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Development and Evaluation of an Electromagnetic Hypersensitivity Questionnaire for Japanese People

Sachiko Hojo,[1,2,3]* Mikiko Tokiya,[4] Masami Mizuki,[5] Mikio Miyata,[6] Kumiko T. Kanatani,[7] Airi Takagi,[8] Naomi Tsurikisawa,[2] Setsuko Kame,[9] Takahiko Katoh,[10] Takuya Tsujiuchi,[1,11] and Hiroaki Kumano[1,11]

[1]Institute of Applied Brain Sciences, Waseda University, Tokorozawa, Japan
[2]Department of Allergy and Respirology, and Clinical Research Center for Allergy and Rheumatology, National Hospital Organization, Sagamihara National Hospital, Sagamihara, Japan
[3]Shokei Gakuin University, Natori, Japan
[4]Faculty of Medicine, Department of Public Health and Epidemiology, Oita University, Oita, Japan
[5]Department of Respiratory Medicine and Allergy, National Hospital Organization, Morioka National Hospital, Morioka, Japan
[6]Clinic of Enviromental Medicine Soyokaze Tokyo, Tokyo, Japan
[7]Department of Health Informatics, Kyoto University School of Public Health, Kyoto, Japan
[8]Division of Biostatistics, Tohoku University Hospital Clinic Research Data Center, Sendai, Japan
[9]Kansai University of Health Sciences, Osaka, Japan
[10]Faculty of Life Sciences, Kumamoto University, Kumamoto, Japan
[11]Faculty of Human Sciences, Waseda University, Tokorozawa, Japan

The purpose of the present study was to evaluate the validity and reliability of a Japanese version of an electromagnetic hypersensitivity (EHS) questionnaire, originally developed by Eltiti et al. in the United Kingdom. Using this Japanese EHS questionnaire, surveys were conducted on 1306 controls and 127 self-selected EHS subjects in Japan. Principal component analysis of controls revealed eight principal symptom groups, namely, nervous, skin-related, head-related, auditory and vestibular, musculoskeletal, allergy-related, sensory, and heart/chest-related. The reliability of the Japanese EHS questionnaire was confirmed by high to moderate intraclass correlation coefficients in a test–retest analysis, and high Cronbach's α coefficients (0.853–0.953) from each subscale. A comparison of scores of each subscale between self-selected EHS subjects and age- and sex-matched controls using bivariate logistic regression analysis, Mann–Whitney *U*- and χ^2 tests, verified the validity of the questionnaire. This study demonstrated that the Japanese EHS questionnaire is reliable and valid, and can be used for surveillance of EHS individuals in Japan. Furthermore, based on multiple logistic regression and receiver operating characteristic analyses, we propose specific preliminary criteria for screening EHS individuals in Japan. Bioelectromagnetics. 37:353–372, 2016.

Key words: idiopathic environmental intolerance; electromagnetic fields; EHS screening tool; multiple chemical sensitivities; allergy symptoms

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*Correspondence to: Sachiko Hojo, Institute of Applied Brain Sciences, Waseda University, 3-7-28 Kaigamori, Aoba-ku, Sendai, Miyagi 981-0942, Japan. E-mail: hojo@shokei.ac.jp

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INTRODUCTION

Sensitivity to electromagnetic fields (EMFs) has generally been referred to as "electromagnetic hypersensitivity (EHS)," whereas the scientific term for this phenomenon is "idiopathic environmental intolerances attributed to electromagnetic fields (IEI-EMFs)" [WHO, 2005; COST, 2011]. We have used the term "EHS" throughout this paper because it was used by Eltiti et al. [2007] in the originally developed questionnaire. The questionnaire was subsequently translated to Japanese and has been used as the Japanese version of Eltiti's questionnaire in the present study.

EHS is characterized by a variety of non-specific symptoms, which affected individuals have attributed to exposure to EMFs [WHO, 2005]. Health effects of exposure to strong EMFs are well-documented, and are generally controlled by regulations and guidelines [ICNIRP, 2009]. In addition, numerous reports exist on health effects of low-level EMF exposure [Hillert et al., 2002; Mohler et al., 2010; Röösli et al., 2010; Rubin et al., 2010; Baliatsas et al., 2012]. However, there has not been, until now, conclusive evidence linking the pathophysiology of EHS to any previous exposure to EMFs [WHO, 2005; COST, 2011]. There is also evidence of a "nocebo effect" in triggering acute health reactions [Rubin et al., 2011; Witthöft and Rubin, 2013]. Moreover, other factors, including poor indoor air quality or stress in the workplace/living environment, may also play significant roles [WHO, 2005].

A very wide range (1.2–13.3%) of estimates exists regarding the prevalence of EHS in the general population [Meg Tseng et al., 2001; Hillert et al., 2002; Levallois et al., 2002; Leitgeb and Schröttner, 2003; Schreier et al., 2006; Preece et al., 2007; Landgrebe et al., 2008; Schröttner and Leitgeb, 2008; Mohler et al., 2010; Röösli et al., 2010; Rubin et al., 2010, 2011; Baliatsas et al., 2012; Hojo and Tokiya, 2012; Nordin et al., 2013]. In Japan, Furubayashi et al. [2009] reported that 1.2% of females showed mobile phone-related and other unusual symptoms around telecommunication masts; however, further reports concerning EHS among the Japanese population are lacking. As well, the number of people with an EHS condition varies between countries. This may be attributed to differences in the definitions of EHS, the methods of assessment used, and media coverage during the survey [COST, 2011].

The lack of a general case definition for EHS, and the absence of a standardized approach for measuring concrete aspects of EHS that would permit a cross-comparison by different investigators, have delayed further studies in this area. Surveys using conventional psychological tests or questions with "yes" or "no" answers have been the most commonly used measures for the evaluation of effects of EMFs on health [Abdel-Rassoul et al., 2007, Berg-Beckhoff et al., 2009; Blettner et al., 2009]. However, investigations using conventional questionnaires failed to reveal any specific symptoms of EHS, nor clarified the severity of symptoms associated with exposure to specific EMF objects.

In the United Kingdom (UK), Eltiti et al. [2007] developed the EHS questionnaire, which evaluates effects of EMF exposure, particularly on EMF-related health conditions.

The main advantage of this EHS questionnaire is that it not only takes into account the individual's belief as to the cause of their symptom(s), but also includes the degree of symptom severity. The study reported that 145 (4.0%) out of 3,633 respondents from a randomly selected general population of 20,000 people met the "screening criteria for EHS." Subsequently, we translated "Eltiti's questionnaire" into Japanese by modifying and adding several questions unique to the Oita version of the Japanese EHS questionnaire, which was confirmed for its validity and reliability, and was used for investigating health effects of EMFs from mobile phone base stations on 520 members of a randomly selected general public (230 males, 20–89 years old; and 290 females, 18–87 years old) in Oita Prefecture, Japan in 2010.

In the past, we [Hojo, 2002; Hojo et al., 2003, 2004, 2005, 2007, 2008a,b, 2009; Hojo and Tokiya, 2012] conducted several investigations in order to elucidate the actual status of multiple chemical sensitivity (MCS) and sick building syndrome or sick house syndrome (SHS) patients in Japan using the quick environmental exposure and sensitivity inventory (QEESI) developed by Miller and Prihoda [1999]. Our findings revealed that a number of MCS/SHS patients complained of hypersensitive reactions to various EMF sources. We have, therefore, been on the lookout for a questionnaire that can evaluate hypersensitive reactions to sources of EMFs in order to assess the genuineness or spuriousness of patients' complaints. However, the above-mentioned "Oita version of Japanese EHS questionnaire" was not used, because it had been significantly modified from the original one [Eltiti et al., 2007]. Therefore, in this study, we accurately re-translated Eltiti's questionnaire, and subsequently developed a new Japanese version (Japanese EHS questionnaire), courtesy of Dr. S. Eltiti.

The aims of the present study were as follows: (1) to evaluate the reliability and validity of the Japanese EHS questionnaire; (2) to reveal characteristics of symptoms in Japanese self-selected EHS

subjects; (3) to reveal characteristics of EMF objects that Japanese self-selected EHS subjects believed were the cause of their EHS-related symptoms and reactions; (4) to reveal characteristics of chronic illnesses (past and present) in Japanese self-selected EHS subjects; and (5) to propose preliminary criteria for the screening of EHS individuals in Japan on the basis of the findings of this study.

METHODS

Structure of the Japanese EHS Questionnaire

The Japanese EHS questionnaire consisted of four sections: (I) biographical information; (II) symptoms and causes; (III) general health data; and (IV) additional questions unique to the Japanese questionnaire. Sections I, II, and III were almost identical to those in the original EHS questionnaire [Eltiti et al., 2007] in terms of the content of questions and the manner in which participants were required to answer them. Some parts of questions were slightly modified after consultation with MCS/EHS specialists, based on specific needs of the Japanese population.

Biographical information. In this section, the participants were asked six questions regarding their age, gender, address, occupation, final academic background, and mean working hours per day.

Symptoms and causes (q1–71). ***Symptoms (q1–57).*** In this section, participants were questioned about the frequency of occurrence of 57 symptoms (Supplementary Table). They were required to indicate their responses using a 5-point scale: 1 (not at all), 2 (a little bit), 3 (moderately), 4 (quite a bit), and 5 (a great deal). It should be noted that symptoms were presented as single words or phrases in the EHS questionnaire used by Eltiti et al. [2007], whereas in the Japanese version, symptoms were presented in the form of questions (Supplementary Table).

EMF-producing objects (q58–66). In this section, nine questions were asked regarding the perception of a link between EMF-producing objects and 57 symptoms. Participants needed to indicate their responses using the 5-point scale described earlier. Furthermore, each participant was asked to write the name of an object and the severity of the symptom, in order to ascertain the presence of any additional EMF objects that were not mentioned in the EHS questionnaire used by Eltiti et al. [2007].

