CIRCADIAN PROFILE OF BLOOD PRESSURE IN WORKERS EXPOSED TO 50 HZ ELECTROMAGNETIC FIELDS

E. Gadzicka, A. Bortkiewicz and M. Zmyslony

Nofer Institute of Occupational Medicine, 90-950 Lodz, Poland

INTRODUCTION

The results of experimental and clinical studies on the biological effects of 50 Hz electromagnetic fields (EMF) are inconsistent or even contradictory. Several of the findings indicate that the exposed people may develop neurovegetative dysfunctions as well as abnormalities of arterial blood pressure (hypo- and hypertension) (1,2). Other results do not provide evidence for the adverse effect of EMF on the circulatory system (3,4,5). Therefore, we have undertaken the present study in order to evaluate the 24-h blood pressure in workers occupationally exposed to 50 Hz EMF, using a modern diagnostic method. Ambulatory blood pressure (ABP) monitoring has been advocated as a tool to study pathophysiology of blood pressure regulation and as an aid in the diagnosis and treatment of hypertension. Human arterial blood pressure shows physiological day/night and short-term fluctuations (6). Circadian profile of blood pressure is one of the most important indicators of blood pressure regulation (7,8).

MATERIALS AND METHODS

Subjects. The groups under study consisted of technical personnel, aged 22 to 67, with the period of work ranging from 1 to 42 years, who were qualified by the occupational health practitioners as fit for work at permissible EMF levels.

The examinations were carried out in the following manner:

- 63 workers at 4 Substations: exposed group. Substations are the element of a power system in which electric power is distributed and/or transformed. The substations under study work with high and extra high voltage (110 kV to 400 kV).
- 42 workers at 4 Radio Link Stations (RLS): the control group. RLS are the elements of a telecommunication system in which signals are transmitted using EM waves focused into very row beams by directional (mostly parabolic) antennas.

The data from the medical examinations and interview indicate that the test groups were homogenous with respect to the level of physical fitness, the dietary and smoking habits (displayed in Table 1). They differed only regarding the amount of alcohol consumed (higher in the control group). Its possible influence on the results of the study was eliminated using statistical methods.

Medical examination. All workers had a general medical examination, including an interview for cardiological and family history, dietary habits and leisure time activity. An ABP monitoring was performed during everyday pro-

Table 1. Characteristics of the groups examined

	Substations: exposed group	Radio Link Stations (RLS): control group
Number	63	42
Age (years)	39.2 ± 9.9	40.7 ± 2.2
Employment (years)	14.9 ± 10.3	12.9 ± 4.0
BMI[1]	26 ±4	25 ±4
No. of smokers (more than 10 cigarettes a day)	21 (33%)	16 (38%)
No. of subjects reporting alcohol consumption (not less than once a month)	18 (29%)*	26 (65%)[2]
EMF exposure: - frequency [Hz]	50	0
$-E_{max}$ [kV/m]	4.3 -6.7	0
$-B_{max}$ [mT]	26.1 -37.3	0
$-E_{dose}$ [(kV/m)h]	0.2 -15.2	0
$-B_{dose}$ [mTh]	1.4 -38.9	0

[1]BMI, body mass index = body mass/height^2 (kg/m^2); [2]Differs significantly between groups ($P = 0.0006$)

fessional and other activities using Oxford Medilog ABP System. The measurements were carried out automatically, every half-hour during daily activities and every hour during sleep. Altogether, approximately 40 measurements were made for each subject. The examination had to be properly coordinated with the workers' working cycle. Mean, highest (H) and lowest (L) systolic (BPS) and diastolic (BPD) blood pressure and heart rate (HR) for 24 h (OVERALL), daytime activity (DAY) and night-time rest (NIGHT) were calculated with the Staessen's standards of arterial blood pressure as reference values (9). The day-night ratios were determined for systolic and diastolic blood pressure (BPSD/BPSN, BPDD/BPDN) and for heart rate (HRD/HRN). The normal values of BP and HR ratios are 1.1 or more. The subjects with BP ratio lower than 1.1 are called non-deepers (subjects without physiological decrease in blood pressure, systolic and/or diastolic, during night). For BP variability analysis the standard deviation (SD) and range (R) in each period were calculated.

Exposure evaluation. The exposure to 50 Hz electric and magnetic fields was assessed by measuring the maximum values of the electric field strength (Emax) and magnetic flux density (Bmax). For measurements, the MEH-1a m (Technical University; Wroclaw, Poland) was applied. Then, from the field's measurements and timing of work shift, the electric field strength and magnetic flux density doses per work shift (EDose and BDose) were estimated.

Statistical analyses. Chi-square test, Student's test (for normal distributions) or non-parametric Mann-Whitney test (for other distributions) was used for analyzing the difference between groups. The mean values of the variables were compared using the analysis of variance with multiple comparison tests. Fisher exact probability test was used for comparing the frequencies of blood pressure abnormalities in each group and logistic regression model for estimating the probability of blood pressure disturbances in exposed workers

RESULTS

The comparison of BP values in the exposed and control groups is shown in Table 2.

