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Physical Activity Program as a Fitness Tool for Workers Exposed to Electromagnetic Field

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Abstract: Electromagnetic field (EMF) exposure at low frequencies may cause some health problems. The present study was designed to test the effect of a comprehensive physical activity program on some fitness aspects of exposed workers with emphasis on cardio-autonomic control. A pre-test post-test experimental design was adopted. A representative sample of 30 workers exposed to low frequency EMF from Abou Qir electrical power station, Alexandria, were included in the study after fulfilling eligible criteria. Each one of the workers was subjected to a predesigned questionnaire including inquiries about sleep pattern subjective symptoms, and work and health satisfaction. Measurements of anthropometric indices, resting heart rate and blood pressure were done. Resting 12 lead ECG and R-R variability test during deep breathing were performed. A venous blood sample was taken for serum cholesterol and complete blood count determination. All these parameters were measured for the participants before and after implementation of a standardized physical activity program (PAP) for 12 weeks. Results revealed significant improvement of some subjective and general complaints, and work and health satisfaction (p<0.05 for all). Heart rate, systolic blood pressure and R-R variability indices showed significant favorable effect of the PAP in the direction of augmenting the protective parasympathetic tone. In conclusion, PAP for workers exposed to EMF seems to be a good tool to improve their fitness and to ameliorate some health risks, emphasizing its importance in preventive implications.

INTRODUCTION

Electromagnetic field (EMF) is determined by the force effect due to summation of electric and magnetic fields. It comprises a broad spectrum of non-ionizing radiation.[1,2] Extremely low frequency EMF is existing whenever electric wiring, electric

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motors and electric devices are found. Exposure may occur at home, at job and in electric vehicles. Workers in electric utilities and nearby power lines are at great risk.[1] the magnetic component of exposure is the suspicious part of low frequency EMF especially among electric utility workers.[3]

On the other hand, high frequency EMF is another issue expressed as radiofrequency radiation which is present in many fields including mobile phones and their base stations.[4,5]

Since the late part of the 20th century there is increasing interest in the health effects of low frequency EMF especially in the form of subjective complaints including neurasthenic symptoms and sleep troubles, disturbances in cardiovascular and gastrointestinal functions and transient hematologic changes.[6] There are also, some existing concerns about childhood leukemias and certain types of cancer.[7] Metabolic parameters including cholesterol may be adversely affected due to exposure to low frequency EMF.[8] Cardiovascular diseases among electric utility workers were studied.[3,9-11] Indices of magnetic field exposure were consistently related to mortality from arrhythmia.[3,11] Heart rate and heart rate variability may be affected by this exposure in a pattern suggesting the domination of sympathetic activity and imposing further cardiovascular risk.[12,13]

Most of the reported health findings due to exposure to low frequency EMF seems to be related to workers' fitness and autonomic nervous control.[6] According to the latest guidelines,[14] all healthy adults aged 18-65 should be getting at least 30 minutes of moderate intensity activity five days of the week. Implementation of a physical activity program was shown to raise fitness, increase productivity and damp many health problems among workers.[15] The outcome of a physical fitness program for workers will be increased if properly designed with its different physical components by a

specialist.[16]

The present study was designed to test the effect of a comprehensive physical activity program on some fitness aspects of workers exposed to low frequency EMF with special emphasis on cardiac autonomic nervous control.

Subjects and Methods

Study design: Before and after experimental study.

Study setting: Abou Qir Electrical Power station, in Alexandria was selected as an example of utilities where workers are exposed to low frequency EMF. The exposure level in the permissible work areas ranged between 50-60 Hz as was obtained from the company records.

Study population: A representative sample of 30 male workers not engaged in any type of physical exercising, with the age range between 30-49 years, with duration of exposure not less than 5 years, and free from chronic diseases including diabetes mellitus, hypertension and unstable coronary artery disease. All the subjects working in the same work shift, fulfilling administrative agreement and gave a concent about their participation were included.

Methods:

Before program measurements:

Each one of the study sample was inquired about his personal, socioeconomic and occupational data. All participants answered a predesigned questionnaire, including 15 questions with 3 point answers (yes, no & sometimes) about sleep pattern, general complaints, cardiovascular and gastrointestinal symptoms. Two questions were addressed about work and health satisfaction with a score from 0 to 10 with zero not at all, and ten fully satisfied. Also, they were asked about sleep hours.

Measurements of weight (Wt), height (m), body mass index (BMI kg/m^2), resting heart rate (HR), systolic (SBP) and diastolic blood pressure (DBP) according to the standard methods.[17]

A resting standard 12 lead electrocardiogram (ECG) was performed for each subject in the supine position without any meal taken in the preceding one hour at least. The R-R deep breathing variability test was done by recording the bipolar limb lead II for one minute, while each examinee breathed deeply six times (inspiration and expiration for 5 seconds each) to produce maximal R-R interval variation at a constant respiratory frequency. The ECG machine was operated at the standard rate of 25 mm/second. The intervals of the tracings were measured by a digitizer. The maximum R-R interval (R-R max) and the minimum R-R interval (R-R min) were identified in one minute. Sokolo-Lyon voltage ($S\text{-}V_1$+ $R\text{-}V_{5\text{-}6}$) was calculated as an index for left ventricular mass (LVM).[19]

Venous blood sample was taken for analysis of total cholesterol by the standard methods. Another part of the sample, was kept unclotted (by adding EDTA) for complete blood count according to conventional methods, to include hemoglobin concentration (Hb), red blood cell count (RBC), packed cell volume (PCV), platelet count, total white blood cell count (WBC). Differential WBC count included percent basophils, esinophils, neutrophils, lymphocytes and monocytes.