Reactions to EMF exposure (q67–71). In this section, participants were required to answer three questions regarding EMF sensitivity (q67), occurrence of static shocks (q70), and negative health changes around EMFs (q71) using the 5-point scale. Moreover, in order to determine if there were any additional EMF-producing objects that were not mentioned in the original EHS questionnaire [Eltiti et al., 2007], participants were required to state specific EMF object(s) affecting their health, along with a detailed description of symptom(s) experienced (q68, a descriptive-type question). Participants were also asked to indicate if they had ever experienced severe electric shock (q69, a "yes" or "no" question).

General health (1–4). In this section, questions 1 to 3–1 and 4 were identical to those in the EHS questionnaire [Eltiti et al., 2007]. However, in order to evaluate the quality of sleep, participants were questioned about average sleeping hours (3–2), and quality of sleep (3–3, sleep disorder; Japanese modification; Supplementary Materials).

Additional questions unique to the Japanese questionnaire. ***The todai health index-depression (THI-D) scale (10 items).*** The THI-D scale is frequently used to assess symptoms of depression in Japan [Takeuchi et al., 1994; Kawada et al., 1999]. Results of the THI-D scale in the present study were compared with those of existing health surveys that have used this method in Japan because most self-selected EHS subjects generally develop symptoms of depression.

Physician-diagnosed chronic illness (present and past). In order to determine the relationship between EHS and other chronic illnesses, including MCS and SHS, participants were provided with a list of chronic illnesses and asked to mark their current illness with a circle within a circle (◎), and their past chronic illnesses with a circle only (○).

Sequence of EHS development. Participants who believed that they had developed EHS or MCS were asked to answer questions regarding the time and sequence of onset of EHS, MCS, and SHS (Supplementary Materials).

STUDY PERIOD AND PARTICIPANTS

Surveys were conducted between 2009 and 2015.

Controls

The control group was comprised of ordinary residents living in cities across Japan. Participants exhibited a wide age range, and were recruited via

mailing lists and information magazines using universities and local non-profit organizations (NPOs) as contacts. The questionnaire was mailed to 2,000 selected persons, with 1,320 questionnaires returned (participation rate, 66%). However, valid data (data concerning age, sex, and at least 90% other entries) were obtained from only 1,306 of the 1,320 returned questionnaires.

Self-Selected EHS Subjects

Self-selected EHS subjects were recruited via two self-help EHS groups in Japan. Questionnaires were mailed to 165 people who cooperated with our research, and were returned from 128 patients (participation rate, 77.6%). However, valid data were obtained from only 127 patients as one patient complained of MCS symptoms and was, therefore, excluded from the study.

Statistical Analyses

Statistical analyses were performed using SPSS for Windows (version 22; IBM, Armonk, NY).

Reliability. Test–retest measures were applied to 52 NPO members (males: $n = 27$, average age: 48.93 ± 16.70 years; females: $n = 25$, average age: 42.76 ± 14.75 years) and 121 students from three universities (males: $n = 38$, average age: 20.00 ± 0.62 years; females: $n = 83$, average age: 20.83 ± 0.91 years). Thus, a total of 173 subjects from the general public (males: $n = 65$, average age: 32.02 ± 17.89 years, age range: 19–76; females: $n = 108$, average age: 25.91 ± 11.65 years, age range: 17–66) were included for test–retest measures. The same test was performed twice in 1–2-week intervals by the same subjects. The score obtained for each question, using the 5-point scale, and the total score from each subscale were determined by intraclass correlation coefficients (ICC). The Kappa (κ) coefficient was calculated for q68 and q69 due to dichotomous response options ("yes" or "no") for these questions. Internal consistency was calculated using Cronbach's α coefficient [Cronbach, 1951] for each subscale in questionnaires obtained from controls and self-selected EHS subjects.

Validity. Discrimination validity of the Japanese questionnaire was determined by comparing scores of each question and total scores for each subscale between self-selected EHS subjects ($n = 127$), and sex- and age-matched (± 5 years) controls ($n = 127$), using bivariate logistic regression analyses, Mann–Whitney U- and χ^2 tests, and with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$).

Furthermore, the distribution pattern of total symptom scores concerning 57 symptoms in both groups is depicted using a histogram (Fig. 1a) and box-and-whisker plots (Fig. 1b). The 25th, 50th, and 75th percentiles were estimated for scores of total symptoms in the control group. The horizontal line in each box represents the median value, whereas those at the bottom and top of the box represent 25th and 75th percentile values, respectively. The median score of total symptoms in self-selected EHS subjects was compared with that of controls using a Mann–Whitney U-test (Fig. 1a and b) with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$). Median values of symptoms (eight principal components) are shown in a radar chart (Fig. 1c).

Preliminary screening criteria for EHS individuals. Multiple logistic regression and receiver operating characteristic (ROC) analyses were implemented between the self-selected EHS subject group ($n = 127$) and the sex- and age-matched control group ($n = 127$); preliminary screening criteria for EHS individuals from the general population were calculated using results of these analyses.

Ethical Considerations

The present study was approved by the ethics committees of the following institutes in Japan: Oita University (approved on June 4, 2009); National Hospital Organization (NHO), Morioka National Hospital, Morioka (approved on June 6, 2012); and NHO, Sagamihara National Hospital, Sagamihara (approved on July 9, 2013), in accordance with the Declaration of Helsinki [WMA, 2013].

RESULTS

Sample Characteristics

Table 1 shows characteristics of controls and self-selected EHS subjects. Mean working hours of EHS patients (6.52 h) were significantly lower than those of controls (8.42 h). There were no significant differences in resident area and final academic background between self-selected EHS subjects, and age- and sex-matched controls. On the other hand, there were significantly fewer full-time workers and more unemployed persons among self-selected EHS subjects when compared with controls.

Principal Component Analysis

Firstly, an exploratory principal component analysis (PCA) of 57 symptoms was carried out on controls ($n = 1{,}306$), using direct oblimin rotation, in order to examine the underlying pattern of

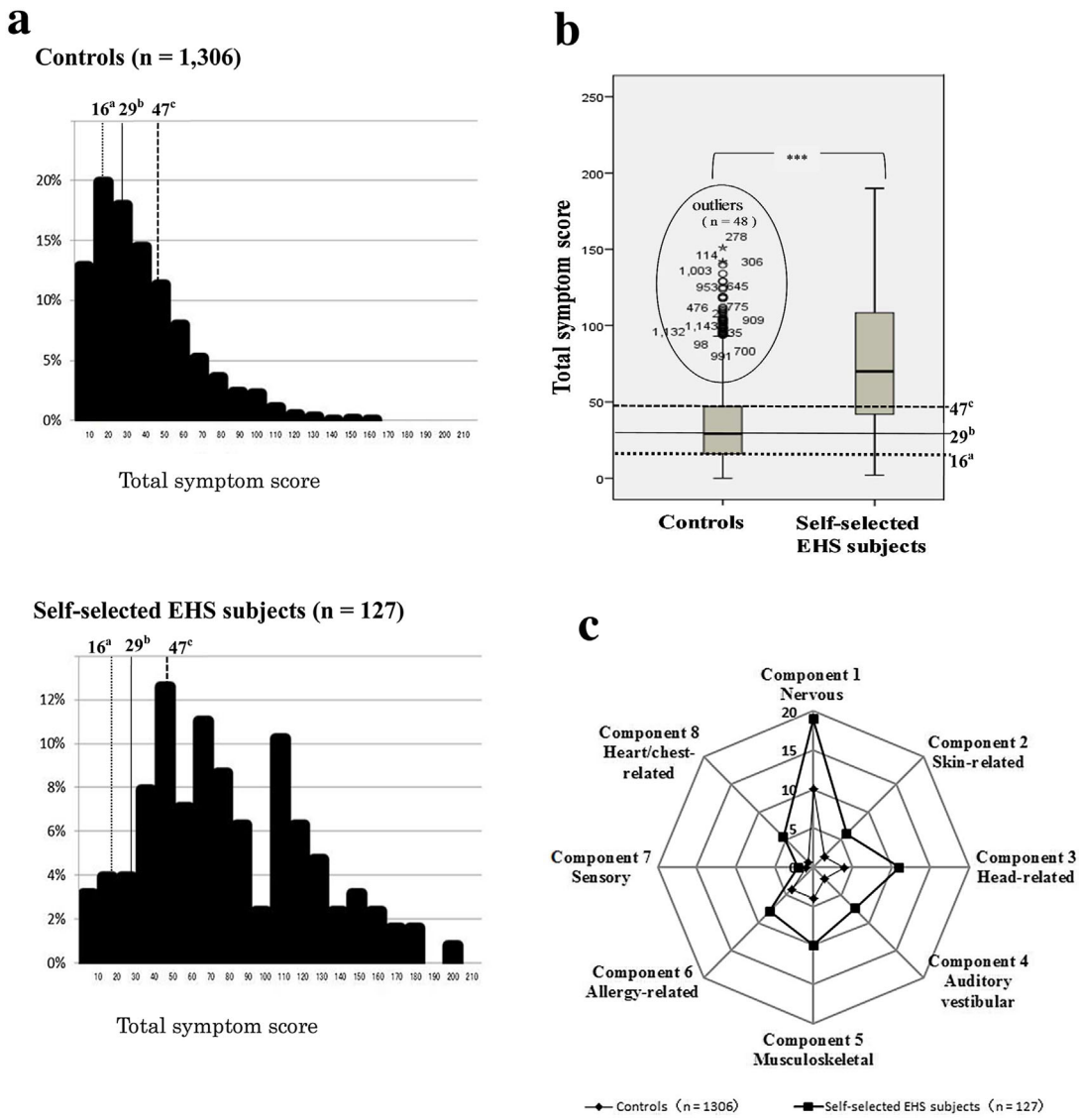

Figure 1. Comparison of total symptom scores between controls and self-selected EHS subjects. **1a**. Histogram showing total symptom scores. EHS: electromagnetic hypersensitivity. **1b**. Box-and-whisker plots showing total symptom scores. Plots inside ellipse represent outliers that are not within normal range. Note: differences in median scores of total symptoms between self-selected EHS subjects ($n = 127$) and controls ($n = 127$) were compared using a Mann-Whitney *U*-test with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$); $^{***}P \leq 0.00001$. For **1a** and **1b**: The [a]25th percentile (16 points), [b]50th percentile (29 points), and [c]75th percentile value of controls (47 points). **1c**. Radar chart showing median values of symptoms for eight principal components (factors 1-8). Differences in median values of symptoms for all eight principal components between self-selected EHS subjects ($n = 127$) and controls ($n = 127$) were analyzed using a Mann-Whitney *U*-test as above. There were significant differences ($P \leq 0.00001$) in median values of symptoms for all eight principal components.

