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BIOELECTRICAL PARAMETERS OF PEOPLE EXPOSED TO RADIOFREQUENCY IN WORKPLACE AND HOUSES PROVIDED TO WORKERS

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ABSTRACT

The affects of radiofrequency (RF) and microwave radiation in workplace have been a subject of continuing investigations. One of the major exposed groups is workers and their families who have been working and living in houses provided to employees of these stations. Therefore, the present study intended to investigate the effect of RF emitted from antenna of 1062 kHz medium wave radio-broadcasting station on bioelectrical parameters of workers and their families living in houses provided to employees of these stations.

The study was carried out on 20 men working in radio-broadcasting station, 11 women and 30 voluntary children (Boy: 15, Girl:13) living in houses provided to workers of the station.

Five bioelectrical parameters such as resistance, reactance, phase angle, body capacitance and basal metabolic rate (BMR) were measured.

E field and power density inside houses was between 0.48 V/m - 2.86 V/m and 0.0001 mW/cm² - 0.0023 mW/cm² respectively. However, the average E field and power density in the playing area of the children was 12.75 V/m and 0.0436 mW/cm². Average E field and power density in the control room desk and around the workplace was 4.04 V/m, 0.0042 mW/cm² and 31.88 V/m, 0.348 mW/cm² respectively.

The results of this study showed that the parameters such as phase angle (°), body capacitance (pF) and reactance (Ω) of girl group were decreased according to control group ($p < 0.01$). In conclusion, some bioelectrical parameters of the children who have been living in houses provided to employees of radio broadcasting stations can be affected by radiofrequencies.

Keywords: bioelectrical parameters, radiofrequencies/microwave, radio-broadcasting station, body capacitance, phase angle, reactance

Abbreviations: RF - radiofrequency, BMR- basal metabolic rate, RFR - Radiofrequency radiation, ELF - the extremely low frequency, AM - amplitude modulation, FM- frequency modulation, VHF - very high frequency, TV - television, UHF - ultrahigh frequency, R - resistance, X - reactance, α - phase angle, C - capacitance, BIA - Bioelectrical Impedance Analysis.

Introduction

Radiofrequency radiation (RFR) occupies the range from 100 kHz to 300 GHz in the electromagnetic spectrum. RFR is a higher frequency (shorter wavelength) than the extremely low frequency (ELF) radiation used in electric power sources, and a lower frequency than infrared radiation (9, 24). This range is used for radiofrequency (RF) communications and microwave sources, including in approximate order by increasing frequency medium wave (MW) radio, amplitude modulation (AM) radio, frequency modulation (FM) radio, very high frequency (VHF) radio and television (TV), ultrahigh frequency (UHF), TV and cellular telephone transmissions and microwave ovens, radar and satellite communications. Natural RFR is negligible, so population exposure is a phenomenon of the current century,

and has increased greatly in recent years (9). People may be exposed to RFR both occupationally and in normal life. On the other hand, children may also be exposed to RFR radiation because of living near to broadcasting station.

There are several studies in relation to population and children exposure to RFR. Dolk et al. (8) identified all 21 radio and TV transmitters in Britain with transmission power of over 500 kW for TV or 250 kW for FM radio, including Sutton Coldfield an inner circle of 2 km, an outer circle of 10 km of residence. They used data for up to 12 years, which were based on a total population living within 10 km of any transmitter of 3.39 million people. The associations suggested by the Sutton Coldfield's study (with adult leukemia, skin melanoma, and bladder cancer) were tested by a new analysis based only on all the other transmitters, excluding Sutton Coldfield. Leukemias and brain cancers in childhood were also examined using data from all 21 sites. There was no significant increasing risk for either disease within the inner 2-km circle or in the over all 10-km circle, and no regular variation with distance. Some authors assessed cancer incidence and mortality around three TV transmitters in northern Sydney (10). Three towers emit TV transmissions in the range of 60 to 215 MHz with one additional channel at approximately 500 MHz. In the study, there was an increased incidence of childhood leukemia and a stronger association of childhood leukemia in correlation

to adult leukemia, which is in contrast with the British data, showing no clear excess in children. However, the authors conclude more detailed studies (e.g., relating cases to power density contours) are required to replicate any association and to look for dose-response relationships before any conclusions can be drawn (10). Cartwright (2) noted that studies cited by Hocking et al. (10) did not unequivocally support their findings. Cartwright also stressed that a more complete knowledge of the causes of childhood leukemia is essential before progressing from association to causation. Mc Kenzie et al. (18) reanalyzed the data obtained by Hocking et al. (10) and determined that one highly-exposed local government area contributed all of the excess. When that area was excluded from the analysis, there was no longer any positive correlation. Kolodynski and Kolodynska (13) reported differences in motor and psychological functions between 11 children living in the area of the radar station and 'control' children living in another region. However, James and Coghill (12) cited Kolodynski and Kolodynska (13) and reported that yet strong evidence for a link between radar exposures in these areas and health effects did not exist. In a recent study of Hocking and Gordon (11), there was an association between residential proximity to the television towers and decreased survival among cases of childhood leukemia in North Sydney, Australia.

