1. Grzegorz TATOŃ[1], 2. Artur Kacprzyk[2], 3. Tomasz ROK[1], 4. Anna WASIK[3], 5. Marcin SIWEK[3]

Department of Biophysics, Chair of Physiology, Faculty of Medicine, Jagiellonian University Medical College (1), Doctoral School of Medical and Health Sciences, Jagiellonian University Medical College (2), Department of Affective Disorders, Chair of Psychiatry, Faculty of Medicine, Jagiellonian University Medical College (3)
ORCID: 1. 0000-0001-7777-6892; 2. 0000-0002-9447-173X; 3. 0000-0003-3846-3900; 4. 0000-0002-5398-6454; 5. 0000-0002-3109-1895

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Is the hypersensitivity to electromagnetic fields caused by a physical mechanism or is it a psychological problem?

Streszczenie. *W ciągu ostatnich kilku lat prowadzono projekty związane z wpływem pola elektromagnetycznego (EMF) na ludzi. Miały one na celu oszacowanie częstotliwości występowania nadwrażliwości elektromagnetycznej (EHS) w Polsce oraz scharakteryzowanie osób cierpiących na ten zespół. Wielu badaczy twierdzi, że EHS nie jest powodowana rzeczywistym fizycznym wpływem EMF, ale jest związana z mechanizmami psychologicznymi. W artykule podsumowano przesłanki płynące z trzech projektów badawczych, które zdają się potwierdzać tę tezę.* ***(Czy nadwrażliwość na pola elektromagnetyczne jest spowodowana mechanizmem fizycznym, czy jest problemem psychologicznym?)***

Abstract*. Over the past few years, projects related to the impact of electromagnetic field (EMF) on humans have been carried out. They were aimed at estimating the prevalence of electromagnetic hypersensitivity (EHS) in Poland and characterization of people suffering from this syndrome.*
Many researchers claim that EHS is not caused by the real physical impact of EMF, but is associated with a psychological mechanism. This paper summarizes the premises of three research projects that seem to confirm this thesis.

Słowa kluczowe: pole elektromagnetyczne, zakres częstotliwości radiowych, nadwrażliwość elektromagnetyczna, IEI-EMF.
Keywords: electromagnetic filed, radiofrequency, electromagnetic hypersensitivity, IEI-EMF.

Introduction

The electromagnetic field (EMF) is one of the physical factors that accompany us in everyday life as a consequence of the rapid technological development. The effect of EMF on the human body is the influence of a physical factor and must be based on physical phenomena. The effects of EMF at the chemical, biochemical and physiological levels and thus the health consequences appear as a result of the transfer of electromagnetic wave energy to the organism [1].

The way in which the radiofrequency electromagnetic field (RF-EMF) acts on the body depends on the radiation characteristics. As a non-ionizing radiation, RF-EMF leads to an increase in tissue temperature [2]. The temperature, which is a measure of the internal energy of any material, increases as a result of the energy transfer from the RF-EMF to the molecules and atoms of the material. These effects are quantified by the Specific Absorption Rate (SAR), which describes the power deposition inside the tissue caused by the RF-EMF exposure, which results in an increase in material temperature. The rise of temperature is even less important than the speed of this process, as the thermoregulation mechanism leads to the equalization of local temperature changes. Since then, only an appropriately intense transfer of energy to the tissue can cause thermoregulation failure, which has health consequences [2]. The effects of RF-EMF on the human body have no cumulative character, as the ionizing radiation has.

The impact of EMF on tissue depends mainly on the amplitude of the electrical component expressed in V/m and on the power density of the EMF quantified in W/m2. It also depends on the frequency of the EMF and will be different with the same strengths of the electrical component for RF-EMFs of different frequencies. The actual safety limits in Poland [3] protect against the potentially negative impact of EMFs in humans with a margin of several dozen times.

In addition to thermal effects, which are obvious and not doubtful, many researchers point at the possibility of non-thermal effects existence. It should be emphasized that any rise in temperature, even no measurable, can change the properties of tissues, e.g. by affecting the viscosity of fluids, or subtle changes in the speed of some biochemical processes, or simply by changing electrical and thermal temperature-dependent tissue parameters. Nevertheless, nonthermal effects have not been convincingly explained or unquestionably confirmed.

