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ELECTRIC AND MAGNETIC FIELDS EXPOSURE AND CARDIOVASCULAR SYSTEM RESPONSE IN SOME OCCUPATIONAL SETTINGS

R. Dănulescu, C. Goiceanu, Eugenia Dănulescu, Micaela Mărgineanu, Carmen Croitoru, Gh. Bălăceanu

Institute of Public Health Iaşi

Abstract: Aim: To reveal the cardiovascular (CV) system response to occupational exposure to low levels of extremely low frequency (ELF) electric and magnetic fields. **Material and methods**: Cross-sectional study (first step) for a two years cohort study has been done. Exposure evaluation comprised magnetic flux density and electric fields intensity measurements as well as ergonomic analysis. Health status assessment included detailed occupational anamnesis, clinical and biochemical examinations, computerized ECG and CV function tests. **Results and discussion**: We have studied 58 subjects occupationally exposed in electric transform and transport facilities (electricians) and 89 electric train drivers. We have used 93 matched care controls. The measured ELF fields had magnetic flux densities of 1.8-34.5μT for electricians and 0.8-18μT for train drivers. The intensities of electric fields ranged between 1.5kV/m and 32kV/m for electricians and between 25V/m and 0.5 kV/m for electric train drivers. The measured values did not exceed general accepted permissible levels. Arrhytmias were found at 20.2% of the train drivers *vs.* 8.1% in controls (OR=3.11, 95% CI: 1.14-8.76) as well as in 20.7% of the electricians (OR=3.2, 95% CI: 1.08-9.77). Conduction disturbances were found in 16.8% of the train drivers *vs.* 5.4% in controls (OR=3.57, 95% CI: 1.15-13.06) as well as in 36.2% of the electricians *vs.* 5.4% in controls (OR=9.99, 95% CI: 3.28-35.90). It is to be mentioned the difference between electricians and drivers: OR=2.8, 95% CI: 1.21-6.51. Myocardial ischemia changes were found in 33.7% of the train drivers *vs.* 8.6% in controls (OR=5.4, 95% CI: 2.18-5.84) as well as at 32.8% of the electricians (OR=5.18, 95% CI: 1.93-14.24). **Conclusions**: The study of CV effects in ELF fields exposure, revealed significantly frequent ECG changes: arrhytmias, conduction disturbances, and myocardial ischemia changes. The ELF fields' occupational exposure seems to be a CV risk factor.

Key words: Electric and magnetic fields, cardiovascular system, ECG changes

Rezumat: Scop: punerea în evidenţă a posibilului răspuns al sistemului cardiovascular la expunerea ocupaţională de nivel redus la câmpuri magnetice şi electrice (CEM) de extrem de joasă frecvenţă (EJF). **Material şi metodă**: s-a realizat un studiu epidemiologic transversal ca primă etapă a unui studiu de cohortă. Evaluarea expunerii a inclus măsurători ale câmpurilor magnetice şi electrice, precum şi analiză ergonomică. Evaluarea stării de sănătate a fost axată pe sistemul CV şi a cuprins analiză profesională detaliată, examinări clinice şi biochimice, EKG computerizată şi probe funcţionale CV. **Rezultate şi discuţii**: grupul studiat a cuprins 58 electricieni, 89 de mecanici de locomotivă şi 93 de martori. Măsurătorile CEM de EJF nu au arătat valori care să depăşească valorile maxime admise. Evaluarea stării de sănătate a

evidenţiat modificări EKG: Aritmii s-au găsit la mecanicii de locomotivă (OR=3,11; 95%CI:1,14-8,76) şi la electricieni (OR=3,2; 95%CI:1,08-9,77); tulburări de conducere au apărut la mecanicii de locomotivă (OR=3,57; 95%CI:1,15-13,06) şi la electricieni (OR=9,99; 95%CI:3,28-35,90); există o diferenţă semnificativă între electricieni şi mecanicii de locomotivă (OR=2,8; 95%CI:1,21-6,51). S-au mai găsit modificări de ischemie miocardică la mecanicii de locomotivă (OR=5,4; 95%CI:2,18-5,84) şi la electricieni (OR=5.18, 95%CI:1.93-14.24). **Concluzii:** studierea răspunsului aparatului CV în expunerea profesională la CEN de EJF modificări EKG semnificativ mai frecvente la expuşi: aritmii, tulburări de conducere, şi aspecte de ischemie miocardică; expunerea profesională la CEM părând să fie un factor de risc CV.

Cuvinte cheie: câmpuri magnetice şi electrice, sistemul cardiovascular, modificări EKG

INTRODUCTION

Electromagnetic pollution is a less known but increasingly present reality. One of the most significant contributions to this pollution has been the technological advances associated with the growth of electrical power generation and transmission systems and their use in domestic and occupational situations (1).

The knowledge of the bioeffects of these extremely low frequency (ELF) fields is considerably limited, and cardiovascular (CV) system effects are generally studied in experimental settings, the epidemiologic studies being rather controversial (2,3,4).

