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Changes in excretion rates of stress hormones in medical staff exposed to electromagnetic radiation

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Abstract The aim of this paper is to study the effect of electromagnetic radiation (EMR) on the excretion rates of stress hormones of medical staff in physiotherapy. The excretion rates of stress hormones cortisol, adrenaline and noradrenaline were followed during morning shift in 15 female physiotherapists using RIA kits and a spectrofluorimetric method. The mean number of treatments with EMR emitting devices per month and the emission of each device was assessed. A control group of nurses, matched by age, sex and work task was used. The psychosocial factors were evaluated and no differences between the two groups was found. Calculations of the individual EMR exposure show levels above the ICNIRP guidelines. Significantly higher excretion rates of cortisol, adrenaline and noradrenaline among the studied physiotherapists in comparison with the control group of nurses were found. In conclusion, our data showed that EMR influenced the excretion rates of stress hormones of medical staff in physiotherapy.

Keywords Cortisol · Adrenaline · Noradrenaline · Medical staff · EMR exposure

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1 Introduction

The medical staff is exposed to different occupational stressors, some rising health and well being concerns (Deane et al. 2002; Elfering et al. 2002; Fujiwara et al. 2004). Little is known about stress at work of the medical staff in physiotherapy, exposed to some common for the medical staff stressors as risk of infections, emotional load of dealing with patients, heavy lifting, exposure to chemicals, but also some specific stressors as the exposure to electromagnetic radiation (EMR) from different devices as equipment for microwave and high frequency diathermy, pulsed magnets, d'Arsonvale devices, optical sources (UV, IR and visible), lasers etc.

The effect of EMR on the stress system is not well studied and most data concern the effect of radiofrequency EMR emitted from mobile phones, broadcasting and TV transmitters. Mann et al. (1998) studied several endocrine parameters in humans exposed at night to a low level (0.2 W/m^2) radiofrequency field from mobile phones at 900 MHz and found a transient 1 h increase in cortisol during the first hour of the exposure. Radon et al. (2001) failed to find an effect of low-level pulsed radiofrequency EMR (carrier frequency 900 MHz, pulsed frequency 217 Hz, average power flux density of 1 W/m^2) on the salivary cortisol. Our earlier data (Vangelova et al. 2002) showed a trend for increase in 11-oxycorticosteroid (11-OCS) excretion rates in operators, working under low-level radiofrequency EMR. Another our study (Vangelova and Israel 2005) showed dose-effect relationship between the excretion of stress hormones and EMR exposure levels.

The aim of the investigation was to study the effect of EMR on the excretion rates of stress hormones of medical staff in physiotherapy.

2 Material and methods

2.1 Subjects

We investigated 15 female physiotherapists, aged 49.5 ± 7.4 years with average length of service 26.4 ± 7.7 years, working in four hospital physiotherapies in Sofia. A control group of nurses, matched by age, work organization and having similar job task was studied. The control group was of average age 48.9 ± 6.9 years and length of service 25.8 ± 7.3 years. All the investigated subjects worked fast-rotating two-shift system: morning shifts (7:30 a.m.–2:00 p.m.) and afternoon shifts (1:30–8:00 p.m.). The investigated subjects have signed informed consent for participation in the study.

2.2 EMR exposure

The method for EMR exposure assessment is presented in details elsewhere (Israel and Tschobanov 2006). In general, the method is based on the following:

In order to establish unified conditions for exposure assessment for different frequencies (over the overall frequency range) we apply a general unified indicator associated with the energetic irradiation dose, according to both—the ICNIRP Guidelines, and the Bulgarian National Standards.

The energy load of the human organism is defined for three cases as a derived quantity of energy falling at external irradiation:

$$W_E = E^2 \cdot T, \quad (V/m)^2 \cdot h,$$

$$W_H = H^2 \cdot T, \quad (A/m)^2 \cdot h,$$

and

$$W_S = S \cdot T, \quad \mu W/cm^2 \cdot h,$$

based on dispersed energy per unit time on human body during the official working shift. W_E, W_H and W_S are the values of the energy load of the organism when the body is exposed to *E*, *V/m*—electric field strength; *H*, *A/m*—magnetic field strength (both in near field zone); and *S*, $\mu W/cm^2$—power density in the far field zone, for time duration of expsosure *T*, *h*.

As the Specific Absorption Rate *SAR*, *W/kg* is used for whole body exposure assessment for an adult man (175 cm/70 kg); and the Specific Absorption *SA*, *J/kg*, the dimension of *SAR* by the time is used for comparison with the energy load of the organism (they both—*SA* and *W* have dimension of energy).

The two types of quantities—W_E, W_H and W_S on the one side, and *SAR*, *SA* on the other do not differ substantially in conditions of air equivalent environment and a human body situated in it.