It seems that when the intensity of the RF-EMF is small (as is the case of telecommunication applications) it does not carry enough energy to cause real health problems. However, there is a certain exception to the rule, saying that the health effects of physical factors must rely on the transfer of EMF energy to the body. There is a class of diseases called psychosomatic diseases. These are specific real physiological health consequences arising on psychological basement, mainly emotional. The phenomenon of hypersensitivity to EMF from various sources (Electromagnetic Hypersensitivity - EHS) might to be an example of this kind of problem.

The phenomenon commonly called EHS should be called an idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) according to the WHO recommendations [4]. This term denotes the situation in which people report health symptoms caused by exposure to week EMFs of very different sources and characteristics.

The low levels exposure cannot cause a significant and harmful increase in body temperature. Since the thermal effect seems to be not a good candidate to explain EHS, and other mechanisms of physical interaction, nonthermal, are questionable, then the only explanation for EHS remains the relation to the psyche.

Aim of the study

The EHS has been the subject of our interest for some years. The research was aimed to access the prevalence of EHS and characterize hypersensitive people in Poland. Two survey studies were conducted to achieve these objectives [5,6]. Furthermore, provocative studies were conducted to determine whether RF-EMF affects people's psychomotor skills and especially those who perceive themselves as hypersensitive. It was investigated whether hypersensitive people can sense EMF on the basis of their feelings. The results of provocative studies were not described previously.

Some of the results obtained so far seem to indicate the psychological basis of the EHS phenomenon, and this paper is devoted to a discussion of these aspects.

Survey studies

So far, we conducted two surveys to characterize EHS in Poland: the first in 2018 [5], and the second two years later [6]. Survey studies were described in detail elsewhere [5-8], so here only the most important information is provided on these studies.

The first study [5,7,8] was conducted as a widely available online survey. The second [6] was designed as a telephone survey in a group representative of the Polish society that consisted of 2,000 people. In the first study, the representativeness of the study group was not ensured because the survey was widely and generally available. This probably caused that only those took part in the study, who were for some reasons interested in the impact of EMF on humans or who are associating their own well-being with its impact. This had consequences for the results and conclusions of the study. The 2018 survey was completed by just over 1,000 people [5].

EHS-related EMF sources

In general conviction, EHS is associated with wireless communication, i.e. with all kinds of devices using radio waves. These can be mobile telephones, mobile phone base stations, or cordless phones. However, it turns out that this is not entirely true and that the results obtained in this context depend on the research methodology.

In both studies, respondents were asked about devices that emit EMF that cause their health problems. The ranking of such devices in the 2018 survey was the following: mobile phone – 65%, laptop – 36%, personal computer – 35%, WiFi router – 34%, TV receiver – 32%, microwave oven – 28%, high voltage line – 21%, mobile telephony base station – 17%, tablet – 10% [7]. Other devices were indicated by less than 10% of people who, according to the eligibility criteria adopted in this study, were included in the group of people potentially hypersensitive to EMF.

In the 2020 survey [6], this ranking was completely different, that is, high voltage line – 11%, mobile phone – 8.4%, mobile telephony base station – 7.8%, computer – 7.5%, other devices – 6.0%. Here, a percentage is given in relation to the total number of respondents, not only those who were considered hypersensitive to EMF. The question was as follows: 'To which of the listed devices do you feel symptoms of hypersensitivity or allergy, when you are close to them? (a) mobile phone; (b) computer; (c) high-voltage line; (d) mobile base station; (e) any electrical appliance.'

The same survey (2020) [6] investigated the problem of sources associated with EHS using another method. First, all participants were asked a question: Do you think that devices that emit an electromagnetic field have a negative impact on yours: (a) well-being; (b) health? Then, only those who answered positively (a) and/or (b) option were asked another question: "Which devices have a negative impact on your health or well being? (a) mobile telephone; (b) laptop; (c) computer; (d) WiFi router; (e) television receiver; (f) microwave oven; (g) high voltage energy line; (h) mobile telephony base station; (i) tablet; (j) energy saving lamp; (k) monitor /screen/display; l) induction oven; m) wireless (stationary) telephone; n) LED lamp; o) others..... The results obtained were as follows: mobile phone – 36%, computer – 18%, TV set – 14%, microwave oven – 10%, high voltage line – 10%, laptop – 7.8%, WiFi router – 7.6%, mobile telephony base station – 5.8%. The remaining devices scored below 5%. 45% of those who answerer this question indicated devices other than mentioned in the list.