Due to the contradictory results in relation to children and adult peoples exposed to RF radiation, and insufficient number of the study on RF exposure and bioelectric parameters, we aimed to investigate the effect of occupational RF exposure on the bioelectrical parameters such as resistance (R), reactance (X), phase angle (α), body capacitance (C) and basal metabolic rate (BMR) of workers, women and children living near the radio-broadcasting station.

Materials and Methods

The study was carried out on 31 workers and women living in houses provided to workers (20 male, 11 female, age: 27-46) and 28 voluntary children (Boy:15, Girl:13, age 5-15) living in houses provided to workers of radiobroadcasting station. Subjects in the control groups were same as age, weight, height and socioeconomic condition with experimental group (adult: 16 male, 15 female, age 27-45; children: 16 boys, 18 girls, age 5-15). The output power, frequency and wavelength of radiobroadcasting station were 300 kW, 1062 kHz (Medium Wave (MW)) and 282.48 m (**Fig. 1**).

The bioelectrical parameters of the subjects in the study were measured by Bioimpedance Analyzer (Biodynamics Model 450, USA). Before four hours analysis, subjects did not exercise and eat something. For BIA (Bioelectrical Impedance Analysis) measurements, subjects lied face up on an examination table in a supine position. Two pairs of sensor electrodes (ECG pads) were placed on the subject's right hand and wrist, and right foot and ankle. Using the Bioimpedance Analyzer's keypad, the subject's gender, age, height and weight were entered. Then, BIA measurement was performed and printout was generated by pressing a button (Biodynamics

Corp., 2007). Power density and E field in working area, houses, playing area of children and around of working area were measured by an electromagnetic field meter (EMR-300, Narda, Germany). Statistical analysis was performed with SPSS 10.0 package (SPSS Inc, Illinois, USA). The analysis of differences between experimental group and control group for each variable was performed using Mann Whitney U-test.



Fig. 1. A view from measurement of area

Results and Discussion

The results of this study showed that RF emitted from the antenna of 1062 kHz medium wave radio-broadcasting station does not affect the bioelectrical parameters and basal metabolic rate of the subjects in this study except some measured parameters of girls ($p > 0.05$) (**Tables 1, 2, 4**). Because of that, some of bioelectrical parameters such as phase angle, body capacitance and reactance of girls exposed to RFR were found to be lower than that of the control subjects ($p < 0.01$) (**Table 3**).

E field and power density inside of the houses measured as between 0.48 V/m- 2.86 V/m and 0.0001 mW/cm² - 0.0023 mW/cm² depend on distance from the antenna. However, the average E field and power density in playing area of the children was 12.75 V/m and 0.0436 mW/cm², respectively. The average E field and power density out of the playing area and houses was 18.64 V/m and 0.0971 mW/cm², respectively. The average E field and power density in the control room desk and around of the workplace was 4.04 V/m, 0.0042 mW/cm² and 31.88 V/m, 0.348 mW/cm², respectively.

TABLE 1

Bioelectrical parameters of men working in the station and living in houses provided to workers

Parameters	Experimental Group Mean $\pm$ S.D (n:20)	Control Group Mean $\pm$ S.D (n:16)	p
Phase Angle ($^{\circ}$)	7.265 $\pm$ 0.620	7.231 $\pm$ 0.641	p>0.05
Body Capacitance (pF)	854.400 $\pm$ 145.940	809.125 $\pm$ 161.142	p>0.05
Resistance (Ω)	476.395 $\pm$ 59.162	501.456 $\pm$ 63.113	p>0.05
Reactance (Ω)	60.665 $\pm$ 7.658	63.168 $\pm$ 6.902	p>0.05
Basal Metabolic Rate (kalori)	1921.100 $\pm$ 235.399	1837.313 $\pm$ 202.281	p>0.05

TABLE 2

Bioelectrical parameters of women living in houses provided to workers

Parameters	Experimental Group Mean $\pm$ S.D (n:11)	Control Group Mean $\pm$ S.D (n:15)	p
Phase Angle ($^{\circ}$)	6.527 $\pm$ 0.456	6.473 $\pm$ 0.640	p>0.05
Body Capacitance (pF)	649.363 $\pm$ 143.317	626.866 $\pm$ 81.733	p>0.05
Resistance (Ω)	574.136 $\pm$ 101.032	571.686 $\pm$ 51.563	p>0.05
Reactance (Ω)	65.309 $\pm$ 8.965	64.700 $\pm$ 8.965	p>0.05
Basal Metabolic Rate (kalori)	1493.0 $\pm$ 220.677	1413.200 $\pm$ 104.193	p>0.05

TABLE 3

Bioelectrical parameters of girls living in houses provided to workers

Parameters	Control Group Mean $\pm$ S.D (n:18)	Experimental Group Mean $\pm$ S.D (n:13)	p
Phase Angle ($^{\circ}$)	6.822 $\pm$ 0.936	5.669 $\pm$ 0.407	p<0.01
Body Capacitance (pF)	546.388 $\pm$ 98.857	447.230 $\pm$ 77.356	p<0.01
Resistance (Ω)	694.566 $\pm$ 73.473	711.400 $\pm$ 88.039	p>0.05
Reactance (Ω)	83.016 $\pm$ 14.477	70.207 $\pm$ 7.311	p<0.01
Basal Metabolic Rate (kalori)	832.222 $\pm$ 146.737	789.692 $\pm$ 229.081	p>0.05

