms who returned completed

questionnaires, two reference participants, matched with respect to age and sex, were recruited through the Swedish population register and sent the same set of questionnaires. Nonresponders in both groups received one reminder. One hundred and seventeen (73%) of the 160 persons with EMF-related symptoms who responded to the advertisement, and 106 (45%) of the 234 reference participants completed the study.

The cases were classified into subgroups based on the EMF sources they reported as symptom-provoking (see further the section “Questionnaires”). An individual was considered as having “MP-related symptoms” (“MP group”) if he or she reported symptoms associated with MP use only, as having “VDT-related symptoms” (“VDT group”) if symptoms were associated with VDT use only, and as having “electromagnetic hypersensitivity” (EHS group) if symptoms were associated also with other kinds of equipment. This symptom-based classification did not always agree with the label adopted by the participant. Symptoms associated with VDT use was reported by one participant only, and this category was therefore excluded from further analysis. Some participants ($n=19$) reported primarily symptoms associated with MP use, but also some symptoms associated with VDT use. Because of low numbers, they were not treated as a separate group, but were assigned to the MP group, due to the predominance of the MP-related symptoms. For comparison with the MP and EHS groups (collectively referred to as the “case groups”), we used both the entire population-based sample of 106 participants that were considered as a fairly representative sample of the general population (population based group) and a subsample of the reference group where the reference participants reporting EMF-related symptoms were excluded (control group). The population-based group and the control group are collectively referred to as the “reference groups.” The use of both a population-based normal sample and a sample screened for EMF-related symptoms to constitute a healthy control sample enables a more elaborate comparison.

The data collection was carried out during a period of 5 months (December 2005–April 2006). A signed informed consent form was obtained from each participant. Participants were paid for their participation. Ethical approval of the study was given by the Regional Ethical Research Board at Umeå University.

Questionnaire instruments

The questionnaire set included a questionnaire mainly comprised of questions about symptoms occurring or aggravated in relation to use of MP, VDT, or electrical equipment in general (EMF-related symptoms). An individual was defined as having a certain symptom if it occurred at least once a week. Since the symptoms asked for are common, it was asked separately, to which extent the symptoms reported in association with perceived EMF exposure were experienced also in the absence of EMF

exposure (EMF-nonrelated symptoms). The symptoms registered, based on earlier studies on MP-related symptoms [23], are listed in Table 2. Additionally, it was asked whether an individual considered him- or herself as sensitive to EMF exposure, in general or from mobile phones specifically. The symptom questionnaire also contained questions concerning demographics, health status, occupation, work situation, and use of various kinds of electrical equipment. Occupations were classified into the categories of management (leading position in companies or public administration and politics), professional (at least 4 years of university education), intermediate (shorter university education), and other (no demand for university education, including blue-collar workers and salesmen) according to the Swedish National Labor Market Board classification of occupations (International Standard Classification of Occupations -88) [24]. To estimate psychosocial workload, an index was computed based on four validated and commonly used questions related to workload, influence on working conditions, support from colleagues, and whether the work was experienced as stimulating and interesting [23].

The questionnaire set further contained the State and Trait subscales of the State-Trait Anxiety Inventory (STAI) [25]; the subscales of Inhibition of Aggression, Muscular Tension, Psychasthenia, Psychic Anxiety, and Somatic Anxiety of the Karolinska Scales of Personality (KSP) [26,27] to assess anxiety; the Beck Depression Inventory (BDI) [28] to assess depression; the Anxiety, Depression, and Somatization subscales of the Symptom Checklist-90 (SCL-90) [29]; the global measure and the subscales of burnout, listlessness, tension, and mental exhaustion of the Shirom-Melamed Burnout Questionnaire (SMBQ) [30] to assess exhaustion syndrome; and the General Perceived Stress Questionnaire (PSQ) [31] to assess stress.

Statistical analysis

The statistical analyses were performed using SPSS for Windows 15.0 (SPSS, Chicago, IL, USA). The MP and EHS groups were compared with each other and with the population-based sample and control group, respectively, on the variables that describe participant characteristics using one-way analysis of variance (ANOVA), the Pearson chi-square test, and Fisher's Exact test. Symptom prevalence in the different groups was compared using the Pearson chi-square test.