It is hard to compare the above results quantitatively due to differences in the methodology of both studies, but one conclusion can certainly be drawn. Not only the RF-EMF emitting devices are linked to EHS health effects. In both surveys, devices that emit RF-EMF and also radiate only extremely low- or low-frequency EMF (EL/LF-EMF) were considered as related to EHS.

It is also worth noting that in the first and third rankings, a TV receiver is placed well above the mobile telephony base stations. Also, the result for the TV set is almost equal as for WiFi router in the first survey and much higher than for WiFi router in the last. The TV sett is to a greater extent an EL/LF-EMF source than an RF-EMF source.

The characteristics of electromagnetic radiation from the RF-EMF and EL/LF-EMF ranges are completely different. The way they affect the body also has to be different. The fact that such different frequency ranges of EMFs are associated by potentially hypersensitive people with the ailments they experience speaks against the real impact of these fields. This observation testifies to the hypothesis about the psychological mechanism.

EHS symptoms

In the surveys mentioned above [5,6] participants were asked about the symptoms associated with the effect of EMF on their health. The results confirmed the reports in the literature that symptoms associated with EHS are nonspecific, of various types, and are often difficult to evaluate objectively [9]. The list of symptoms is long and they concern various aspects of well-being, from migraines, general fatigue, problems with concentration, through problems related to the circulatory system (palpitations, reduced/increased heart rate, pressure disorders, rashes, tearing, or shortness of breath).

The nonspecificity of symptoms means that they are not characteristic of one particular condition but can be associated with many problems. Furthermore, EHS is often associated with conflicting symptoms in different people. Some of them say that their heart rate is decreasing and others that it is increasing. Some say that they are stimulated by the action of EMF, and others that they are drowsy and sleepy.

The symptoms reported the most frequently in the 2018 study [5] were general fatigue – 80%, headache – 74%, eye pain – 68%, irritability – 66%, problems with concentration – 64%, sleep disorders – 41%, and anxiety – 37%. 32% of the respondents indicated drowsiness, while 19% indicated insomnia. 10% declared an increase in blood pressure and 3.5% a reduction in pressure. 9.3% observed an elevated heart rate and 1.0% a reduced heart rate.

In the 2020 study conducted on a representative group of Polish society, EHS symptoms were also investigated [6]. The following question was sent to all respondents: 'Do you have health symptoms associated with the use of electrical appliances that others do not feel in similar circumstances?' People who answered the above question in the affirmative (88 people, that is, 4.4%) were asked to indicate the symptoms from the list previously prepared. Of these: 57% indicated headache, 16% eye pain, 10% fatigue, 8% insomnia, 4.5% anxiety, and 4.5% falls asleep problems.

The biggest problem with the symptoms of EHS is that many of them are difficult to assess objectively and quantitatively (e.g. general fatigue, headache, or anxiety). This makes the diagnosis of patients complaining about this syndrome dubious but also makes a scientific research on EHS difficult. The qualification of people who participate in scientific projects to the hypersensitive group of people, as well as the evaluation of the physician to whom the patient

reports symptoms, can be made mainly based on the self-determination of the subject [6,10].

The multitude of reported symptoms, and also the often observed contradictions of symptoms (especially these, which can be objectively controlled) reported by different hypersensitive people could possibly suggest that EHS is more of a psychological problem.

EHS eligibility criteria

One of the problems associated with EHS research is the identification of hypersensitive people. To conduct reliable studies, it is necessary to recruit a group of people who are potentially hypersensitive to EMF and often also the control group, i.e. those who are not hypersensitive. The potential bias occurs when a person who is not hypersensitive to EMF is included in a study group, but also when a hypersensitive person belongs to the control group. As mentioned above, there are no objective and quantitative criteria for the undoubtful classification of EHS subjects [6,10].