TABLE 4

Bioelectrical parameters of boys living in houses provided to workers

Parameters	Control Group Mean $\pm$ S.D (n:16)	Experimental Group Mean $\pm$ S.D (n:15)	p
Phase Angle ($^{\circ}$)	6.118 $\pm$ 0.688	5.833 $\pm$ 0.482	p>0.05
Body Capacitance (pF)	475.062 $\pm$ 83.757	452.666 $\pm$ 68.832	p>0.05
Resistance (Ω)	720.587 $\pm$ 73.675	718.206 $\pm$ 63.638	p>0.05
Reactance (Ω)	77.006 $\pm$ 9.536	73.046 $\pm$ 6.120	p>0.05
Basal Metabolic Rate (kalori)	785.750 $\pm$ 125.358	706.466 $\pm$ 169.261	p>0.05

The application of the bioelectric impedance analysis (BIA) method is growing in popularity because it is safe, noninvasive, rapid, portable, inexpensive, easy to use, and amenable for laboratory, clinical, and field assessment of human body composition. Recently, great advances were made in the art of accurately measuring the electrical properties of matter (14). However, giving the definition of some BIA parameters such as resistance, reactance, phase angle, body capacitance and basal metabolic rate would help to understand physics of BIA.

Resistance and reactance are terms from physics which are part of the complex field of materials and their effects on electricity. Resistance is the ratio of electrical potential (voltage) to the current in a material. A material with low resistance conducts well, while a material with high resistance conducts poorly. In the human body, low resistance is associated with large amounts of fat-free mass. High resistance is associated with smaller amounts of fat-free mass. Reactance is the effect on an electrical current caused by a material's ability to store energy. Reactance is seen as a time delay between an applied electrical potential and current. A material that stores energy readily has high reactance, and causes a large delay in the current. A material that stores energy poorly has low reactance and causes a small delay in the current. In the human body, high reactance is associated with large amounts of body cell mass (intracellular mass). Low reactance is associated with smaller amounts of body cell mass. Phase angle is proportional to the ratio of reactance and resistance. Phase angle is an indicator of cellular health and integrity. Research in humans has shown that the relationship between phase angle and cellular health is increasing and nearly linear. A low phase angle is consistent with an inability of cells to store energy and an indication of breakdown in the selective permeability of cellular membranes. A high phase angle is consistent with large quantities of intact cell membranes and body cell mass (1).

Body capacitance is the total energy storage capacity of the body cell mass compartment. A high capacitance is an indicator of large quantities of intact cellular membranes. A low capacitance indicates lower quantities of intact cellular membranes. Capacitance is determined by the number and quality of cell membranes contained within the body cell mass compartment. Basal metabolic rate (BMR) is the number of calories metabolized at rest during 24 hours (1).

Certain organs and organ systems are reported to be affected by RF, in terms of functional disturbance, structural alterations, or both. Some reactions to RF exposure may lead to measurable biological effects that remain within the range of normal (physiological) compensation. Some reactions, on the other hand, may be potential or actual health hazards (16).

Some of the studies indicated a possible effect of RF radiation on children and adults (2, 4-6, 8, 10-13, 15, 18-20). However, the results of the studies are inconsistent. One of the areas, which have insufficient number of the studies, is the effect of RF radiation on bioelectrical parameters of human being. Therefore we planned the present study. The results of this study showed that RF emitted from the antenna of 1062

kHz medium wave radio-broadcasting station does not affect the bioelectrical parameters and basal metabolic rate of the subjects in this study except some parameters measured in girl group ($p > 0.05$). The bioelectrical parameters such as phase angle, body capacitance and reactance of girls exposed to RFR were found to be lower than that of the control subjects ($p < 0.01$).

It is reported that electromagnetic fields may affect the body mass (7, 23). However, generally, the results of the present study were supported by some studies that observe relation between RF and metabolism (17, 22). Ray and Behari (21) investigated the effect of exposure to sub lethal levels of microwaves. The authors measured several physiological parameters during and after microwave exposure in both control and exposed animals. The study indicated that the animals exposed to microwaves tended to eat and drink less and thus showed a smaller gain in body weight. It is proposed that a nonspecific stress response due to microwave exposure and mediated through the central nervous system is responsible for the observed physiological changes. The results of bioelectrical parameters measured in girls of this study may be explained by the suggestion of the study mentioned above.

However, Celik et al. (3) investigated the nutritional status of people occupationally exposed to RF. The authors determined that the mean of lipid, carbohydrates, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids and sodium intake were significantly different from standard values. The results of Celik et al. (3) indicated that RF radiations can affect the metabolism of people exposed to RF radiation.

Conclusions

In conclusion, some bioelectrical parameters of the children who have been living in houses provided to employees of radio broadcasting stations can be affected by radiofrequencies. However, further studies are necessary.

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