Group mean values from the STAI, KSP, BDI, SCL-90, SMBQ, and PSQ were compared using multivariate ANOVA (MANOVA) with group (MP, EHS, and population-based sample or control group) as a between-subject variable and age and sex as covariates. The multivariate tests were performed using Wilks Lambda. When the multivariate tests revealed significant differences between the groups, univariate analyses of variance were employed for the dependent variables. Whenever the univariate tests revealed significant differences, post hoc comparisons were performed to detect

differences between the specific groups, using Tamhane's procedure. The comparison between the case groups and the population-based group and the comparison between the case groups and the control group were performed separately.

The variables that did not satisfy the criterion of normal distribution (the BDI, the Depression subscale of the SCL-90, the Listlessness and Mental Exhaustion subscales of the SMBQ, and the PSQ) were square-root transformed. The transformed values were used in the statistical analysis, but the results are presented in original units for ease of understanding. In all tests, the significance level was set at .05. Bonferroni correction was used to adjust for multiple tests.

Results

Participant characteristics

Participant characteristics are given in Table 1. The MP group was significantly younger than both the EHS group and the reference groups and had more men. Further, the proportion of smokers was significantly larger in both reference groups than in the case groups. The EHS group was significantly less occupationally active than the MP and the reference groups and had more participants with disability pension. The MP participants with VDT-related symptoms also did not differ from those without VDT-related symptoms in any other aspect.

Symptoms

The case groups reported a significantly higher number of symptoms than the reference groups, and the EHS group reported a higher number than did the MP group (Table 2). This was the case both for EMF-related and EMF-nonrelated symptoms. The specific symptoms were reported by a larger percentage of the MP and EHS groups when compared to the two reference groups; however, for the large majority of the symptoms, they were less commonly reported by the MP group than by the EHS group. The exceptions were sensations of warmth behind/around and on the ear. Sensations of warmth, together with burning skin and concentration difficulties, were also the symptoms most commonly reported by the MP group. The most common EMF-nonrelated symptoms reported by the EHS group were general discomfort followed by fatigue, sleeping disorders, and concentration difficulties. The symptom pattern was essentially the same for EMF-related and EMF-nonrelated symptoms, except that most EMF-related symptoms were more frequent than their EMF-nonrelated equivalents. The symptoms most commonly attributed to EMF exposure by the population-based group were warmth sensations on or behind/around the ear, burning skin, headache, and fatigue. The EHS groups had experienced EMF-related symptoms for a longer time than the MP and the population-based group.

Table 1

Self-reported participant characteristics in percentage among participants with MP-related symptoms and general EHS, and population-based (PB) and control (C) groups

Participant characteristics	MP (n=45)	EHS (n=71)	PB (n=106)	C (n=63)
Age [mean (S.D.)] ^{1, 2, 4, 5}	45.7 (12.9)	51.6 (11.7)	48.3 (12.7)	51.4 (11.4)
Female ^{1, 2, 4, 5}	62	82	80	71
Regular exercise	78	80	67	68
Smoker ^{2, 3, 4, 5}	4	10	23	24
Years of EMF-related symptoms [mean (S.D.)] ^{1, 3}	7.1 (4.3)	13.9 (7.1)	7.7 (7.8)	–
Occupation				
Management	7	5	3	5
Professional	36	31	23	18
Intermediate	21	17	13	7
Other	36	47	61	70
Employment status				
Full or part time ^{1, 3, 5}	62	16	73	73
Full or part time sick leave	18	25	12	9
Disability pension ^{1, 3, 5}	13	35	4	5
Unemployed or retired	7	17	11	14
VDT work				
None	23	40	34	34
≤4 h/day	53	30	48	51
>4 h/day	25	30	19	14
Index of psychosocial workload				
Low	24	29	31	32
Medium	42	51	48	49
High	34	20	21	20
Working capability				
Good ^{3, 5}	68	50	80	84
Moderate	17	22	12	10
Not so good ^{3, 5}	15	28	8	6
Self-reported sensitivity				
EMF from mobile phones ^{1, 2, 4}	18	2	2	0
EMF in general ^{1, 2, 3, 4, 5}	38	92	1	0
None ^{1, 2, 3, 4, 5}	44	6	97	100

Significant difference: 1, MP/EHS; 2, MP/PB; 3, EHS/PB; 4, MP/C; 5, EHS/C (Bonferroni adjustment for multiple tests).