One of the objectives of the survey conducted in 2020 [6] was to determine the methodology for the qualification of hypersensitive people in future studies. To this end, the survey asked for a declaration of hypersensitivity through a series of questions formulated in different ways. Since then, it has been possible to define and test several different criteria. Differently formulated questions were used, which all can be reduced to the question "are you hypersensitive to electromagnetic fields?". Such questions were associated with declared symptoms observed or with declared sources of EMF causing deterioration of well-being. This approach allowed us to strengthen the criteria for qualifying individuals to the group of hypersensitive people. This solution is based on the assumption that if the subjects declare themselves as suffering from EMF, they are more likely to be true if they also determine the circumstances related to their hypersensitivity. Solutions that assume the use of more than one question as a criterion for identifying people who are hypersensitive to EMF are suggested in the scientific literature [11].

Depending on how the questions considered EHS were formulated and how the different questions were combined into more complex criteria, a very different number of hypersensitive people in the population was estimated, ranging from 1.8% to almost 22% [6]. Of particular note it is one of the asked questions: 'Do you think that devices emitting electromagnetic fields have a negative effect on your: (1) well being and/or (2) health?' The words "well being" and "health" in Polish (in this language the survey was conducted) can be treated as synonyms in relation to physical health status. Replacement of one with the other resulted in a statistically significant change in the estimation of the number of individuals potentially hypersensitive to EMF from 18.2% to 21.9% for (1) and (2), respectively.

The proper definition of eligibility criteria is a serious problem for scientists who carry out projects related to EHS, but it should also be taken into account by the recipients of the results of such projects. The conclusions drawn should be interpreted carefully and attention should always be paid to the recruitment methodology of the study population.

It should be noted that the interpretation of the questions considering EHS is an individual and strongly subjective matter depending on the intellectual capabilities of the respondents, their education, belonging to specific social groups, and also on their personality. This conclusion is another argument for the psychological background of EHS.

Results of provocative studies

In addition to the surveys previously discussed, provocative studies were also conducted, which aimed to check whether exposure to RF-EMF with specific characteristics has an impact on psychomotor skills.

In our newest study, not described so far, 57 adult women of any age were involved. They were asked to complete several forms to determine their health status and possible EHS. Two questionnaires were offered based on standard psychological tools. The first, completed once, was based on the Memphis Temperament Assessment Tool (TEMPS-A), which is a standard method used in psychology to determine affective temperaments [12]. The second survey was conducted twice, before and just after the experiment, and aimed at determining the subjects' anxiety. It was based on the STAI-X (State Trait Anxiety Inventory) questionary [13].

The main part of the experiment was a series of tests focused on the psychomotor abilities of the participants, i.e., reflexes, perceptiveness, or adequacy of reactions. These tests were performed on a computer equipped with a dedicated software. The same set of psychomotor tests was performed three times. Once without exposure to RF-EMF and twice in the presence of an artificially generated EMF with a frequency of 2.157 GHz and an electrical field intensity of 2.96 ± 0.08 V/m (the background EMF was estimated at 0.101 ± 0.002 V/m). A generator (Gator Transmitter, Berkeley Variatronics Systems, US) coupled to an omnidirectional antenna (Kathrein K 80010749, KATHREIN-Werke KG, Germany) was used as RF-EMF source.

During the first two cycles of tests, participants knew that EMF was 'on' in one of the two cycles and 'off' in the second, but they did not know in which of them EMF was present. The researcher conducting the experiment also did not have this information (double-blind trial). In the third test cycle, EMF was always 'on', and both the participants and the researcher were aware of this.

After all tests, the volunteers described their feelings about subsequent test cycles. They describe their well-being and determine on their feelings in which of the first two cycles EMF was present. Well being was determined on a scale of 0 – 5, where 0 meant very bad and 5 – very good.

The effect of RF-EMF exposure on outcomes was investigated in two ways, with regard to real and perceived exposure. To describe the participants' reaction to real exposure, the results of the tests when the field was REALLY turned on (one of the first two cycles and the third cycle) were taken into account. To study perceived exposure, only the results of the cycles INDICATED by the participant as being performed in the presence of EMF were considered.