symptoms and to condense their total number. Direct oblimin rotation was chosen over the usual varimax rotation owing to the viewpoint that this allows for components to be correlated to one another. Components with a factor loading over 0.4 were chosen, resulting in 12 components with eigenvalues greater than one, and accounting for 59.3% of the variance. Next, evaluation of the scree plot revealed only one component above the marked elbow, indicating that the first component accounted for 28.79% of the variance. However, owing to the complex nature of EHS and the lack

TABLE 1. Characteristics of Controls and Self-Selected EHS Subjects

	Controls (total) ($n = 1306$)	Controls (met set screening criteria[a]) ($n = 60$)	Controls (age and sex matched) ($n = 127$)	Self-selected EHS subjects ($n = 127$)	χ^2 test P value
Biographical information					
Gender					
Male	373 (28.6%)	10 (16.7%)	26 (20.5%)	26 (20.5%)	1.000 n.s.
Female	933 (71.4%)	50 (83.3%)	101 (79.5%)	101 (79.5%)	
Total	1306 (100%)	60 (100%)	127 (100%)	127 (100%)	
Age (years)					
19≧	144 (11.0%)	4 (6.7%)	3 (2.4%)	4 (3.1%)	0.977 n.s.
20–39	491 (37.6%)	22 (36.7%)	9 (7.1%)	8 (6.3%)	
40–50	424 (32.5%)	20 (33.3%)	68 (53.5%)	68 (53.5%)	
60≦	247 (18.9%)	14 (23.2%)	47 (37.0%)	47 (37.0%)	
Total	1306 (100%)	60 (100%)	127 (100%)	127 (100%)	
Mean ± SD	40.49 ± 18.00	43.10 ± 17.03	54.28 ± 13.87	54.35 ± 14.34	
Area					
Hokkaido/Tohoku[b]	602 (46.6%)	31 (51.7%)	6 (4.7%)	6 (4.7%)	
Kantou/Koussin/ Hokuriku[c]	232 (18.0%)	9 (15.0%)	51 (40.2%)	54 (42.5%)	0.941 n.s.
Tokai/Kinki/ Chugoku[d]	286 (22.1%)	11 (18.3%)	54 (42.5%)	54 (42.5%)	
Kyushu/Shikoku/ Okinawa[e]	172 (13.3%)	9. (15.0%)	16 (12.6%)	13 (10.2%)	
Education					
Primary school	17 (1.4%)	2 (3.4%)	5 (4.1%)	3 (2.4%)	0.113 n.s.
High school	610 (50.1%)	21(35.6%)	47 (38.5%)	32 (25.6%)	
College/University	530 (43.5%)	30 (50.8%)	65 (53.3%)	82 (65.6%)	
Graduate	60 (4.9%)	6 (10.2%)	5 (4.1%)	8 (6.4%)	
Total	1217 (100%)	59 (100%)	122 (100%)	125 (100%)	
Occupation					
Unemployed	127 (11.1%)	4 (6.8%)	16 (13.1%)	42 (33.9%)	
Student	171 (14.9%)	16 (29.1%)	6 (4.9%)	4 (3.2%)	
Homeworker	184 (16.0%)	7 (11.9%)	22 (16.4%)	37 (29.8%)	$4.59 \times 10^{-6*}$
Part-time worker	178 (15.5%)	7 (11.9%)	26 (21.3%)	16 (12.9%)	
Full-time worker	489 (42.5%)	25 (42.4%)	54 (49.6%)	25 (20.2%)	
Total	1149 (100%)	59 (100%)	122 (100%)	124 (100%)	
Mean working hours per day[f] ± SD	8.21 ± 3.57	9.06 ± 3.16	8.42 ± 3.57	6.52 ± 3.38	$6.25 \times 10^{-5*}$

Note: Differences in scores between groups were analyzed by χ^2 tests with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$).

EHS, electromagnetic hypersensitivity; SD, standard deviation; n.s., not significant.

[a]Controls met set screening criteria for EHS: controls who met set screening criteria for EHS individuals.

[b]Hokkaido/Tohoku: seven prefectures (e.g., Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima).

[c]Kantou/Koussin/Hokuriku: thirteen prefectures (e.g., Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Niigata, Toyama, Ishikawa, Fukui, Yamanashi, Nagano).

[d]Tokai/Kinki/Chugoku: thirteen prefectures (e.g., Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama, Tottori, Shimane, Okayama, Hiroshima, Yamaguchi).

[e]Kyushu/Shikoku/Okinawa: twelve prefectures (e.g., Tokushima, Kagawa, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, Okinawa).

[f]Mean working hours per day: included housework and school hours.

*$P \leq 0.00001$.

of information regarding the pattern of EHS symptoms, we deemed it more appropriate to examine several multivariate solutions. The present study was aimed at developing a measure that could be used to explore specific aspects of EHS; therefore, we looked for several forced factor solutions (10-, 9-, 8-, 7-, and 6-factor) with direct oblimin rotation. A forced eight-factor solution was chosen for the following five reasons: (1) it contained the least number of cross-loaded items; (2) it also had the highest number of items loaded onto each component; (3) the items that loaded onto each component resulted in cohesive symptom categories; (4) it was able to account for 51.9% of

TABLE 2. Factor Loadings From Forced Eight-Factor Principal Component Analysis of Controls ($n = 1306$)

Principal components		1	2	3	4	5	6	7	8
Symptoms		Nervous	Skin-related	Head-related	Auditory vestibular	Musculo-skeletal	Allergy-related	Sensory	Heart/chest-related
Eigenvalue		16.41	2.77	2.22	2.08	1.58	1.53	1.52	1.32
Proportion (%)		28.79	4.85	3.89	3.64	2.76	2.68	2.67	2.31
Cumulative proportion (%)		28.79	33.64	37.53	41.17	43.93	46.61	49.28	51.59
q12	Depression	**0.811**	0.190	-0.363	0.302	-0.245	0.241	0.263	0.371
q13	Difficulty in concentrating	**0.806**	0.219	-0.347	0.282	-0.169	0.242	0.408	0.352
q14	Difficulty in focusing attention	**0.767**	0.230	−0.332	0.275	−0.188	0.234	0.426	0.354
q24	Fatigue	**0.752**	0.195	−0.432	0.262	−0.461	0.296	0.241	0.277
q55	Stress	**0.721**	0.199	−0.373	0.203	−0.377	0.232	0.248	0.260
q25	Foggy thinking	**0.702**	0.184	−0.503	0.375	−0.323	0.244	0.292	0.338
q21	Exhaustion	**0.669**	0.161	−0.468	0.231	−0.426	0.314	0.234	0.266
q2	Anxiety	**0.633**	0.194	−0.184	0.165	−0.229	0.381	0.099	0.320
q34	Memory difficulties	**0.472**	0.120	−0.206	0.197	−0.440	0.214	0.448	0.300
q54	Sleep disturbances	**0.439**	0.212	−0.334	0.298	−0.344	0.117	0.348	0.313
q49	Skin irritation	0.232	**0.757**	−0.212	0.270	−0.248	0.307	0.166	0.168
q52	Skin redness	0.235	**0.741**	−0.236	0.187	−0.071	0.342	0.165	0.228
q53	Skin swelling	0.137	**0.720**	−0.186	0.149	−0.121	0.225	0.221	0.269
q56	Tingling sensations	0.193	**0.689**	−0.203	0.284	−0.270	0.105	0.290	0.192
q41	Pain/Soreness of the skin	0.126	**0.611**	−0.183	0.360	−0.272	0.250	0.219	0.217
q48	Skin burning sensations	0.073	**0.548**	−0.164	0.240	−0.270	−0.056	0.273	0.231
q51	Skin rash	0.319	**0.427**	−0.306	0.238	0.051	0.255	0.242	0.190
q6	Blisters on the skin	0.129	**0.397**	−0.141	0.247	−0.019	0.388	−0.012	0.264
q26	Headaches	0.349	0.162	**−0.881**	0.277	−0.224	0.206	0.196	0.266
q20	Dull headaches	0.294	0.195	**−0.871**	0.282	−0.293	0.260	0.232	0.305
q35	Migraines	0.198	0.115	**−0.851**	0.187	−0.157	0.125	0.217	0.193
q28	Heaviness in the head	0.436	0.195	**−0.803**	0.301	−0.339	0.196	0.208	0.356
q46	Sharp pain in the head	0.209	0.290	**−0.790**	0.314	−0.254	0.183	0.263	0.303
q22	Eye problems	0.365	0.227	**−0.442**	0.364	−0.348	0.307	0.222	0.189
q15	Digestive problems	0.351	0.217	**−0.406**	0.374	−0.087	0.277	0.394	0.327
q43	Pressure in the ear	0.198	0.272	−0.323	**0.716**	−0.251	0.122	0.308	0.305
q39	Pain in the ear	0.174	0.190	−0.324	**0.713**	−0.153	0.181	0.356	0.320
q44	Ringing in the ear	0.266	0.181	−.0284	**0.648**	−0.230	0.217	0.163	0.340
q38	Nausea	0.331	0.196	−0.420	**0.561**	−0.182	0.327	0.355	0.382
q23	Facial prickling	0.146	0.401	−0.291	**0.559**	−0.141	0.130	0.378	0.229
q57	Warmth in the ear	0.143	0.365	−0.094	**0.533**	−0.221	−0.079	0.177	0.278
q33	Loss of appetite	0.390	0.078	−0.365	**0.437**	−0.065	0.209	0.414	0.267
q42	Pain/Warmth in the head	0.264	0.259	−0.257	**0.436**	−0.275	0.225	0.205	0.370
q36	Muscle tension	0.235	0.212	−0.291	0.278	**−0.661**	0.178	0.330	0.168
q37	Muscle weakness	0.270	0.190	−0.225	0.477	**−0.591**	0.153	0.335	0.268
q40	Pain in joints	0.210	0.192	−0.341	0.461	**−0.587**	0.327	0.293	0.233
q50	Numbness	0.255	0.339	−0.238	0.421	**−0.568**	0.125	0.253	0.285
q47	Sickness	0.401	0.330	−0.359	0.332	**−0.558**	0.236	0.268	0.373
q4	Back pain	0.344	0.208	−0.332	0.198	**−0.550**	0.338	0.095	0.356
q7	Blurry vision	0.351	0.090	−0.311	0.229	**−0.460**	0.295	0.211	0.358
q29	High blood pressure	0.097	0.099	−0.151	−0.041	**−0.387**	0.052	0.235	0.310