We divide the time of being in the working environment with non-ionizing radiation (NIR) into two sets of intervals for exposure duration: real exposure time at work with a device T_{app} [*h*], and a total duration of the working shift *T* [*h*]. The difference between them is so called ''void time'' when there is no real exposure (''zero'' exposure).

We use the ''chronometer scenario'' method because the void time has no equipartioned-averaged evaluation. The duration time is introduced by the number of devices and the number of patients serviced by the individual.

The measuring method is unified as the following parts of its nature: equipment; distances to the particular device, mandatory for the measurement—six distances depending on the frequency range (the wavelength); list with the mandatory restrictions to the behavior of the operator, performing the measurement.

The method was used for assessment of the exposure in several physiotherapy units. Assessment of the exposure in those units is shown on Table 1. There *j*, mA/m^2 is the calculated current density, and *J*, mA/m^2 is the basic

Table 1 Characteristics of the EMR emitting devices and exposure in physiotherapy

Frequency	Devices	Calculated parameter	Basic restriction ICNIRP Guidelines
≤2 kHz	Pulsed ''magnets''	$j \approx 0.28/0.31$ A/m^2	$J \leq 2$ mA/m^2
≤2 kHz	Interferentz	$j \approx 0.69$ mA/m^2	$J \leq 2$ mA/m^2
$f \leq 2.5$ kHz	Generator for ultrasound therapy	$j \approx 3.8$ mA/m^2	$J \leq 2$ mA/m^2
≤100 kHz	Diadynamik (Bulgaria)	$j \approx 0.15$ mA/m^2	$J \leq 1$ A/m^2
≤100 kHz	Galvanostat	$j \approx 0.15$ mA/m^2	$J \leq 1$ A/m^2
150/300 kHz	D'Arsonval	SAR ≤ 0.4 W/kg	0.4 W/kg
27,12 MHz	UHF devices	SAR = 3.71/9.78 W/kg	0,4 W/kg
2450 MHz	Medical radar	SAR = 0.31/5.3 W/kg	0.4 W/kg whole body 20 W/kg for limbs 10 W/kg for head

restriction proposed by ICNIRP Guidelines. Calculating the relative values for the whole frequency range in the studied physiotherapies the obtained quota is much larger than 1.

2.3 Light sources (polychromatic)

Quartz (UVB-1, UVB, UVA, Visible: S ≈ 17.6 mW/cm^2
Solux Infrarouge, without filters: S ≈ 286.1 mW/cm^2
Solux Infrarouge, with filter B1: S ≈ 4.9 mW/cm^2

2.4 Noise and microclimate

The noise and microclimate were measured, too, and they were found to be within the hygienic limits with no differences between the groups.

2.5 The psychosocial factors

The psychosocial factors were assessed by the questionnaire ''My job'', based on checklists, containing five subscales (Kompier et al. 1994). The working condition scale contains items about work posture, lighting, noise, vibrations, temperature, humidity, flow, dust, odors, etc. The job content scale sums eighteen items as a monotony, tasks, requiring intense concentration, time pressure, work organization, etc. The job control scale includes ten items such as novelties at work, control of schedule of patients, methods of work, promotion, etc. The work related social support scale sums ten items: five ones concerning support from co-workers and five from supervisors. Health complaints scale is the sum of sixteen items.

2.6 The excretion rates of stress hormones

The excretion rates of stress hormones were followed during the morning shift (7:30–14:00). The following three periods were studied: early morning (6:30 – 8:30), second period (8:30–11:00) and third period (11:00–13:30). The urine aliquids were stored at –20°C and the subsamples for catecholamine assay were acidified to pH 3 with 6N HCL prior refrigeration. Urine free cortisol was assessed by radio immunological kit (Orion Diagnostica, Espoo, Finland): interassay CV 5.2, 5.2, 6.1% for low, mean and high value urine samples. The catecholamines adrenaline and noradrenaline were measured with spectrofluorimetric method (Vangelova 2000).

2.7 Statistics

The effect of EMR exposure and time-of-day variations of the studied stress hormones were analyzed with between-subjects effects (SPSS). Variation analysis (one-way ANOVA) and correlation analysis were used to calculate the psychosocial factors and the relationships between the studied variables.

3 Results

Our data show no significant differences of psychosocial factors between the exposed and control group (Table 2). The studied physiotherapists and control group had a feeling of strain at work and emotional load of dealing with patients, increased risk of infections, heavy lifting and work tasks, requiring concentration. The working conditions were described as moderate, but the physiotherapists found the lighting unsatisfactory. The number of psychosomatic complaints is comparatively high with both studied groups, slightly higher for physiotherapists in comparison to the control group of nurses. The main psychosomatic complaints were musculoskeletal disorders (pain in the back, bones and muscles), numbness and/or timbling sensation in the limbs, physical and mental exhaustion, fatigue, dizziness, etc.