The analysis of quantitative parameters describing the psychomotor skills of the subjects did not show any statistically significant dependence on real or perceived exposure. Regardless of whether subjects could be considered hypersensitive or not, there were no differences in response times, task precision, or response adequacy. No differences were observed even after taking into account possible fatigue during successive tests, as well as the impact of the learning process.

Do hypersensitive people feel EMF?

The provocative experiment did not show any evidence of causation or even correlation between the objective parameters that describe the psychomotor abilities of the women studied and their exposure to EMF. However, the question arises of whether the experiment participants were able to determine from their feelings and possible symptoms in which of the first two cycles of tests ('blind') they were exposed to EMF?

Among the 57, 40 participants attempted to guess whether the EMF was generated during the first or second test cycle. They subjectively assessed their well-being during the performance of the tasks. The reference point for the guess could have been the third cycle, in which they knew with certainty that EMF was present. The other 17 ladies were unable to determine when EMF was present and denied guessing. Almost half of those 40 ladies (19 i.e., 47.5%) correctly indicated one of the two blind cycles, while 21 failed. This shows that the correct assignment of exposure to the cycle was completely random. A score of 19 is not significantly different from a statistical prediction (50%, i.e., 20 cases).

A similar result was obtained when the analysis was limited only to potentially hypersensitive subjects. Based on an interview conducted before the study, 17 of the participants could be considered potentially hypersensitive to EMF. Of these, only 10 attempted to indicate which of the first two blind test cycles was performed in the presence of EMF. Five of them indicated it correctly and five did not.

The impact of EMF exposure on subjective assessment of participant well-being has also been tested. As in the case of the results of the psychomotor skills test, the real exposure and perceived exposure were analyzed. The results are shown in Table 1. The table presents a summary of the average well-being of the participants during psychomotor tests described on a scale of 0 – 5 ('0' means very bad, while '5' means very good mood). The average level of well-being was calculated when the exposure was real and when it was only perceived. The results were presented separately for the general population (all together), for women considered to be potentially hypersensitive to EMF and other women, i.e., not considered to be electrosensitive.

Table 1. Subjective assessment of the well-being of the participants in the provocative study when psychomotor tests were performed under conditions of perceived and real exposure. The numbers indicate the average subjectively assessed well-being on a scale of 0 – 5 (0 - very bad, 5 - very good mood). The parameter *p* determines the statistical significance of the difference between the situation where the real or perceived field was turned on and off. Statistically significant differences are denoted by asterisks ($p < 0.05$).

Well-being in conditions of:	Perceived exposure			Real exposure		
	ON	OFF	*p*	ON	OFF	*p*
Entire population	3,7	4,3	0,012*	4,1	3,9	0,380
Hypersens. to EMF	3,5	4,1	0,208	4,1	3,5	0,208
Insensitive to EMF	3,8	4,4	0,029*	4,1	4,1	0,794

Statistically significant differences occurred in the case of perceived exposure, while real exposure to RF-EMF did not affect the subjective well-being of the participants. Interestingly, the differences were significant for the overall study population and for women who were not identified as potentially hypersensitive. In the hypersensitive group to EMF, there was a difference in average well-being between the situation where they were convinced that the field works (value 3.5) and the situation where they considered that the field was not included (value 4.1). However, this difference is not statistically significant (probably due to the small size of this group). It is worth noting that all subjects felt better while convinced that the field was off.

The above results are in agreement with reports in the literature that people who perceive themselves as hypersensitive to EMF cannot determine on the basis of their feelings whether the field is present or not in blind trials [14,15]. Substantial assessment of the well-being of the subjects is not influenced by actual exposure to EMF, but is related to the perception of this exposure. This observation is also consistent with the literature reports [14,15] and is also one of the most important premises for the psychological background of the symptoms attributed to the impact of EMF.