(*Continued*)

TABLE 2. ***(Continued)***

	Principal components	1	2	3	4	5	6	7	8
q1	Allergies	0.226	0.265	−0.173	0.155	−0.056	**0.707**	0.105	0.075
q45	Runny or stuffy nose	0.264	0.208	−0.248	0.278	−0.142	**0.612**	0.333	0.073
q19	Dry skin	0.313	0.455	−0.305	0.211	−0.167	**0.546**	0.142	0.177
q3	Asthma	0.054	0.063	−0.037	−0.046	−0.130	**0.525**	0.106	0.197
q18	Dry cough	0.164	0.089	−0.231	0.199	−0.252	**0.497**	0.320	0.320
q5	Bad taste in the mouth	0.305	0.208	−0.287	0.208	−0.346	**0.418**	0.388	0.397
q31	Impaired sense of smell	0.105	0.153	−0.134	0.179	−0.132	0.193	**0.789**	0.173
q32	Impaired sense of taste	0.135	0.195	−0.193	0.203	−0.241	0.135	**0.770**	0.184
q30	Hoarse dry throat	0.333	0.177	−0.244	0.314	−0.339	0.394	**0.462**	0.309
q16	Disorientation	0.223	0.127	−0.080	0.013	−0.086	−0.024	**0.450**	0.431
q9	Cardiac(Heart) pains	0.178	0.161	−0.268	0.268	−0.168	0.124	0.231	**0.824**
q10	Chest pains	0.254	0.228	−0.318	0.312	−0.279	0.226	0.298	**0.782**
q8	Breathing difficulties	0.318	0.214	−0.260	0.360	−0.383	0.374	0.292	**0.644**
q27	Heart palpitations	0.232	0.225	−0.358	0.367	−0.448	0.225	0.240	**0.620**
q17	Dizziness	0.353	0.151	−0.450	0.451	−0.180	0.273	0.086	**0.490**
q11	Cold sweat	0.385	0.265	−0.194	0.299	−0.056	0.229	0.268	**0.473**

Fifty-seven symptoms in control group ($n = 1{,}306$) were analyzed by forced eight-factor principal component analysis with oblimin rotation and Kaiser's normalization as described by Eltiti et al. [2007].

the variance; and (5) the same analysis was used in the study by Eltiti et al. [2007]. Table 2 illustrates eight categories that were revealed following further inspection of items within each component: nervous (10 items), skin-related (8 items), head-related (7 items), auditory and vestibular (8 items), musculoskeletal (8 items), allergy-related (6 items), sensory (4 items), and heart/chest-related (6 items). Factor loadings resulted in a high value of over 0.4 (0.406–0.881) with the exception of two symptoms, blisters on the skin (0.379) and high blood pressure (0.387). An eight-factor principal component analysis was implemented in 246 people who presented with "q67 $\geq$ 1 point" in the general population (EHS group), in the same way as reported by Eltiti et al. [2007]. Finally, eight-factor principal component analysis was attempted in 127 self-selected EHS subjects. As a result, principal components were almost consistent with those of the entire general population (Table 3).

Reliability

The test–retest method revealed significant correlations for ICCs of all 5-point scale questions and total scores of each subscale (Table 4). A high to moderate value of over 0.6 (0.623–0.863) was noted with the exception of component 4, q64, q65, and q71 (Table 4). In addition, κ coefficients of q68 and q69 were 0.442 and 0.484, respectively. Although significant, reproducibility of these values was not high. Taken together, these findings indicate high reliability of the Japanese EHS questionnaire. High Cronbach's a coefficients (0.853–0.953) from all subscales, with the exception of "Reaction to EMFs (0.528)," indicated good internal consistency for each question (Table 5).

Total Symptom Score and Eight Symptoms Component

Total symptom scores for self-selected EHS subjects were widely distributed, as seen in Figure 1a. The 25th, 50th, and 75th percentiles for total symptom scores in controls were 16, 29, and 47 points, respectively. The median score of self-selected EHS subjects was significantly higher than that of controls ($P < 0.0005$), as shown in Figure 1b. An outlier is defined as a point that exceeds 1.5 times the interquartile range from the 75th percentile line, and it should be noted that there were 48 (3.7%) outliers for the controls. With regard to the median score of eight principal components, shapes of the radar chart in both groups were quite similar (Fig. 1c). The median score of each component for self-selected EHS subjects was significantly higher ($P < 0.0005$) than that of controls.

TABLE 3. Factor Loadings for Controls, EHS Group[a] and Self-Selected EHS Subjects in a Forced Eight-Factor Principal Component Analysis

		Group		
Symptom		Controls ($n = 1306$)	EHS group[a] ($n = 246$)	Self-selected EHS subjects ($n = 127$)
Nervous				
q12	Depression	0.811	0.792	0.736
q13	Difficulty in concentrating	0.806	0.656	0.790
q14	Difficulty in focusing attention	0.767	0.639	0.755
q24	Fatigue	0.752	0.786	0.584
q55	Stress	0.721	0.776	0.651
q25	Foggy thinking	0.702	0.560	0.770
q21	Exhaustion	0.669	0.677	0.521
q2	Anxiety	0.633	0.678	0.699
q34	Memory difficulties	0.472	0.489	−0.607
q54	Sleep disturbances	0.439	0.486	0.657
Skin-related				
q49	Skin irritation	0.757	0.742	0.678
q52	Skin redness	0.741	0.695	0.631
q53	Skin swelling	0.720	0.722	0.705
q56	Tingling sensations	0.689	0.698	0.772
q41	Pain/soreness of the skin	0.611	0.603	0.700
q48	Skin burning sensations	0.548	0.744	−0.533
q51	Skin rash	0.427	0.462	0.457
q6	Blisters on the skin	0.397	0.516	0.350
Head-related				
q26	Headache	−0.881	−0.831	0.827
q20	Dull headache	−0.871	−0.779	0.794
q35	Migraines	−0.851	−0.807	0.751
q28	Heaviness in the head	−0.803	−0.672	0.803
q46	Sharp pain in the head	−0.790	−0.728	0.689
q22	Eye problems	−0.442	0.509	0.554
q15	Digestive problems	−0.406	−0.551	0.603
Auditory vestibular				
q43	Pressure in the ear	0.716	0.795	−0.724
q39	Pain in the ear	0.713	0.738	−0.707
q44	Ringing in the ear	0.648	0.583	−0.497
q38	Nausea	0.561	0.591	0.574
q23	Facial prickling	0.559	0.570	0.672
q57	Warmth in the ear	0.533	0.625	0.455
q33	Loss of appetite	0.437	−0.432	0.720
q42	Pain/warmth in the head	0.436	0.507	0.531
Musculo/Skeletal				
q36	Muscle tension	−0.661	0.598	0.748
q37	Muscle weakness	−0.591	0.671	0.661
q40	Pain in the joints	−0.587	0.625	0.688
q50	Numbness	−0.568	0.529	−0.650
q47	Sick feeling	−0.558	0.497	0.572
q4	Back pain	−0.550	0.458	0.666
q7	Blurry vision	−0.460	0.577	−0.624
q29	High blood pressure	−0.387	0.329	0.751
Allergy-related				
q1	Allergies	0.707	0.694	0.498
q45	Runny or stuffy nose	0.612	0.544	0.543
q19	Dry skin	0.546	0.689	0.568

(*Continued*)

TABLE 3. (*Continued*)

Symptom		Group		
		Controls ($n = 1306$)	EHS group[a] ($n = 246$)	Self-selected EHS subjects ($n = 127$)
q3	Asthma	0.525	0.531	0.714
q18	Dry cough	0.497	0.485	0.655
q5	Bad taste in the mouth	0.418	0.502	0.568
Sensory				
q31	Impaired sense of smell	0.789	0.760	0.675
q32	Impaired sense of taste	0.770	0.734	0.461
q30	Hoarse dry throat	0.462	0.516	0.581
q16	Disorientation	0.450	0.493	−0.753
Heart/Chest-related				
q9	Cardiac/heart pains	0.824	0.812	0.684
q10	Chest pains	0.782	0.816	0.654
q8	Breathing difficulties	0.644	0.516	0.700
q27	Heart palpitations	0.620	0.568	0.542
q17	Dizziness	0.490	0.553	0.589
q11	Cold sweat	0.473	0.445	0.510

[a]EHS group Controls who had a score higher than 1 point for q67 ("Are you sensitive to electromagnetic fields, e.g., radio frequencies and magnetic fields produced by electrical objects such as televisions, computers, and mobile phones?").