Personality traits and stress

The case groups (MP and EHS) scored on average higher than the reference groups on almost all assessed aspects of

personality traits and stress (Table 3). In general, these differences were statistically significant for the global measure and all SMBQ subscales, the KSP subscales Muscular Tension and Somatic Anxiety, the BDI, and all

Table 2

Percentage of participants reporting various symptoms (experienced at least once a week) among subjects with MP-related symptoms and general EHS, and population-based (PB) and control (C) groups

Symptoms	EMF-nonrelated symptoms				EMF-related symptoms			
	MP (n=45)	EHS (n=71)	PB (n=106)	C (n=63)	MP (n=45)	EHS (n=71)	PB (n=106)	C (n=63)
Dizziness	18 ¹	42 ^{1, 3, 5}	13	11	27 ^{1, 4}	75 ^{1, 3, 5}	7	0
General discomfort	29 ¹	77 ^{1, 3, 5}	11	10	73 ^{2, 4}	92 ^{3, 5}	9	0
Difficulties concentrating	36	68 ^{3, 5}	18	13	42 ^{1, 2, 4}	81 ^{1, 3, 5}	10	0
Memory loss	31	49 ^{3, 5}	12	10	22 ^{1, 4}	61 ^{1, 3, 5}	3	0
Fatigue	33 ¹	75 ^{1, 3, 5}	27	21	38 ^{2, 4}	80 ^{3, 5}	11	0
Headache	22	51 ^{3, 5}	21	16	58 ^{2, 4}	73 ^{3, 5}	19	0
Warmth behind/around ear	47 ^{2, 4}	41 ^{3, 5}	4	0	84 ^{2, 4}	66 ^{3, 5}	12	0
Warmth on ear	42 ^{2, 4}	39 ^{3, 5}	5	0	80 ^{2, 4}	67 ^{3, 5}	19	0
Burning skin	36 ²	62 ^{3, 5}	12	6	64 ^{2, 4}	90 ^{3, 5}	20	0
Tingling/tightness	18 ¹	54 ^{1, 3, 5}	3	2	51 ^{2, 4}	79 ^{3, 5}	4	0
Sleeping disorders	33 ¹	73 ^{1, 3, 5}	30	21	20 ^{1, 4}	65 ^{1, 3, 5}	4	0
Tinnitus	24	41 ^{3, 5}	11	11	20 ⁴	49 ^{3, 5}	2	0
Numbness	13	34 ^{3, 5}	10	9	22 ^{1, 2, 4}	59 ^{1, 3, 5}	2	0
Mean (S.D.) number of symptoms	4.0 ^{1, 2, 4} (3.3)	7.4 ^{1, 3, 5} (3.6)	1.8 (2.4)	1.3 (2.0)	6.3 ^{1, 2, 4} (3.0)	9.7 ^{1, 3, 5} (3.3)	1.2 (2.1)	0 (0)

Significant difference: (1) MP/EHS; (2) MP/PB; (3) EHS/PB; (4) MP/C; (5) EHS/C (Bonferroni adjustment for multiple tests).

Table 3

Mean (S.D.) scores on various instruments on personality traits and stress among participants with MP-related symptoms and general EHS, and population-based (PB) and control (C) groups