According to WHO priorities our study aimed to reveal possible CV effects of occupational exposure to relatively low levels of ELF magnetic and electric fields (5). The study hypothesis stated that long-term, low-level exposure to ELF fields causes clinical and/or electrophysiological changes of CV system.

MATERIAL AND METHODS

The epidemiological design cross-sectional and cohort retrospective studies - departure point for 2 years cohort prospective study - has been performed in order to establish and test exposure-effects associations, and the causality.

We have studied two occupationally exposed lots: 58 electricians exposed in electric transform and transport facilities (age = 40.86 ± 7.11 years, length of service = 17.46 ± 7.50 years) and 89 electric train drivers (age = 43.04 ± 6.28 years, length of service = 18.95 ± 5.67 years). We have used 93 controls (age = 40.58 ± 8.14 years, length of service = 20.05 ± 8.34 years), matched by age and length of service homogeneity and distribution, as well as for the other potential confounding factors: smoking habits, alcohol consumption, known CV risk factors (obesity, stress, sedentariness), occupational and environmental exposure to cardio-toxic substances).

Exposure evaluation included magnetic (magnetic flux density) and electric fields (intensity) measurements and ergonomic analysis. The measuring device was a specific ELF meter (MSI 95 AJK) with uniaxial probes for electric and magnetic fields. Multiple measurements were made in each

workplace in order to define the patterns of ELF fields (6,7).

Health status assessment focused on CV system and comprised detailed occupational anamnesis, clinical and biochemical examinations, ECG, blood pressure measure and CV function tests (Crampton) (8,9). The recording of the heart electrical activity (standard ECG) was performed using a 12 channels computerized electrocardio-graph (Hanover software). ECG analysis especially focused on arrhytmias (sinus arrhytmia, supraventricular arrhythmia, tachycardias, bradycardias, premature atrial or ventricular contractions), and on conduction disturbances (especially minor conduction disturbances), considering the hypothesis of peculiarly interference of ELF fields in sinus impulses genesis and/or in myocardial conductive function (10,11). An analysis of the duration and amplitude of deflections and intervals in the ECG tracing was also performed.

RESULTS AND DISCUSSION

The measurements of the ELF fields are summarized in the following table. The measured values did not exceed general accepted permissible levels.

Table 1. Exposure to ELF fields, by study

Lot	magnetic flux densities (μT)		electric fields intensities (V/m)	
	frequent values	mean	frequent values	mean
electricians	6.4-21.7	14.05±6.26	5300-12200	8104±4930
electric train drivers	0.9-9.6	5.75±3.22	150-360	245±126
controls	0.05-0.8	0.35±0.28	3-10	5.8±3.7

The **health status assessment** revealed a rather poor CV symptomatology and, as well as Crampton test, did not reveal either significant differences vs. control and significant associations with exposure parameters. ECG was extremely important because it showed peculiar ECG diagnoses and peculiarities of ECG tracings, useful evidence for the hypothesis changes.

In the first year of the study we have more frequently found at the exposed, arrhytmias - sinus bradycardias (12.9%), synus tachycardias (4.8%), sinus arrhytmias (2.7%) as well as conduction disturbances consisting in minor conduction disturbances (MCD- 19.7%) and incomplete right bundle brunch block (4.8%). Myocardial ischemia changes (33.33%) have also been found. The ECG changes prevalence was 60.54% in exposed *vs.* 17.2% in controls.

Arrhytmias were found in 20.2% of the train drivers vs. 8.1% in controls, significantly associated with ELF field exposure: Yates'chi square: 5.16, $p < 0.05$, OR = 3.11, 95% CI: 1.14-8.76; Arrhytmias were found in 20.7% of the electricians *vs.* 8.1% in controls also significantly associated with ELF field exposure: Yates'chi square: 4.49, $p < 0.05$, OR = 3.2, 95% CI: 1.08-9.77 (fig.1).

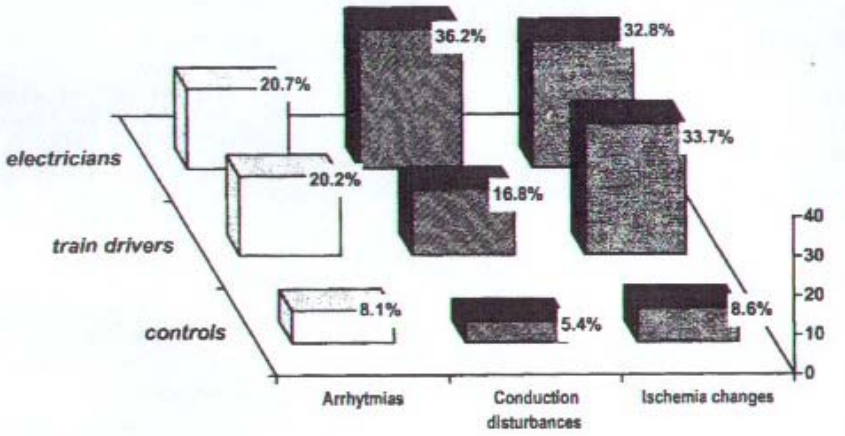

Fig. 1 Possible cardiovascular output of exposure to ELF magnetic and electric fields