Validity

Firstly, validity was evaluated in the same way as reported by Eltiti et al. [2007], that is, by comparing EHS responses of self-selected EHS subjects with those of the control group; the Mann–Whitney *U*-test with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$) was used, revealing significant differences between both groups (Table 6). Furthermore, the χ^2 test revealed that a significantly higher ($P < 0.0005$) proportion of self-selected EHS subjects (87.4%) had identified EMF-producing object(s) and described, in detail, specific symptoms they believed were caused by the object(s) (q68, $\chi^2 = 150.20$, $P < 0.0005$) when compared with controls (12.6%). A significantly higher number of self-selected EHS subjects (66.4%) experienced severe electric shock (q69, $\chi^2 = 10.0$, $P = 0.003$) when compared with controls (49.6%). In summary, Mann–Whitney *U*- and χ^2 tests revealed that when compared with age- and sex-matched controls, self-selected EHS subjects described a greater severity of symptoms, poorer levels of general health and well-being, and the belief that their symptoms were caused by exposure to objects that emitted EMFs.

Furthermore, in the present study, logistic regression analysis was also performed to compare the discriminatory power of each question in the Japanese EHS questionnaire (Table 7). Results of the logistic regression analysis revealed that the odds ratio (OR; 0.85) for mean working hours per day was significantly lower in self-selected EHS subjects than in controls (I. Biographical Information). Furthermore, ORs for total symptoms score and for each of the eight principal components (components 1–8; 1.05–1.60) were significantly higher (II–1. Symptoms). Similarly, ORs for total score (1.22) and for each of the nine EMF-producing objects (2.61–4.29), especially electrical appliances (q59, 4.29), telecommunication masts (q65, 3.87), and fluorescent lighting (q60, 3.60), were also very high (II–2. EMF-producing Objects). The ORs for all questions, particularly q68 (90.96) and q67 (9.96), were very high (II–3. Reactions to EMFs), whereas ORs for well-being (0.59), good health (0.34), and sleep (0.53) were significantly lower (III. General Health). The OR for average sleeping hours per day was 1.22, indicating that self-selected EHS subjects slept longer than controls. However, the OR for sleep disorders was 2.22, implying that self-selected EHS subjects experienced more sleep disorders than controls. Furthermore, the OR for the total score of THI-D was 1.21, suggestive of an increased tendency for depression amongst self-selected EHS subjects when compared with controls.

Multiple Logistic Regression and ROC Analyses

Multiple logistic regression and ROC analyses were performed in self-selected EHS subjects, and in sex- and age-matched control groups to narrow down items that can aid in discrimination of EHS

TABLE 4. Intraclass Correlation Coefficients of Test–Retest Data

Subscales	Questionnaire items	Intraclass correlation coefficient (ICC)	*P*-value
II-1 Symptoms	Component 1_Nervous score (10 items)	0.791	<0.0001
	Component 2_Skin-related score (8 items)	0.863	<0.0001
	Component 3_Head-related score (7 items)	0.705	<0.0001
	Component 4_ Auditory vestibular score (8 items)	0.585	<0.0001
	Component 5_Musculoskeletal score (8 items)	0.716	<0.0001
	Component 6_Allergy-related score (6 items)	0.815	<0.0001
	Component 7_Sensory score (4 items)	0.641	<0.0001
	Component 8_ Heart/chest-related score (6 items)	0.708	<0.0001
	Total score of Symptoms (57 items)	0.773	<0.0001
II-2 EMF-producing objects	q58_Computers	0.573	<0.0001
	q59_Electric appliances	0.623	<0.0001
	q60_Fluorescent lighting	0.789	<0.0001
	q61_Microwave ovens	0.816	<0.0001
	q62_Mobile phones	0.645	<0.0001
	q63_Power lines	0.658	<0.0001
	q64_Radio/Television transmitters	0.389	0.0012
	q65_Telecommunication masts	0.421	0.0003
	q66_Televisions	0.620	<0.0001
	Total score of EMF-producing objects (9 items)	0.709	<0.0001
II-3 Reaction to EMFs	q67_Sensitive to EMFs	0.656	<0.0001
	q70_ Occurrences of static electric shock	0.719	<0.0001
	q71_Negative health change around EMFs	0.417	0.0003
	Total score of Reaction to EMFs (5 items)[a]	0.655	<0.0001
III General health	1_ Well-being	0.829	<0.0001
	2_ Good health	0.670	<0.0001
	3_1 Sleep	0.703	<0.0001
	3_2 Sleeping hours per day	0.746	<0.0001
	3_3 Sleep disorder	0.715	<0.0001
IV-1 THI-D	Total score of THI-D (10 items)	0.783	<0.0001

Test–retest reliability was estimated by calculating intraclass correlation coefficients (ICC); significance of ICC was determined using an *F*-test. A total of 173 people from the general population participated in this study (see text).
EMF, electromagnetic field; THI-D, todai health index-depression scale.
[a]Total score of reaction to EMF score: calculated by adding scores of q67–q71.

TABLE 5. Cronbach's α Coefficient from Each Subclass in Controls and Self-Selected EHS Subjects

	Cronbach's alpha coefficient	
Questionnaire items	Controls ($n = 1306$)	Self-selected EHS subjects ($n = 127$)
II-1 Symptoms (57 items)	0.953	0.968
Eight factor principal components (8 items)	0.872	0.921
Component 1 (Nervous; 10 items)	0.905	0.928
Component 2 (Skin-related; 8 items)	0.794	0.865
Component 3 (Head-related; 7 items)	0.873	0.904
Component 4 (Auditory vestibular; 8 items)	0.780	0.832
Component 5 (Musculo-skeletal; 8 items)	0.785	0.837
Component 6 (Allergy-related; 6 items)	0.678	0.657
Component 7 (Sensory; 4 items)	0.574	0.616
Component 8 (Heart/chest-related; 6 items)	0.797	0.837
II-2 EMF-producing objects (9 items)	0.900	0.953
II-3 Reaction to EMFs (5 items)	0.500	0.582
IV-1 THI-D (10 items)	0.893	0.912

EMF, electromagnetic field; THI-D, todai health index-depression scale.

TABLE 6. Answer Distribution for Reactions to Nine EMF-Producing Objects in Self-Selected EHS Subjects and in Age- and Sex-Matched Controls

Objects	Not at all *n* (%)	A little bit *n* (%)	Moderately *n* (%)	Quite a bit *n* (%)	A great deal *n* (%)	Z^a *P*-value
q58_Computers						
Controls	82 (65.1)	24 (19.0)	13 (10.3)	3 (2.4)	4 (3.2)	−9.23
Self-selected EHS subjects	16 (14.4)	14 (12.6)	27 (24.3)	18 (16.2)	36 (32.4)	$2.72 \times 10^{-20*}$
q59_Electrical appliances						
Controls	98 (79.7)	16 (13.0)	5 (4.1)	3 (2.4)	1 (0.8)	−10.724
Self-selected EHS subjects	13 (12.4)	19 (18.1)	20 (19.1)	18 (17.1)	35 (33.3)	$7.85 \times 10^{-27*}$
q60_Fluorescent lighting						
Controls	110 (88.7)	8 (6.5)	3 (2.4)	2 (1.6)	1 (0.8)	−9.772
Self-selected EHS subjects	33 (28.5)	14 (12.1)	15 (12.9)	21 (18.1)	33 (28.4)	$1.49 \times 10^{-22*}$
q61_Microwave ovens						
Controls	108 (86.4)	9 (7.2)	4 (3.2)	2 (1.6)	2 (1.6)	−9.005
Self-selected EHS subjects	31 (31.0)	9 (9.0)	8 (8.0)	16 (16.0)	36 (36.0)	$2.16 \times 10^{-19*}$
q62_Mobile phones						
Controls	95 (75.4)	14 (11.1)	9 (7.1)	5 (4.0)	3 (2.4)	−10.38
Self-selected EHS subjects	16 (14.3)	12 (10.7)	14 (12.5)	16 (14.3)	54 (48.2)	$3.06 \times 10^{-25*}$
q63_Power lines						
Controls	105 (85.4)	7 (5.7)	7 (5.7)	1 (0.8)	3 (2.4)	−8.499
Self-selected EHS subjects	31 (32.0)	10 (10.3)	9 (9.3)	14 (14.4)	33 (34.0)	$1.92 \times 10^{-17*}$
q64_Radio/Television transmitters						
Controls	108 (87.8)	8 (6.5)	5 (4.1)	1 (0.8)	1 (0.8)	−8.045
Self-selected EHS subjects	31 (37.8)	6 (7.3)	9 (11.0)	9 (11.0)	27 (32.9)	$8.64 \times 10^{-16*}$
q65_Telecommunication masts						
Controls	108 (87.8)	4 (3.3)	8 (6.5)	2 (1.6)	1 (0.8)	−11.288
Self-selected EHS subjects	15 (14.7)	10 (9.8)	12 (11.8)	12 (11.8)	53 (52.0)	$1.51 \times 10^{-29*}$
q66_Televisions						
Controls	95 (74.8)	20 (15.7)	8 (6.3)	3 (2.4)	1 (0.8)	−8.493
Self-selected EHS subjects	27 (23.9)	27 (23.9)	20 (17.7)	16 (14.2)	23 (20.4)	$2.02 \times 10^{-17*}$
Total score of EMF-producing objects	0	1–9	10–18	19–27	28–36	*Z P*-value
Controls	72 (56.7)	42 (33.1)	9 (7.1)	3 (2.4)	1 (0.8)	−10.783
Self-selected EHS subjects	8 (6.3)	29 (22.8)	27 (21.3)	39 (30.7)	24 (18.9)	$4.16 \times 10^{-27*}$
q67[b]_Sensitive to EMFs						
Controls	106 (86.2)	14 (11.4)	3 (2.4)	0 (0.0)	0 (0.0)	−12.58
Self-selected EHS subjects	11 (9.0)	19 (15.6)	17 (13.9)	14 (11.5)	61 (50.0)	$2.71 \times 10^{-36*}$
q70[c]_Occurrences of static electric shock						
Controls	32 (25.2)	51 (40.2)	17 (13.4)	16 (12.6)	11 (8.7)	−3.445
Self-selected EHS subjects	12 (9.7)	48 (38.7)	24 (19.4)	17 (13.7)	23 (18.5)	5.71×10^{-4} n.s.