Questionnaire instrument	MP (n=45)	EHS (n=71)	PB (n=106)	C (n=63)
STAI				
Trait ¹	38.9 (13.0)	38.8 (12.3)	34.2 (10.0)	33.9 (10.8)
State	34.6 (12.5)	34.6 (14.1)	30.8 (10.7)	30.9 (11.7)
KSP				
Inhibition of aggression	23.2 (6.1)	23.6 (5.2)	22.9 (5.8)	23.6 (5.8)
Muscular tension ^{1, 2}	18.9 (6.7)	20.5 (6.7)	16.3 (5.1)	16.0 (5.3)
Psychasthenia ¹	22.7 (7.8)	24.4 (5.4)	20.4 (5.2)	20.6 (5.5)
Psychic anxiety	19.7 (7.0)	19.7 (6.1)	18.4 (6.1)	18.7 (6.3)
Somatic anxiety ^{1, 2}	17.5 (6.5)	19.4 (6.6)	14.8 (4.9)	15.0 (5.0)
BDI ^{1, 2}	9.59 (9.6)	10.56 (9.3)	5.84 (6.5)	4.87 (5.1)
SCL-90				
Anxiety ^{1, 2}	0.66 (0.72)	0.76 (0.85)	0.30 (0.40)	0.29 (0.39)
Depression ^{1, 2}	0.86 (0.54)	0.94 (0.46)	0.65 (0.45)	0.62 (0.45)
Somatization ^{1, 2}	0.90 (0.74)	1.3 (0.93)	0.61 (0.64)	0.60 (0.65)
SMBQ				
Global ^{1, 2}	3.52 (1.74)	3.99 (1.48)	2.70 (1.26)	2.63 (1.22)
Burnout ^{1, 2}	3.52 (1.88)	4.04 (1.66)	2.67 (1.40)	2.58 (1.39)
Listlessness ^{1, 2}	1.80 (0.57)	2.06 (0.43)	1.68 (0.50)	1.65 (0.51)
Tension ¹	3.52 (0.96)	3.38 (0.96)	2.96 (0.76)	2.91 (0.76)
Mental exhaustion ^{1, 2}	1.77 (0.52)	1.94 (0.47)	1.54 (0.40)	1.54 (0.39)
PSQ	0.56 (0.22)	0.56 (0.17)	0.49 (0.18)	0.47 (0.16)

The *P* values refer to the comparison (MANOVA) between MP+ EHS and a reference group (PB or C).

Significant difference: (1) (MP+EHS)/PB; (2) (MP+EHS)/C (Bonferroni adjustment for multiple tests).

subscales from the SCL-90, but not for the STAI State subscale nor for the PSQ or the KSP subscales Inhibition of Aggression and Psychic Anxiety (Tables 3 and 4). For the STAI Trait subscale, the KSP Psychasthenia subscale, and the SMBQ Tension subscale, there was a significant difference between the case groups and the population-

based group, but not between the case groups and the control group. The post hoc comparison revealed that the EHS group differed from the reference groups in more aspects than did the MP groups (Table 4). The EHS group also scored higher than the MP group on all scales except for the STAI, the KSP subscale Psychic Anxiety, and the SMBQ Tension subscale. However, only the differences for the Somatization subscale of the SCL-90 and the Listlessness subscale of the SMBQ were statistically significant.

Table 4

Results (*P* values) from post hoc comparisons (Tamhane's procedure) of the differences in mean scores between groups with MP-related symptoms, EHS, and population-based (PB) and control (C) groups respectively

Questionnaire instrument	MP/EHS	MP/PB	EHS/PB	MP/C	EHS/C
STAI					
Trait	.999	.120	.030	.125	.046
State	.985	.167	.211	.268	.356
KSP					
Inhibition of aggression	.982	.999	.8993	.989	.999
Muscular tension	.546	.106	<.001	.080	<.001
Psychasthenia	.466	.387	<.001	.481	<.001
Psychic anxiety	.999	.664	.393	.841	.687
Somatic anxiety	.357	.078	<.001	.123	<.001
BDI	.781	.051	<.001	.019	<.001
SCL-90					
Anxiety	.944	.008	<.001	.009	<.001
Depression	.815	.070	<.001	.045	<.001
Somatization	.028	.091	<.001	.123	<.001
SMBQ					
Global	.386	.022	<.001	.015	<.001
Burnout	.406	.024	<.001	.014	<.001
Listlessness	.043	.533	<.001	.403	<.001
Tension	.913	.006	.007	.004	.006
Mental exhaustion	.235	.049	<.001	.068	<.001
PSQ	.999	.181	.012	.058	.002

Significant differences between groups are indicated in bold.

Discussion

The differences in symptom picture, with the MP group reporting predominantly symptoms of somatosensory character, referred to the head (warmth behind/around/on the ear, burning skin, tingling/tightness) and the EHS group reporting more symptoms of neurasthenic character (fatigue, concentration difficulties, dizziness) were expected and correspond with previous observations [22,23,32]. The MP group resembles individuals with VDT-related complaints in that symptoms are reported predominantly from one part of the body [10,12].