Significantly higher excretion rates of cortisol among the physiotherapists in comparison to the control group were found (Fig. 1, Table 3). The excretion rates of cortisol followed the typical diurnal rhythm with highly significant time-of-day variations.

The adrenaline excretion rates (Fig. 2, Table 3) were significantly higher in the studied physiotherapists in comparison to the control group. Also, significantly higher excretion rates of noradrenaline (Fig. 3, Table 3) with the physiotherapists in comparison to the nurses were found. On Table 3 it can be seen that the effect of EMR on noradrenaline excretion rates was the most significant. Also, the effect of time-of-day on cortisol excretion rates was more significant in comparison to the effect of EMR indicating preservation of the circadian rhythm of the

Table 2 Psychosocial factors in the two groups—exposed to EMR and control group

Scales/Groups	Maximal scores	Exposed group	Control group
Working conditions	17	7.1 ± 3.0	7.1 ± 9.8
Work content	16	5.4 ± 3.2	7.0 ± 3.2
Control	10	2.9 ± 2.02	5.3 ± 1.8
Social support	10	2.3 ± 1.9	2.6 ± 2.4
Psychosomatic complains	16	9.4 ± 3.3	8.9 ± 2.7

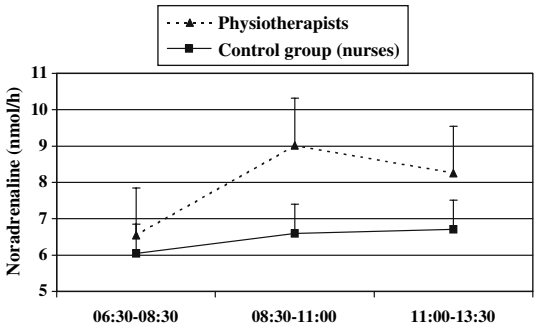


Fig. 1 The excretion rate of cortisol in physiotherapists exposed to EMR and control group

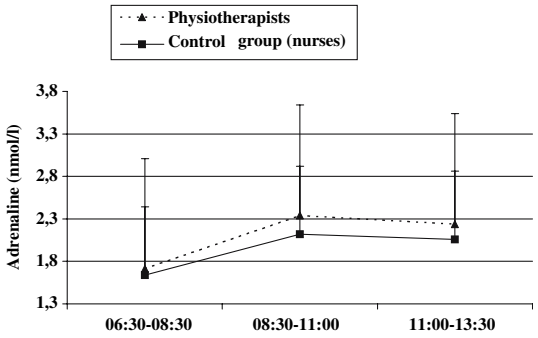


Fig. 2 The excretion rates of adrenaline in physiotherapists exposed to EMR and control group

Table 3 The between subject effects (SPSS) of EMR and time-of-day on cortisol, adrenaline and noradrenaline in physiotherapists in comparison to control group

Indices	Cortisol	Adrenaline	Noradrenaline
$EMR_{(df = 1,69)}$	$F = 7.171$	$F = 7.869$	$F = 10.643$
	$p = 0.009$	$p = 0.007$	$P = 0.002$
$Time\text{-}of\text{-}day_{(df = 2,69)}$	$F = 12.231$	NS	NS
	$p = 0.000$		

hormone under EMR exposure. The time-of-day variations of adrenaline and noradrenaline were not significant.

4 Discussion

Our data show significant effect of EMR radiation on the excretion rates of stress hormones during the working day. The work conditions, work content, work control and psychosocial support showed no significant differences between the exposed and control group. No acute incidents and changes in the task requirements among the groups during the period of the study were registered. The number of treatments in the studied physiotherapy units did not exceed the number of treatments by the studied control

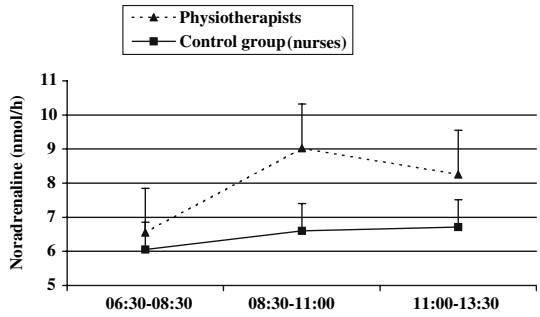


Fig. 3 The excretion rates of noradrenaline in physiotherapists exposed to EMR and control group

group. The studied physiotherapists had no complains concerning the EMR emissions and were not aware of the level of the exposure during the study.