Note: Differences in scores between groups were analyzed using a Mann–Whitney *U*-test with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$).

EMF electromagnetic field; n.s: not significant.

[a]Z: Mann–Whitney *U*-test; α level: 0.0005.

[b]q67: "Are you sensitive to electromagnetic fields (e.g., radio frequency and magnetic fields produced by electrical objects such as television, computers, and mobile phones)?"

[c]q70: "How frequently do you experience static shocks (e.g., from metals and car doors)?"

$^*P \leq 0.00005$.

individuals from the general population during screening. Multiple logistic regression analysis revealed the following three items: "Total symptom score;" "q67, Sensitive to EMFs;" and "q68, Detailed description" (Table 8). The area under the ROC curve for predicted values was high (0.976). Sensitivity and specificity of predicted values using the three items were 94.3% and 94.3%, respectively, higher than analysis results obtained from individual items (Table 9). Based on these findings, we suggested the following preliminary screening criteria for EHS individuals from the general population: (1) the total symptom score should be greater than or equal to 47 points (the 75th percentile of the controls, Fig. 1a); (2) the score for q67 ("Are you sensitive to electromagnetic fields?") should be greater than or equal to 1; and (3) individuals should be able to describe, in detail, the EMF source and the kind of symptoms developed in response to q68. A total of 82 (64.6%) self-selected EHS subjects and 60 (4.59%) controls met the set

TABLE 7. Estimates of the Relative Risks of EHS for Each Potential Predictor Tested Separately in the Japanese EHS Questionnaire

	Questionnaire items	Odds ratio	95%CI (min–max)	*P*-value
I Biographical	Final academic background	1.63	(1.08–2.46)	0.021
	Mean working hours per day[a]	0.85	(0.79–0.93)	1.27×10^{-4}
II-1 Symptoms	Component 1_Nervous score (10 items)	1.15	(1.11–1.19)	2.83×10^{-12}
	Component 2_Skin-related score (8 items)	1.26	(1.17–1.35)	4.37×10^{-10}
	Component 3_Head-related score (7 items)	1.18	(1.12–1.24)	7.25×10^{-11}
	Component 4_Auditory vestibular score (8 items)	1.44	(1.30–1.59)	1.87×10^{-12}
	Component 5_Musculoskeletal score (8 items)	1.21	(1.14–1.28)	3.85×10^{-11}
	Component 6_Allergy-related score (6 items)	1.28	(1.19–1.38)	4.12×10^{-10}
	Component 7_Sensory score (4 items)	1.60	(1.35–1.90)	6.33×10^{-8}
	Component 8_ Heart/chest-related score (6 items)	1.47	(1.33–1.64)	8.78×10^{-13}
	Total score of Symptoms (57 items)	1.05	(1.03–1.06)	6.78×10^{-14}
II-2 EMF[c]-producing objects	q58_Computers	2.85	(2.20–3.71)	4.77×10^{-15}
	q59_Electrical appliances	4.29	(2.97–6.19)	8.33×10^{-15}
	q60_Fluorescent lighting	3.60	(2.52–5.14)	2.03×10^{-12}
	q61_Microwave ovens	2.87	(2.15–3.83)	9.45×10^{-13}
	q62_Mobile phones	2.98	(2.32–3.83)	1.48×10^{-17}
	q63_Power lines	2.61	(1.99–3.42)	3.74×10^{-12}
	q64_Radio/Television transmitters	2.92	(2.10–4.05)	1.75×10^{-10}
	q65_Telecommunication masts	3.87	(2.79–5.38)	5.94×10^{-16}
	q66_Televisions	2.95	(2.17–4.00)	4.94×10^{-12}
	Total score of EMF-producing objects (9 items)	1.22	(1.16–1.28)	6.90×10^{-15}
II-3 Reactions to EMFs	q67_Sensitive to EMFs	9.66	(5.16–18.09)	1.40×10^{-12}
	q68_Detailed description	90.96	(38.61–214.26)	5.85×10^{-25}
	q69_Experience a severe electric shock	2.40	(1.44–4.01)	8.19×10^{-4}
	q70_Occurrences of static electric shock	1.40	(1.14–1.71)	0.001
	Total score of Reactions to EMFs (4 items)	2.20	(1.80–2.68)	7.56×10^{-15}
III General health	1_ Well-being	0.59	(0.45–0.78)	2.05×10^{-4}
	2_ Good health	0.34	(0.24–0.48)	3.74×10^{-10}
	3_1 Sleep	0.53	(0.40–0.70)	9.44×10^{-6}
	3_2 Sleeping hours per a day	1.22	(0.99–1.50)	0.058
	3_3 Sleep disorder	2.22	(1.73–2.84)	3.37×10^{-10}
	4_ Chronic illnesses	1.83	(1.10–3.02)	0.019
IV-1 THI-D	Total score of THI-D (10 items)	1.21	(1.14–1.28)	2.20×10^{-11}

Note: Differences in scores between groups were analyzed using bivariate logistic regression analysis with Bonferroni correction for multiple tests (100 tests; $P < 0.0005$).
CI, confidence interval; EMF, electromagnetic field; THI-D, todai health index-depression scale.
[a]Mean working hours per day: including housework and school hours.

TABLE 8. Discrimination Power of EHS Scales When Used Alone (Univariate) or When Combined in a Multiple Logistic Regression Model

Scale	*P*-value	Odds ratios (95%CI) for one point increase	Area under ROC curve
Individual scale			
Total symptom score	1.77×10^{-4}	1.044 (1.021–1.067)	0.851 (0.803–0.900)
q67_Sensitive to EMFs	3.73×10^{-4}	3.119 (1.667–5.835)	0.934 (0.901–0.968)
q68_Detailed description	7.18×10^{-6}	21.252 (5.594–80.737)	0.906 (0.864–0.948)
Multiple scales[a]			
Total symptom score	1.17×10^{-4}	1.041 (1.020–1.063)	
q67_Sensitive to EMFs[d]	1.41×10^{-5}	3.503 (1.989–6.169)	0.976 (0.959–0.994)
q68_Detailed description	2.64×10^{-7}	22.755 (6.924–74.784)	

Note: Significant differences in scores between groups were evaluated by setting an α value of 0.0005 in consideration of multiplicity, according to a Bonferroni correction.
CI, confidence interval; ROC, receiver operating characteristic; EMFs, electromagnetic fields.
[a]Multiple scales: each of three items listed below is a factor in one multiple logistic prediction (see text).

TABLE 9. Sensitivity and Specificity Resulting From the Application of High Cut-Off Points for Total Symptoms, q67 and q68 scales, and for All Three Scales Taken Together

Scale	Sensitivity (%)	Specificity (%)
Individual scale		
Total symptom cut-off		
45	73.8	79.7
47[a]	**73.8**	**81.3**
48	72.1	81.3
q67_Sensitive to EMFs cut-off		
1	**91.0**	**86.2**
2	75.4	97.6
3	61.5	100.0
q68_Detailed description cut-off		
1	**88.5**	**92.7**
Multiple scale scores[b]		
Total symptom score q67_Sensitive to EMFs q68_Detailed description	**94.3**	**94.3**

Note: Significant differences in scores between groups were evaluated by setting an α value of 0.0005 in consideration of multiplicity according to a Bonferroni correction.
[a]47: The 75th percentile of controls.
[b]Multiple scale scores: Each of three items listed is a factor in one multiple logistic prediction (see text).

screening criteria for EHS. Significant differences in resident areas, final academic background, and occupation were not noted between individual characteristics of these 60 controls and those of the remaining 1,246 control subjects (Table 1). However, the number of females was significantly higher among the 60 controls who met the set screening criteria ($P < 0.0005$) when compared to others (Table 1).

EMF Objects That Self-Selected EHS Subjects Believed Were the Cause of Their Symptoms

Almost none of the controls responded to q68 ("Provide a detailed description of EMF-producing objects and the specific symptoms caused by these."), whereas 111 (87.4%) of the 127 self-selected EHS subjects responded to the same question in detail. Thus, we analyzed contents described by the 111 subjects in response to q68.

A summary of nine EMF-producing objects (q58–66), which Japanese self-selected EHS subjects believed were the cause of their symptoms, is presented in Figure 2a. Furthermore, details of electrical appliances listed in this study are presented in Figure 2b.