The frequency of EMF-nonrelated symptoms reported by the case groups was considerably lower than that of EMF-related symptoms, but the overall symptom picture was similar. The prevalence of EMF-nonrelated and EMF-related symptoms in the population based sample is fairly consistent with previous observations [6,8,33–35]. There was a considerable discrepancy between the symptom-based classification made by the authors and the labels adopted

by the participants themselves. In the EHS group, as expected, almost all participants described themselves as being sensitive to EMF exposure in general. In the MP group, however, almost half of the participants described themselves as not being particularly sensitive to EMF exposure, neither from electrical equipment in general nor from mobile phones specifically, although they all reported symptoms occurring during MP use and volunteered to the study because of these symptoms. Of the participants in the population-based group reporting EMF-related symptoms, almost none considered themselves as being particularly sensitive to EMF exposure. Part of this difference may be due to self-selection bias; however, it is unlikely that bias would account for all of the rather profound difference between the two case groups.

The results from the assessment of self-reported personality traits and stress suggest that EMF-related symptoms are associated with (self-reported) anxiety, depression, somatization, symptoms of exhaustion, and stress. In comparison to both the population-based group and the control group, all these traits and conditions were found to be more prominent in the EHS group and to some extent also in the MP group. A direct comparison between the two case groups revealed significant differences only for somatization and listlessness. However, comparisons with the two reference groups suggest that the MP group shows no significantly increased levels of anxiety, somatization, and stress, but does exhibit increased symptoms of exhaustion and depression. The elevated levels of anxiety, depression, somatization, and stress in the EHS group agree with earlier findings, and exhaustion may be added to the list of important psychological factors associated with EHS [12,18]. The degrees of anxiety (as assessed with the SCL-90), depression, and exhaustion reported by the case groups fall between those of the general population and those observed in patients with depression or psychosomatic disorders, corresponding with other observations of symptoms attributed to environmental factors [36,37]. The elevated levels of somatization should be interpreted with caution, since the somatization subscale of the SCL-90 consists of items describing various somatic symptoms, many of which are reported as EMF-related by the case groups. As would be expected, the severity of the investigated conditions is somewhat lower in the present study of nonpatients than in previous studies of patients [17,38,39]. The interindividual variation is, however, high in both case groups, and for most variables, both individuals scoring very low and those scoring very high can be found, this further emphasizing the heterogeneity of these groups.

It has been observed that individuals with EHS often have a less favorable prognosis with respect to both medical and social factors than individuals with VDT-related symptoms (mostly skin symptoms) [10]. Our data indicate that there may be a similar difference between people with EHS and people with MP-related symptoms. The results further support the idea of a subdivision between those who report symptoms related to EMF exposure from specific sources

and those who report EHS. In the present study, the EHS group presented a high number of participants on sick leave or having received disability pension. Many of these reported a generally diminished quality of life due to EMF-related symptoms and described their situation as having ceased work due to EMF-related symptoms. Similar reports were not given by the MP group. Effects of the differences in illness duration and social consequences on the assessed variables are to be expected, but the magnitude of these effects is uncertain.

Data on physiological characteristics of subjects with EMF-related symptoms support the view on stress and distress as important factors. Signs of hyperresponsiveness to sensory stimuli have been observed, together with modest but distinctive deviations in heart rate variability (HRV), suggesting a shift in the autonomic nervous system regulation toward sympathetic dominance [40–43]. The observations correspond with the frequent reporting of symptoms that may be associated with autonomic nervous system derangement, e.g., dizziness, fatigue, and sleeping disorders [44–46]. Groups with different symptom attribution seem to differ also in physiological aspect. In a group with MP-related symptoms, signs of hypersympathotone was observed only under induced stress, whereas investigations of groups with EHS have revealed differences between EHS subjects and controls also during rest [40,43]. In EHS subjects, indications of parasympathetic withdrawal during nighttime have also been observed, which indicates deviations in autonomic activity not only in response to acute stressors [41]. An association between changes of the HRV toward sympathetic predominance and perceived stress have been demonstrated both in the laboratory and in daily life [47,48]. Similarly, effects of anticipatory stress on HRV during sleep suggesting parasympathetic withdrawal have been observed, and disturbance of the normal HRV pattern has been suggested as one of the mechanisms through which stress disrupts sleep [49]. The observations on the physiological characteristics of people with EMF-related symptoms consequently further support the view on stress and distress as important factors in this condition, as well as the hypothesis of differences between subgroups with different symptom attribution.