Conduction disturbances were found in 16.8% of the train drivers *vs.* 5.4% in controls: Yates'chi square: 5.01, $p < 0.05$, OR = 3.57, 95% CI: 1.15-13.06 (significant association with ELF field exposure); as well as in 36.2% of the electricians *vs.* 5.4% in controls: Yates'chi square: 21.71, $p < 0.00001$, OR = 9.99, 95% CI: 3.28-35.90 (significant association with ELF field exposure).

It is to be mentioned the difference between electricians and drivers: Yates'chi square = 6.1, $p < 0.05$, OR = 2.8, 95% CI: 1.21-6.51, which seems to point out a significantly greater ELF effect on CV system in the case of electricians whose exposure, in terms of both electric and magnetic field is significantly greater ($p < 0.0001$ for means differences for both fields).

Myocardial ischemia changes were found in 33.7% of the train drivers *vs.* 8.6% in controls: (Yates'chi square: 15.87, $p < 0.001$, OR = 5.4, 95% CI: 2.18-5.84), as well as in 32.8% of the electricians *vs.* 8.6% in controls: (Yates'chi square: 12.6, $p < 0.001$, OR = 5.18, 95% CI: 1.93-14.24) (fig.1), which emphasis a significant association with ELF field exposure:

These statistical associations support the hypothesis that occupational exposure to ELF fields is a risk factor for CV system, being involved in underlying mechanisms of conductivity as well as in the etiology of ischemic phenomena (11,12,14).

For better defining associations and interactions, we studied the associations between exposure parameters and ECG aspects suggesting conductive, ischemic

and arrhythmic changes, by using Spearman R nonparametric correlation.

The conduction disturbances significant and medium Spearman R correlation with the length of service in ELF exposure, conditions have been found: $R = 0.52, t = 4.57, p < 0.0001$ for electricians and $R = 0.48, t = 5.04, p < 0.0001$ for train drivers.

For exposure level there were noticed higher correlations for electricians ($R = 0.67, t = 6.74, p < 0.00001$) and for drivers ($R = 0.59, t = 6.82, p < 0.00001$).

The myocardial ischemia changes small but significant correlations ($R = 0.33, t = 2.62, p < 0.01$ for electricians and $R = 0.30, t = 2.98, p < 0.001$ for train drivers) with the length of service, as well as small significant correlations ($R = 0.38, t = 3.05, p < 0.001$ for electricians and $R = 0.34, t = 3.42, p < 0.0001$ for train drivers) with exposure levels have been found.

We found some interesting correlations with exposure levels and length of service, especially for conduction disturbances; if a relation exists with ischemia changes, it seems to interfere with other risk factors.

The first stage of the prospective study showed: a slight increase of effective yearly exposure time (+8% for electricians, respectively +13% for train drivers) and:

- a slight increase, of arrhytmias (+3.4% for electricians, respectively +4.5% for train drivers) and especially of sinus tachycardias, without significant differences when comparing with their prevalence in the first year;
- a slight ascending evolution of conduction disturbances up to 41.4 % (+5.1%) for electricians and up to 19.1% (+2.2%) for train drivers, especially of MCD (up to 22.4%). Even if there were not significant differences (possible due to the small size of the lot), this trend support however a dose effect relationship, especially considering the slight increase of these CV changes in the second year (slightly higher exposure).
- an almost steady state of myocardial ischemia changes (+0.7% in the second year).

The above ascending trends were attributable to longer and greater exposed subjects.

Until now, the longitudinal study confirms previous findings and reveals evolutionary aspects pertinent to the studied hypotheses argumentation.

There is ongoing survey and analysis.

CONCLUDING REMARKS

The study of CV effects in ELF fields exposure, revealed significantly frequent ECG changes: arrhytmias, conduction disturbances, and myocardial ischemia changes.

This hypothesis statistically and epidemiologically emphasized by means of revealing causal relationships of exposure with CV changes, has put into evidence a real scientific challenge. These findings revealed the importance of our research realized on humans occupationally exposed to ELF electric and magnetic fields below general accepted standards.

The ELF fields occupational exposure seems to be a CV risk factor direct

and/or indirect involvement of these fields in the genesis of complex changes of myocardial excitability and conductivity, as well as in the ischemia pathogenesis.

Our study stimulates the research both in the direction of improvement ECG diagnosis by Holter method in ELF exposure, and in the direction of better understanding the intimate interaction mechanisms of these fields (13).

Further survey could confirm if these findings are important not only for occupational health (by requiring health protection standards revision) but also for cardiology, by calling cardiologists' attention to evaluate potential hazards in occupational settings including ELF.

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