

RISK OF CARDIOVASCULAR DISTURBANCES IN RELATION TO EXPOSURE TO ELECTROMAGNETIC FIELDS

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INTRODUCTION

Exposure to electromagnetic fields (EMF) from man-made sources is almost permanent. Theoretically, it is possible that this exposure may induce some harmful effects in humans (1). Research on the biological effects of EMF is associated with 2 main frequency ranges: extremely low frequency (**ELF**, 50–60 Hz) and radio-frequency (RF, 3 kHz–300 GHz). The **data** on cardiovascular changes in exposed workers are conflicting. Some authors have reported reduced systolic blood pressure or electrocardiogram (**ECG**) abnormalities such as sinus arrhythmia and sinus tachycardia in people exposed to **50** Hz EMF. Others do not confirm these findings (2,3). In subjects exposed to RF EMF, the following symptoms were observed heart rhythm disturbances, impaired conduction, decreased amplitude of ECG records and blood pressure changes (e.g., hypo- or hypertension) (4). Our data revealed more frequent electrocardiographic abnormalities in RF EMF workers (5). Considering these discrepancies, we have undertaken a study to evaluate circulatory system disturbances in workers occupationally exposed to EMF at different exposure levels and frequencies.

METHODS

Subjects. The study groups consisted of technical personnel and security service workers, aged 21 to 69 years, who worked from 1 to 42 years, and who were deemed fit for work at permissible EMF levels by the occupational health practitioners. The examinations were carried out in several groups. Exposed group (I) consisted of 71 workers at 4 **AM** broadcast stations, which operated at frequencies up to 1503 kHz. The main sources of EMF in the AM broadcast stations were the transmitting antennas (half-wave dipole), radio transmitters and feeders (which conduct radio signals from the transmitter to the antenna). Exposed group (II) consisted of 40 workers at 10 radio services. Mobile radio communication network requires permanent technical supervision; its users organize special radio service units. During the service operations, undesirable EMF are generated by unscreened transmitters, improper tuning instruments or transmitting-receiving antennas installed in the service-rooms. Exposed group (III) consisted of 63 workers at 4 substations. Substations are the element of a power system in which electric power is distributed and/or transformed. The substations under study worked with high and extra-high voltage (110 kV to 400 kV). The substation equipment is a source of electric and magnetic **50** Hz field. The Control group (0) was comprised of 42 workers at 4 radio link stations.

Radio link stations are the elements of a telecommunication system in which signals are transmitted using EM waves focused into very low beams by directional (mostly parabolic) antennas. Because the antennas are installed in highly inaccessible locations and the radiation beams run high above the ground, the workers of the radio link stations are free from exposure to EMF. Table 1 shows the characteristics of the groups examined.

Table 1. Characteristics of the groups examined

Groups	<u>Exposed</u>			<u>Non-exposed</u>
	Broadcast Stations (I)	Radio-services (II)	Substations (III)	Radio Link Stations (O)
No. of workers	71	40	63	42
Age (years)	46.9±13.1*	36.9±11.5	39.2±9.9	40.7±9.2*
Period of employment (years)	18.6±12.1	12.5±9.5	14.9±10.3	12.9±4.0
BMI ¹ (kg.m-2)	26±3	25±3	26±4	25±4
No of smokers (>10 cig/day)	33(47%)	15(38%)	21(33%)	16(38%)
No. of subjects reporting alcohol consumption (not less than 1/month)	59(83%)*	2(5%)*	18(29%)*	26(65%)*
<u>EMF exposure:</u>				
Frequency	738-1503 kHz	150-170 MHz	50 Hz	0
E _{max}	50-550 [V/m]	2-55 [V/m]	4.3-6.7 [kV/m]	0
B _{max}	negligible	negligible	26.1-37.3 [mT]	0
Edose	50-260 [(V/m)h]	irregular exposure	0.2-15.2 [(kV/m)h]	0
Bdose	negligible	negligible	1.4-389 [mTh]	0

¹BMI = body mass index;

* Significant difference between exposed and non-exposed group ($p < 0.05$).