The present study confirmed our previous data (Vangelova et al. 2002; Vangelova and Israel 2005) for significantly higher excretion rates of stress hormones under EMR exposure, the highest for noradrenaline.

There is data that the long-term effects of increased secretion of stress hormones or changes in their circadian rhythms are associated with functional disorders and health implications (McEwen 1998; Tsigos and Chrousos 2002). The increased level of catecholamines adrenaline and noradrenaline influences the heart rate, blood pressure, etc. Recent studies clearly showed interaction between work stress related cortisol secretion and anthropometric, endocrine, metabolic and hemodynamic variables (Fraser et al. 1999; Chrousos 2000). Furhter, stress hormones affect the immune function (Rosmond et al 1998).

The results of our study show significant increase of stress hormones (catheholamines and cortisol) under exposure of EMR in physiotherapy that can be associated with increase of the health risk. This result is in accordance with the papers cited above but under influence of other stressors (not only EMR). Further studies are needed to evaluate the effect of different EMR exposure on stress system.

Summing up, significantly higher excretion rates of stress hormones in the medical staff under EMR exposure in physiotherapy were found. As outlined above, the chronic elevation of stress hormones may be associated with health implications. Reduction of EMR exposure in physiotherapy both by technical solutions and limiting the time of exposure should be encouraged.

References

Chrousos, G. P. (2000). The role of stress and the hypothalamic-pituitary-adrenal axis in the pathogenesis of metabolic syndrome: Neuroendocrine and target tissue-related causes. *International Journal of Obesity, 24*(Suppl. 2), S50–S55.

Deane, R., Chummun, H., & Prashad, D. (2002). Differences in the urinary stress hormones in male and female nurses at different ages. *Journal of Advanced Nursing, 37*(3), 304–310.

Elfering, A., Grebner, S., Semmer, N. K., & Gerber, H. (2002). Time control, catecholamines and back pain among young nurses. *Scandinavian Journal of Work and Environmental Health, 28*(6), 386–393.

Fraser, R., Ingram, M. C., Anderson, N., Morrison, C., Davies, E., & Connell, J. M. C. (1999). Cortisol effects on body mass, blood pressure, and cholesterol in general population. *Hypertension, 3*, 1374–1378.

Fujiwara, K., Tsukishima, E., Kasai, S., Masuchi, A., Tsuts, A., Kawakami, N., Miyake, H., & Kishi, R. (2004). Urinary catecholamines and salivary cortisol on workdays and days off in relation to job strain among female health providers. *Scandinavian Journal of Work and Environmental Health, 30*(2), 129–138.

Israel, M., & Tschobanoff, P. (2006). Exposure to non-ionizing radiation of personnel in physiotherapies. In S. N. Ayropetyan & M. S. Markov (Eds.), *Bioelectromagnetics: Current concepts* (pp. 367–376). Springer Press.

Kompier, M., & Levi, L. (1994). Stress at work: causes, effects and prevention. A guide for small and medium sized enterprises. European Foundation for Improvement of Living and Working Conditions. Geneva.

Mann, K., Wadner, P., Brunn, G., Hassan, F., Hiemke, C., & Roschke, J. (1998). Effects of pulsed high frequency electromagnetic fields on the neuroeudocrine system. *Neuroendocrinol, 67*, 139–144.

McEwen, B. S. (1998). Protective and demaging effects of stress mediators. *New England Journal of Medinine, 338*(3), 171–179.

Randon, K., Parera, D., Rose, D-M., Jung, D., & Vollrath, L. (2001). No effects of pulsed radiofrequency electromagnetic fields on melatonin, cortisol and selected markers of the immune system in men. *Bioelectromag, 22*, 280–287.

Rosmond, R., Dallman, M. F., & Bjorntorp, P. (1998). Stress related cortisol secretion in men: Relationships with abdominal obesity and endocrine, metabolic and hemodinamic abnormalities. *The Journal of Clinical Endocrinology and Metabolism, 83*, 1853–1859.

Tsigos, C., & Chrousos, G. P. (2002). Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress. *Journal of Psychosomatic Medicine, 53*(4), 865–871.

Vangelova, K. (2000). Method for assessment of catecholamines adrenaline and noradrenaline in urine. In: Methods for Investigations in Hygiene. *National Center of Hygiene, Medical Ecology and Nutrition, Sofia, 2*, 2–4 (in Bulgarian).

Vangelova, K., Israel, M., & Mihailov, S. (2002). The effects of low level radiofrequency electomagnetic radiation on the excretion rates of stress hormones in operators during 24 hour shifts. *Central European Journal of Public Health, 10*, 23–27.

Vangelova, K., & Israel, M. (2005). Variations of melatonin and stress hormones under extended shifts and radiofrequency electromagnetic radiation. *Reviews on Environmental Health, 20*(2), 151–161.