The similarity between the MP group in this study and subjects with VDT-related symptoms in previous investigations may partly be explained by the prevalence of VDT-related symptoms in a part of the MP group. However, participants with both MP-related and VDT-related symptoms did not differ from participants with only MP-related symptoms in other aspects than the presence of VDT-related symptoms, as was also expected from our previous contacts with people with MP- and/or VDT-related symptoms.

It is worthwhile noting that MP and EHS participants tended to score differently on single items such as the PSQ and the STAI (data not reported). The MP subjects scored high on items describing work-related stress and tension [“I feel under pressure from deadlines” (PSQ); “I feel inade-

quate” (STAI)], whereas the EHS participants scored high on items describing fatigue, exhaustion, worry, and anxiety [“I am afraid of the future” (PSQ); “I do not feel secure” (STAI)]. This may partly be explained by the fact that more MP participants were occupationally active. However, it may also reflect differences in processes underlying sustained cognitive and physiological activation and, thus, contributing to symptom development. It has, for example, been suggested that perseverative cognition (e.g., worrying) is a possible mediator between an acute stress response and sustained activation and that it also may act as a stressor in itself [50]. These authors have highlighted the association between worry and somatic symptoms and hypothesize that worry may have this effect by expanding the duration of a stressor beyond the traditional reactivity period, leading to a sustained vigilant state. They further suggest that the worry may have detrimental effects on the perceived coping ability of the worrying individual, which, together with the elevated vigilance would contribute to disease. Subjects with MP-related symptoms considering themselves “electrosensitive” have been observed to report worry about health risks associated not only with EMF but with various factors of modern life, such as tainted food and environmental pollution, to a higher extent than subjects with MP-related symptoms that did not consider themselves electrosensitive [17]. It is possible that worry is one of the factors involved in the generalization of EMF-related symptoms to EHS. Both stress and worry have been proposed to be important factors in the development of various conditions with a symptom picture resembling that of EMF-related symptoms (fibromyalgia, multiple chemical sensitivity, chronic fatigue syndrome, etc.) [19,50–52]. An association between worry and autonomic nervous system changes toward sympathetic predominance has also been proposed [50]. The similarities in symptom pattern and the present finding on personality traits and stress highlight the role of psychological factors in electromagnetic sensitivity.

The study has some important limitations. Due to the cross-sectional nature of the data, no conclusion about cause and effect can be drawn from the results. The psychological factors investigated may indicate vulnerability for developing EMF-related symptoms, but these psychological states may also be a consequence of having a long-term disabling condition. The participants also are not randomly selected and might not form a representative sample of people with EMF-related symptoms. Particularly, there is a risk of over-reporting of symptoms. The high number of questionnaires may also have discouraged people from participating. This might be one of the reasons for the rather low response rate (45%) in the population-based sample. The low response rate of the referents and the further reduction of the number of participants in the control group are an important note of caution. Moreover, the four groups differed with respect to age, sex, and smoking habits. The difference between groups with respect to age and smoking may have resulted in an underestimation of somatic symptoms, mainly in the MP

group. However, as previous investigations also suggest that those with MP-related symptoms generally are younger than those with EHS, and more likely to be men, these differences may well represent a real difference between symptom groups [23,43]. Although the group differences between cases and referents tended to be somewhat larger when comparing with the control group, the overall results were consistent across the two reference groups.

Conclusions

The results of the present study suggest that people with MP-related symptoms differ from those with EHS, with respect to prevalence and severity of EMF-related as well as EMF-nonrelated symptoms. The MP participants reported symptoms localized to the head, many of which of somatosensory character, whereas EHS participants reported more neurasthenic symptoms. The data further indicate higher levels of anxiety, depression, somatization, exhaustion, and stress in people with EMF-related symptoms than in the general population and in controls without EMF-related symptoms, with higher levels in people with EHS than in people with MP-related symptoms. The observations support a formerly suggested subdivision of individuals with EMF-related symptoms according to the EMF sources to which the symptoms are attributed. The differences observed are likely to be important for the development of the conditions with time as well as for the degree of disability due to symptoms and should be considered in the choice of medical treatment and remedial activities. The differences between MP-related symptoms and EHS should further be considered in the choice of selection criteria in further research, as well as in the interpretation of results, as study participants that differ in symptom attribution may differ also in other aspects.

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