In 38% of the subjects from group I and 23% of the subjects from group II, BPS and/or BPD exceeded the upper limits of the normal range. The difference

Table 2. Blood pressure and heart rate in the groups examined

Parameters	Exposed Group	Control Group	Statistical Significance
BPSD	132.0 ± 14.1	125.7 ± 12.1	0.032
BPSD(H)	158.3 ± 14.7	151.3 ± 15.5	0.046
BPSD(L)	104.3 ± 14.4	100.2 ± 12.8	ns
BPDD	79.4 ± 8.9	75.8 ± 9.8	ns
BPDD(H)	105.0 ± 13.8	103.0 ± 16.1	ns
BPDD(L)	55.5 ± 10.7	54.1 ± 9.9	ns
HRD	81.3 ± 10.3	86.8 ± 8.9	0.011
BPSO	129.2 ± 14.0	122.0 ± 11.9	0.014
BPSO(H)	158.7 ± 14.8	152.7 ± 16.4	ns
BPSO(L)	95.2 ± 15.8	88.5 ± 13.3	0.040
BPDO	77.6 ± 9.3	73.2 ± 9.3	0.041
BPDO(H)	105.0 ± 13.8	103.0 ± 16.2	ns
BPDO(L)	51.5 ± 9.2	49.4 ± 7.3	ns
HRO	78.7 ± 9.6	82.1 ± 9.1	ns
BPSN	117.3 ± 17.6	106.7 ± 12.2	0.002
BPSN(H)	135.1 ± 20.8	126.4 ± 14.3	0.030
BPSN(L)	99.2 ± 19.3	87.6 ± 11.3	0.001
BPDN	68.2 ± 11.9	62.5 ± 7.4	0.01
BPDN(H)	81.3 ± 12.4	78.7 ± 10.0	ns
BPDN(L)	55.2 ± 9.8	50.8 ± 7.4	0.028
HRN	67.4 ± 9.0	65.4 ± 10.1	ns
BPSD/BPSN	1.14 ± 0.1	1.18 ± 0.1	ns
BPDD/BPDN	1.18 ± 0.1	1.22 ± 0.1	ns
HRD/HRN	1.22 ± 0.1	1.34 ± 0.1	0.007

between groups was statistically significant ($P = 0.04$). The percentage of workers with elevated BPSN and BPDN was significantly higher among the exposed group than the controls (33% vs. 4% and 15% vs. 0%, respectively).

In the exposed workers, the percentage of non-deepers (BPSD\N 43% vs. 23%, BPDD\N 23% vs. 8%) was higher than in the control group. The BP values were related to the parameters of EMF exposure: BPDOver, BPDD and BPDN were found to depend on the period of employment ($P = 0.023$, $P = 0.05$, $P = 0.001$, respectively). BPSN and BPDN were significantly correlated with the maximum values of the electric and magnetic fields ($P = 0.043$ and $P = 0.026$).

DISCUSSION AND CONCLUSIONS

Our study revealed significant differences in the circadian profile of arterial blood pressure in workers occupationally exposed to EMF, in comparison with con-

trols (higher mean BPSN and BPDN values, higher maximal BPSN, higher minimal BPSN and BPDN values and the percentage of non-deepers in the exposed group). These results indicate an impaired neurovegetative regulation of blood pressure, which may lead to hypertension and eventually to target organ damage.

Significant disturbances in blood pressure occurred first at night; therefore, occasional blood pressure measurement is insufficient to detect them. In workers exposed to 50 Hz electromagnetic fields, blood pressure control should be supplemented by 24-h blood pressure monitoring.

REFERENCES

1. Asanova, T.P. and Rakov, A.T. 1966, The state of health of persons working in electric fields of outdoor 400 and 500kV switch-yards, *Gigiena Truda I Professionalnye Zabolevania,* **10**, 50-52.
2. Sazanova, T.E. 1967, Physiological and hygienic assessment of labour conditions at 400-500 kV outdoor switch-yards, Scientific Publications, Issue 46, Profizdat, Institute of Labour Protection of the All-Union Central of Trade Unions, (Translation 1975, Publication No. 10, IEEE Power Engineering Society Piscataway, New Jersey).
3. Hauf, R. 1982, Electric and magnetic fields at power frequencies, with particular reference to 50 and 60 Hz, in M.J. Suess (ed.), *Non-ionizing radiation protection*, (Copenhagen: WHO Regional Office for Europe).
4. Korpinen, L. and Partanen, J. 1993, Influence of 50 Hz electric and magnetic fields on the pulse rate of human heart, *Bioelectromagnetics*, **15**, 503-512.
5. Danilin, V.A., Voronin, A.K. and Modorski, V.A. 1969, The state of health of personnel working in high-voltage electric fields, *Gigiena Truda I Professionalnye Zabolevania,* **13**, 51-52.
6. Nystrom, F., Malmstrom, O., Karlberg, B.E. and Ohman, K.P. 1996, Twenty-four-hour ambulatory blood pressure in the population, *Journal of Internal Medicine,* **240**, 279-284.
7. Van Ittersum, F.J., Ijzerman, R.G., Stehouwer, C.D.A. and Donker, A.J.M. 1995, Analysis of twenty-four-hour ambulatory blood pressure monitoring: what time period to assess blood pressures during waking and sleeping?, *Journal of Hypertension,* **13**, 1053-1058.
8. Middeke, M., Kluglich, M. and Holzgreve, H. 1991, Circadian blood pressure rhythm in primary and secondary hypertension, *Chronobiology International,* **8(6)**, 451-459.
9. Staessen, J., Fagard, R., Lijnen, P., Thijs, L., Van Hoof, R. and Amery, A. 1990, Reference values for ambulatory blood pressure: a meta-analysis, *Journal of Hypertension,* **8 (6)**, S57-S64.