The following three additional types of EMF-producing objects, other than the nine (q58-q66) included in the questionnaire, were also reported to

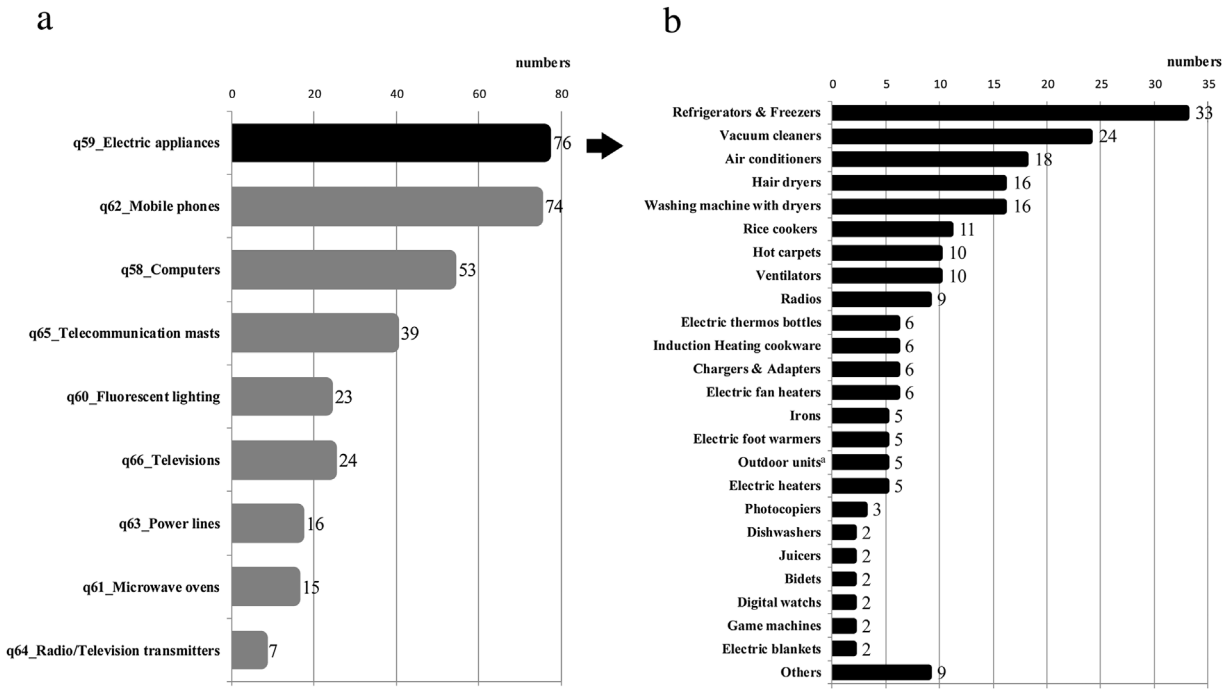

Figure 2. EMF sources. **2a**. Electromagnetic field objects that Japanese self-selected EHS subjects ($n = 165$) believed as cause of symptoms (multiple answers). **2b**. Details of electrical appliances from Fig. 2a. Outdoor units[a] included air conditioner compressors and heat pump-type water heater systems, among others (multiple answers).

cause symptoms in Japanese self-selected EHS subjects: vehicles (75 respondents, 63.6%) including cars and buses (28.8%), trains (21.2%), Shinkansen high speed bullet trains (3.4%), and subways (3.4%); telecommunications equipment other than mobile phones (61 respondents, 53.4%) including wireless LANs (22.9%), landline phones (15.3%), security sensors (12.7%), and equipment using Wi-Fi (7.6%); and medical equipment (nine respondents, 7.6%) including magnetic resonance imaging (MRI; 2.5%), medical measuring instruments emitting low-frequency EMFs (1.7%), X-ray (0.8%), dental equipment (0.8%), and apparatus measuring bone density (0.8%).

Physician-Diagnosed Chronic Illness (Past and Present)

Results from 116 of the 127 self-selected EHS subjects and 681 of the 1,306 subjects among the controls, who agreed to provide valid responses for a list of "physician-diagnosed chronic illnesses," are shown in Table 10. At the time of answering, none of the controls were undergoing treatment for environmental hypersensitivity (SHS, MSC, and EHS) as depicted in Table 10. However, in 46 (39.66%) of the 116 self-selected EHS subjects, their symptoms had been diagnosed as EHS, which was further complicated by MCS. A χ^2 test revealed that proportions of participants who claimed to be undergoing treatment for chronic illnesses entitled "Autonomic imbalance" and "Other allergy symptoms" at the time of the survey were highly significant among the self-selected EHS subjects compared with controls (Table 10).

It is notable that the proportion of self-selected EHS subjects who suffered from several allergy symptoms (64.66%) in the past was significantly higher ($P < 0.00001$) than corresponding proportion of controls (41.85%), as seen in Table 10. The proportion of patients whose symptoms were diagnosed as autonomic imbalance, allergy nasal catarrh, allergy conjunctivitis, rash, hay fever, food allergies, and other allergy symptoms in the past was also significantly higher in self-selected EHS subjects than in controls. However, there was no significant difference in the proportion of patients diagnosed with diabetes mellitus, high blood pressure, heart disease, migraine, atopic dermatitis, and bronchial asthma between the two groups (Table 10).

Sequence of EHS Development Estimated by Self-Selected EHS Subjects

A summary of the estimated progression of symptoms by self-selected EHS subjects is shown in Figure 3. Our study revealed that EHS was present in only 18.52% of self-selected EHS subjects, with a majority (81.52%) of self-selected EHS subjects having presented with both MCS and EHS symptoms. In half of such self-selected EHS subjects SHS or MCS symptoms occurred before EHS symptoms, whereas a relatively small proportion of self-selected EHS subjects (14.81%) presented with EHS symptoms were subsequently followed by MCS symptoms.

Responses to Open Question of How the Individual Has Been Suffering From EHS Syndrome

Most self-selected EHS subjects described their symptoms in detail. Furthermore, many of them expressed facing financial difficulties following resignations due to sickness, and their concern regarding a lack of understanding about EHS by general physicians and the public. Firstly, self-selected EHS subjects stated there were few physicians who had profound knowledge of both MCS and EHS. Secondly, they claimed that they were treated for diseases with various names based on their symptoms but to no avail; moreover, they were even forced to change hospitals several times. Thirdly, their symptoms were diagnosed as mental disorders, resulting in strained family relationships.

DISCUSSION

The reliability of the Japanese EHS questionnaire was confirmed by high to moderate ICC values (0.623–0.863) obtained for all 5-point scale questions and total scores of each subscale, with the exception of four items (component 4, q64, q65, and q71) in the test–retest analysis (Table 4). In addition, high Cronbach's α coefficients (0.853–0.953) from all subscales, with the exception of "Reaction to EMFs (0.528)," indicated good internal consistency for each question (Table 5).

The validity of the Japanese EHS Questionnaire was confirmed by observing significant differences ($P < 0.0005$) in all scorers, with the exception of two items (q69 and q70) between self-selected EHS subjects, and age- and sex-matched controls, using simple logistic regression analysis (Table 7). ORs for q68 (90.96) and q67 (9.66) were extremely high, indicating the high discriminatory power of these two questions in the screening of EHS individuals from the general public. Similarly, the OR of the total symptom score, which was used as the main criterion, was also found to be significantly high (OR; 1.05, $P = 6.78 \times 10^{-4}$). In addition, significantly high ORs were observed for all nine EMF-producing objects, especially electrical appliances (OR: 4.29), telecommunication masts (OR: 3.87), and fluorescent lighting (OR: 3.60), and for the total score for EMF-producing objects in this study (OR: 2.61–4.29). Thus, these

TABLE 10. Comparison of the Prevalence of Chronic Illnesses Between Controls and Self-Selected EHS Subjects

	Chronic illnesses at present				Chronic illnesses in the past			
	Controls ($n = 681$)	Self-selected EHS subjects ($n = 116$)	χ^2 test		Controls ($n = 681$)	Self-selected EHS subjects ($n = 116$)	χ^2 test	
Chronic illness	n (%)	n (%)	P-value		n (%)	n (%)	P value	
Diabetes mellitus	7 (1.03)	1 (0.86)	0.868	n.s.	11 (1.62)	2 (1.72)	0.932	n.s.
High blood pressure	49 (7.20)	5 (4.31)	0.253	n.s.	37 (5.43)	7 (6.03)	0.793	n.s.
Heart diseases	10 (1.47)	2 (1.72)	0.834	n.s.	9 (1.32)	6 (5.17)	0.005	n.s.
Autonomic imbalance	5 (0.73)	6 (5.17)	1.52×10^{-4}	**	23 (3.38)	20 (17.24)	1.00×10^{-9}	***
Migraines	8 (1.17)	2 (1.72)	0.623	n.s.	33 (4.85)	9 (7.76)	0.194	n.s.
Allergy symptoms[a]	84 (12.33)	16 (13.79)	0.661	n.s.	285 (41.85)	75 (64.66)	5.06×10^{-6}	***
Atopic dermatitis	11 (1.62)	3 (2.59)	0.462	n.s.	60 (8.81)	16 (13.79)	0.091	n.s.
Bronchial asthma	9 (1.32)	4 (3.45)	0.095	n.s.	52 (7.64)	15 (12.93)	0.057	n.s.
Allergic nasal catarrh	31 (4.55)	2 (1.72)	0.158	n.s.	109 (16.01)	36 (31.03)	1.05×10^{-4}	**
Allergic conjunctivitis	12 (1.76)	2 (1.72)	0.977	n.s.	59 (8.66)	28 (24.14)	7.80×10^{-7}	***
Rash	8 (1.17)	0 (0.00)	0.241	n.s.	69 (10.13)	25 (21.55)	4.24×10^{-4}	***
Hey fever	44 (6.46)	4 (3.45)	0.207	n.s.	123 (18.06)	39 (33.62)	1.19×10^{-4}	***
Food allergies	5 (0.73)	5 (4.31)	0.001	n.s.	46 (6.75)	24 (20.69)	9.52×10^{-7}	***
Other allergy symptom[b]	0 (0.00)	2 (1.72)	6.02×10^{-4}	*	33 (4.85)	9 (7.76)	0.194	n.s.
Sick house syndrome	0 (0.00)	4 (3.45)	1.19×10^{-6}	***	8 (1.17)	23 (19.83)	7.64×10^{-22}	***
Multiple chemical sensitivity	0 (0.00)	46 (39.66)	2.75×10^{-64}	***	7 (1.03)	19 (16.38)	7.74×10^{-18}	***
Electromagnetic hypersensitivity	0 (0.00)	46 (39.66)	2.75×10^{-64}	***	1 (0.15)	19 (16.38)	5.04×10^{-25}	***
Others	7 (1.03)	9 (7.76)	1.77×10^{-6}	***	42 (6.17)	41 (35.34)	1.90×10^{-21}	***

Note: Differences in prevalence of chronic illnesses between self-selected EHS subjects ($n = 116$) and controls ($n = 681$) were analyzed using χ^2 test with Bonferroni correction for multiple tests (40 tests; $P < 0.000125$). n.s.: not significant.