Exposure evaluation. For each worker, the exposure to EMF was assessed by maximum values of the electric field strength (E_{max}), the magnetic flux density (B_{max}) and doses per workshift (ED_{8h} and BD_{8h}). For measurements, the HOLIDAY Industries (USA) measuring set and MEH-1a meter (Technical University; Wroclaw, Poland) were used.

Medical examination. All workers had a general medical examination, including an interview for family history of cardiovascular disease. A routine

12-lead ECG was recorded using a Medea system (Gliwice; Poland). The results were evaluated using generally adopted standards. In addition, a 24-h ECG recording was performed using Medilog 3000 (Oxford, England) from 2 bipolar leads, CM5 and CS1. The results obtained were then compared to the international standards for Holter ECG parameters according to the criteria adopted at the 3rd Holter Symposium in Vienna in 1988. A 24-h ambulatory blood pressure monitoring (ABP) test was performed during professional and other activities using Oxford Medilog ABP System. The results were related to the Staessen's reference values of arterial blood pressure (6).

Statistical Analysis. Differences between the exposed groups and controls were analyzed using chi-square and Student's t test (for normal distributions) or non-parametric Mann-Whitney test (for other distributions). Mean values were compared using analysis of variance with multiple comparison tests. Fisher exact probability test was used to compare the frequencies of ECG and blood pressure abnormalities in each group. Logistic regression was utilized to investigate the relationship between the probability of abnormalities and variables such as age, number of cigarettes smoked, amount of consumed alcohol, duration of work and exposure levels.

RESULTS

The data from the medical examinations and interview indicated that the test groups were similar with respect to the level of physical fitness and dietary habits. They differed in the age of workers, number of cigarettes smoked and the level of alcohol intake. The possible influence of these factors on the results of the study was eliminated by statistical procedures.

Our studies did not reveal any significant differences between the exposed and non-exposed groups in the frequency of abnormalities in resting ECG. Significant differences between group I and the other groups were found for abnormalities present in one of the recordings (resting and/or Holter) (Table 2).

In groups II and III, the abnormalities in 24-h and/or resting ECG were also more frequent than in the non-exposed group, but the differences were insignificant. For Holter ECG recordings, heart rhythm disturbances dominated in group I, whereas repolarization impairments were dominant for the other 2 groups. Blood pressure monitoring revealed increased frequency of elevated BP in group III (38%) vs. the non-exposed group (23%). The difference between groups III and 0 was statistically significant ($p = 0.04$).

The risk analyses revealed that the probability (odds ratio) for abnormalities in resting and/or 24-h ECG was 6.6 for group I, 2.0 for group II and 1.4 for group III in comparison with the control group. On the other hand, a significantly higher risk for increased blood pressure was detected by the ABP method in group III. The increase was mostly due to an elevated systolic blood pressure at night (odds ratio = 12.5).

Table 2. The percentage of subjects in each group with ECG and BP abnormalities

Groups	<i>Percentage of subjects with ECG abnormalities</i>			
	<u>A:</u> <u>resting ECG</u>	<u>B:</u> <u>Holter monitor</u>	<u>A and/or B</u>	<u>ABP</u>
I	34	56*	83*	6
II	30	32.5	55	20
III	29	40	48	38*
0	26	31	40	23
<i>p</i> value	ns	<i>P</i> = 0.02	<i>P</i> = 0.001	<i>P</i> = 0.04

*Differs significantly from Group 0 value, *p* values indicated in last row.

DISCUSSION AND CONCLUSIONS

Our findings indicate that electrocardiographic abnormalities are more frequent in workers exposed to radio-frequency EMF than in non-exposed workers or in workers exposed to 50 Hz EMF. The changes in resting and/or 24-h ECG records varied in type and influence on cardiac function—from impairments of ventricular conduction to dangerous heart rhythm disturbances. On the other hand, an increase in BP was found using the ABP method in the substation workers exposed to 50 Hz EMF compared with the non-exposed subjects and workers exposed to other EMF frequencies. Our results suggest that the frequency of electromagnetic fields determines the type of the observed cardiovascular disturbances, but further research is required.

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