EHS is related to personality

The STAI-X form was used to assess subjects' anxiety before and after the experiment [13]. The level of anxiety of the participants could be expected to be higher before the study than after, because a new challenge is usually associated with stress. It could also be expected that the level of anxiety would be higher in the group hypersensitive to EMF, which should be related to the fear of a potentially harmful factor. In both, those identified as potentially hypersensitive and others, anxiety levels were observed to be higher before the study than after it, but these differences were not significant. There was also no difference between the anxiety level of potentially electrosensitive and insensitive women.

More interesting conclusions can be drawn from the TEMPS-A results. The TEMPS-A survey consists of 110 questions, to which the respondents answer YES or NOT. The subject is asked to mark an answer that has been true for most of her life. The survey questions are designed to identify personality traits associated with experiencing and understanding emotions. The TEMPS-A allows us to determine the amplitude of five components that characterize the way the subject experiences emotions. These are the depressive, cyclothymic, hyperthymic, irritable, and anxious components [12]. The contribution of each component is examined with a specific group of questions and the result is given as a percentage expressing the number of positive responses in relation to the total number of questions concerning the specified component. The personality of the subject is characterized by five numbers between 0 and 100, which correspond to the share of particular components. The average share of individual personality types was calculated in the group of women who were identified as potentially hypersensitive to EMF (17 women) and in the rest (40 women). The results are presented in Table 2.

Table 2. The average share of personality types in subjects divided into the group of potentially hypersensitive to EMF (EHS) and insensitive (Others). The results were obtained using the TEMPS-A tool. The components that showed statistically important differences between EHS and Others are indicated by asterisks ($p < 0.05$).

Component	EHS	Others	*p*
Depressed	44,5	32,3	0,003*
Cyclothymic	36,7	25,0	0,030*
Hyperthymic	39,2	46,2	0,213
Irritable	25,0	19,2	0,186
Anxious	39,0	23,8	0,009*

Participants who described themselves as hypersensitive to EMF showed a statistically higher share of depressive, cyclothymic, and anxious components. The characteristics of the affective temperaments of the ladies taking part in the experiment suggest that the perception of themselves as a person hypersensitive to EMF is connected to their personality, and in particular to the contribution of depressive and anxiety components. The connection between EHS and anxiety and depressive affective temperament seems obvious if one considers that people characterized by an anxious type of temperament tend to worry and ruminate. They are accompanied by

constant mental and physical tension, which can turn into somatic symptoms. On the other hand, people with depressive temperament traits have lower energy levels, which can be associated with greater fatigue [11], which is one of the typical symptoms of EHS.

SUMMARY

All observations discussed in this paper suggest that psychological mechanisms are possibly the cause of EMF hypersensitivity or at least a strong factor that affects its development. Such conclusions coincide with numerous reports in the literature, but also with the position of the World Health Organization [4]. Research in this field is still ongoing, and there are also reports suggesting that EHS is related to the real physical impact of EMF. Attempts are also made to create models that explain the phenomenon of EHS by linking the psychological and physical mechanisms of the impact of EMF on humans [16]. However, it should be emphasized that at this stage, neither the literature reports nor the results of our own research clearly determine whether EHS is related or not to the real physical impact of the EMF.

***Authors**: Grzegorz Tatoń, PhD, Department of Biophysics, Chair of Physiology, Faculty of Medicine, Jagiellonian University Medical College, Św. Łazarza 16, 31-530 Kraków, Poland, E-mail: g.taton@uj.edu.pl; Artur Kacprzyk, MD, Doctoral School of Medical and Health Sciences, Jagiellonian University Medical College, E-mail: artur.kacprzyk@doctoral.uj.edu.pl; Tomasz Rok, PhD, Department of Biophysics, Chair of Physiology, Faculty of Medicine, Jagiellonian University Medical College, E-mail: tomasz.rok@uj.edu.pl; Anna Wasik, PhD, Department of Affective Disorders, Chair of Psychiatry, Faculty of Medicine, Jagiellonian University Medical College, E-mail: anna.wasik@uj.edu.pl; Marcin Siwek, MD, PhD, Assoc. Prof., Department of Affective Disorders, Chair of Psychiatry, Faculty of Medicine, Jagiellonian University Medical College, E-mail: marcin.siwek@uj.edu.pl.*

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