[a]Allergy symptoms: percentage for "Allergy symptoms" does not represent the sum of percentages from "Atopic dermatitis" to "Other allergy symptoms" because some participants described more than one allergy symptom.

[b]Other allergy symptoms: allergy diseases other than those described above.

*$P \leq 0.0005$.

**$P \leq 0.0001$.

***$P \leq 0.00001$.

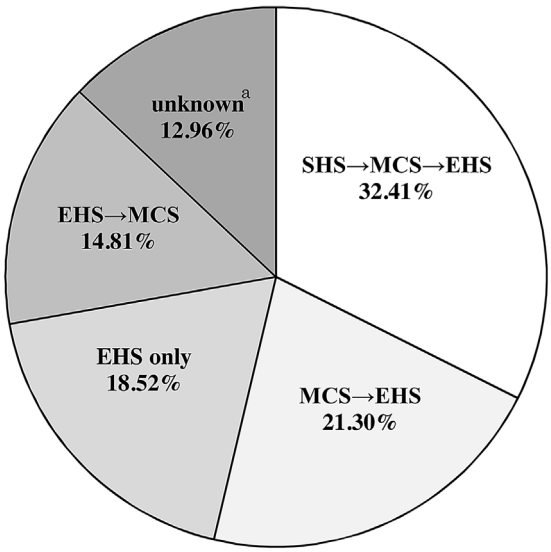

Figure 3. Speculated sequence of onset of SHS, MCS, and EHS by Japanese self-selected EHS subjects. SHS: sick house syndrome; MCS: multiple chemical sensitivity; EHS: electromagnetic hypersensitivity. [a]Both MCS and EHS were associated; however, it is unknown which occurred first.

three items may be considered to be the primary EMF-producing objects believed by self-selected EHS subjects in Japan to be the cause of symptom onset; further studies exploring this are warranted.

Results of Mann–Whitney *U*- and χ^2 tests also indicated that, compared to controls, self-selected EHS subjects reported a greater severity of symptoms, poorer levels of general health and well-being, and a belief that their symptoms were due to exposure to objects that emit EMFs (Table 6). These results were consistent with those reported by Eltiti et al. [2007], who used the same tests (Mann–Whitney *U*- and χ^2 tests) in their UK-based study. The extreme statistical significances shown in Table 6 arose from the selection process: the EHS subjects already shared these beliefs, while the controls did not even understand the questions.

Characteristics of Symptoms in Japanese Self-Selected EHS Subjects

Principal component analysis of 57 symptoms in controls ($n = 1{,}306$) revealed the following eight main symptom subscales: nervous system, skin, head, auditory and vestibular, musculoskeletal system, allergy, sensory system, and heart/chest (Tables 2 and 3). Findings of the present study are similar to those reported by Kato and Johansson [2012], who used a different questionnaire and observed that major subjective symptoms developed by Japanese self-selected EHS subjects included fatigue/tiredness, headache, and difficulty in concentrating, remembering, and thinking. In the study by Eltiti et al. [2007], an eight-factor principal components analysis of symptoms in the English general population resulted in eight symptom subscales: neurovegetative, skin, auditory, headache, cardiorespiratory, cold-related, locomotor, and allergy-related symptoms; these findings are similar to those observed in the present study. Nordin et al. [2013] conducted an exploratory principal component analysis and reported that symptoms of EHS individuals in Sweden could be divided into five significant groups: airway symptoms, skin and eye symptoms, cardiac, dizziness and nausea, and cognitive and affective symptoms. As described in WHO fact sheet 296 [WHO, 2005], EHS is characterized by a variety of non-specific symptoms, which are attributed to EMF exposure by afflicted individuals. Symptoms most commonly experienced included dermatological symptoms (redness, tingling, and burning sensation) as well as neurasthenia and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitations, and digestive disturbances). Hence, taking these factors into consideration, we assumed that the main symptoms of self-selected EHS subjects in Japan could be evaluated using eight symptom categories described in previous studies conducted in Europe.

Relationship Between EHS and Other Chronic Illnesses (IV-3 Additional Questions)

Close relationships between allergy symptoms and MCS/EHS are often observed in clinical practice [Rea et al., 1991]. However, so far, few reports exist describing the relationship between MCS/EHS and chronic illness, including allergy symptoms. Findings of the present study (Table 9) are new and are suggestive of a close relationship between MCS/EHS and allergy symptoms. Nevertheless, further studies are required to investigate underlying mechanisms responsible for this close relationship. The Japanese EHS questionnaire can be used as an effective tool to analyze the relationship between MCS/EHS and allergy symptoms, and to determine effective, future treatment modalities for MCS/EHS patients.

EMF Sources Believed by Japanese Self-Selected EHS Subjects as Cause of Their Symptoms

Similar to the study conducted in the UK, we found nine types of EMF sources (computers, electrical appliances, fluorescent lighting, microwave ovens, mobile phones, power lines, radio/television transmitters, telecommunication masts, and televisions), which Japanese self-selected EHS subjects considered as the cause of their symptoms in the present study. Interestingly, the following EMF

sources were selected by the majority of Japanese self-selected EHS subjects: electric appliances, followed by mobile phones, computers, and telecommunication masts (Fig. 2). Furthermore, besides the aforementioned nine sources in the questionnaire, several new types of EMF sources, including those used for transportation (e.g., cars, buses, Shinkansen), communication devices other than mobile phones (e.g., wireless LAN, Wi-Fi, security equipment), and medical devices (MRI, X-rays, dental therapeutic instrument) were also nominated by self-selected EHS subjects. Hence, we believe that these new EMF sources should be added to the Japanese version of EHS questionnaires in future surveys.

Work Style and Relationship With MCS

Consistent with results reported by Kato and Johansson [2012] in Japan and Hillert et al. [2002] in Sweden, the number of full-time workers was significantly lower, whereas the number of unemployed persons and part-time workers was significantly higher among self-selected EHS subjects when compared with controls in the present study (Table 1).

EHS resembles MCS, another disorder associated with low-level environmental exposure to chemicals, because both EHS and MCS are characterized by a range of non-specific symptoms that lack an apparent toxicological and physiological basis and/or independent verification [WHO, 2005]. Rea et al. [1991] reported that more than 80% of EHS patients presented with MCS. The results of the present study (Fig. 3) are consistent with those of Rea et al. [1991].

Proposal of Preliminary Criteria for Screening Japanese EHS Individuals

Based on the results of multiple logistic regression and ROC analyses in the present study, we propose the following preliminary criteria for the screening of Japanese EHS individuals: (1) the total symptom score should be greater than, or equal to, 47 points (75th percentile of controls, Fig 1a); (2) the score for q67 ("Are you sensitive to electromagnetic fields?") should be greater than, or equal to, 1; and (3) individuals should be able to describe the EMF source and the kind of symptoms developed in detail in response to q68.

Preliminary criteria suggested by the present study for the screening of EHS individuals in the general population are similar to those proposed by Eltiti et al. [2007]. However, the 75th percentile for controls was 26 points in the UK, and 47 points in Japan. Eighty-two (64.6%) of the 127 self-selected EHS subjects met with set screening criteria for EHS individuals. Furthermore, 60 subjects from the controls (1,306 respondents out of 2,000) also met with these preliminary screening criteria, suggesting that 3.0–4.6% of the general public in Japan may be EHS individuals, even though none are currently diagnosed with SHS or MCS /EHS. In addition, significant differences were not observed in all scores between 60 subjects from the control group and self-selected EHS subjects (data not shown).

Based on the fact that only 1% of the population of Japan is aware of EHS, determined by a preliminary survey [Hojo and Tokiya, 2012], some of these 60 subjects may have some knowledge of EHS; however, the majority of them most probably have no knowledge of this condition. Thus, it is very important that these unsuspecting individuals, who may have developed EHS symptoms, visit a qualified medical specialist. However, it is worthy to note that in response to the open question on the last page of the questionnaire ("Please provide a detailed description of how you have been suffering from EHS syndromes," Supplementary Materials), many self-selected EHS subjects described how only a few medical doctors had professional knowledge of EHS/MCS, and most were generally incompetent with regards to the treatment of this condition in Japan. Consequently, Japanese self-selected EHS subjects have suffered greatly in their day-to-day life [Ito et al., 2012], making it imperative to have specialists who are familiar with EHS, as well as MCS and SHS.

Future Directions

As stated in the COST fact sheet [COST, 2011], individuals who think they are sensitive to EMF actually feel symptoms; therefore, it is important to endeavor to improve, and to understand the mechanisms and causal relations associated with their condition. The limitation of this study is that this is one of the descriptive survey findings for perceptions of causation in a self-selected group who believes EMF is a cause of their symptoms. Thus, systematic approaches, including the provision of information, support for patients with symptoms of earlier stages, and treatment for persons with prolonged and severe symptoms, are required. We believe that it is time to develop and initiate a systematic approach, wherein the provision of information about EHS to general physicians and the public is mandatory in Japan. The Japanese EHS questionnaire can be used as an effective tool for providing such information.

The COST fact sheet also states that "the choice of treatment should be based on a broad evaluation of the patient's symptoms and situation (including medical, psychosocial, and environmental aspects) and taking the patient's motivation for different

interventions into account. Cognitive therapy has been reported to improve well-being and the ability to cope with persisting symptoms in some patients." We agree that multi-faceted therapies are useful for the treatment of EHS individuals with severe and long-lasting symptoms, and believe the Japanese EHS Questionnaire will be useful in evaluating such therapies.

CONCLUSION

The Japanese EHS questionnaire is highly reliable and valid, and can be used to screen EHS individuals from the general population in Japan. This questionnaire can be used to elucidate the actual status of EHS individuals in Japan, to evaluate the effects of therapies or lifestyle changes in people presenting with EHS-related symptoms, and as a cross-comparison of groups studied by different investigators.

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SUPPORTING INFORMATION

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