Physical activity program (PAP):

A standardized program was designed by the experts in physical training according to the recommended guidelines.[16] The program time was 12 weeks, with a unit each week composed of 3 sessions. Each session is about 45 to 60 min and entails, warm-up, main part and cool-down. The main part of the physical activity program was directed for all body groups of muscles including neck, shoulders, arms, chest, trunk, abdomen, pelvis, back and lower limbs. Details of this program is mentioned elsewhere.[21]

After program measurements:

All data and investigations collected before

were gathered again, including questionnaire, physiological and laboratory tests for comparison.

Statistical analysis:

Data was analyzed by SPSS package version 11. Mean quantitative values of before and after measurements were tested by t-test for difference in one group. Difference in qualitative variables was tested by X^2 test. Calculation of % change was done by the equation:

$$\% \ change = \frac{After\ measurment - Before\ measurement}{Before\ measurement} X\ 100$$

The level of significance of p was considered at 0.05.

RESULTS

Characteristics of the studied sample:

The mean age of the studied sample was 38.5±5.22 years, 90% of them were married. The mean duration of exposure was 15.6±6.01 years, with a mean daily work hours of 8.3±1.52 hours. Those below and above the age of 40 years were nearly equally distributed. Most of them were technical workers (80%). About half of them had middle education (43%). About 67% of the sample goes to work by a vehicle. (Table I).

Table 1: Characteristics of the study sample.

Variable		no.	%
Age	<40 years	16	53.3
	40+ years	14	46.7
Job	Technical	24	80.0
	administrative	6	20.0
Education	Primary	6	20.0
	Middle	13	43.0
	Post – middle	6	20.0
	High	5	16.7
Transportation	Walking	10	33.3
	Vehicle	20	66.7

Comparison between subjective symptoms before and after PAP:

Insomnia, difficulty to start sleep, continuous deep sleep, feeling active after waking up, want to sleep again after waking up, late wake up from sleep in the vacation day, headache and sense of easy fatigability were significantly improved after the PAP in comparison to before ($p<0.01$ for all). Meanwhile, there were no significant changes in cardiovascular and gastrointestinal symptoms. (Table 2)

Percent change in measurements before and after PAP:

There was significant improvement in the scores of work and health satisfaction for the favor of after measurement ($p= 0.038$ & 0.041 respectively). Also, PAP showed significant reduction in Wt and BMI among the studied sample ($p= 0.004$ & 0.019 respectively). However, no difference was observed for sleep hours. (Table 3)

Significant reductions in HR and SBP were observed ($p= 0.000$ & 0.0151 respectively); meanwhile, significant increase for R-R max and R-R min were found ($p= 0.000$ & 0.0008 respectively) in comparison between before and after PAP measurements. No changes in DBP and Sokolow index were detected. (Table 4)

There was significant reduction in total WBCs, basophils neutrophils, lymphocytes and monocytes after PAP compared to before ($p= 0.041$, 0.039, 0.000, 0.000 and 0.0013 respectively). Esionophils was the only significant parameter that showed an increase after PAP ($p= 0.000$). There were no significant differences for serum cholesterol level and other hematologic parameters. (Table 5)

Table 2: Change in subjective symptoms before and after the PAP.

Variables	Before program		After program		X^2	P
	no.	%	no.	%		
Insomnia:						
Yes	14	46.7	3	10.0		
No	6	20.0	18	60.0	13.7	0.001*
Sometimes	10	33.0	9	30.0		
Difficulty to start sleep:						
Yes	6	20.0	1	3.3		
No	4	13.3	16	53.3	21.4	0.0002*
Sometimes	20	66.7	13	43.3		
Continuous deep sleep:						
Yes	2	6.7	6	20.0		
No	16	53.3	6	20.0	18.6	0.001*
Sometimes	12	40.0	18	60.0		
Feeling activity after waking up:						
Yes	5	16.7	25	33.3		
No	8	26.7	1	3.3	26.8	0.0001*
Sometimes	17	56.7	4	13.3		
Want to sleep again after waking up:						
Yes	10	33.3	2	6.7		
No	3	10.0	26	86.7	22.8	0.0001*
Sometimes	17	56.7	2	6.7		

Table (2): continue

Variables	Before program		After program		X^2	P
	no.	%	no.	%		
Late wake up from sleep in the vacation day:						
Yes	19	63.3	10	33.3		
No	6	20.0	18	60.0	10.8	0.006*
Sometimes	5	16.7	2	6.7		
Headache:						
Yes	5	16.7	3	10.0		
No	11	36.7	20	66.7	12.3	0.002*
Sometimes	14	46.7	7	23.3		
Sense of easy fatigability:						
Yes	7	23.3	2	6.7		
No	8	26.7	19	63.3	10.86	0.003*
Sometimes	15	50.0	9	30.0		
Dyspnoea on mild to moderate exertion:						
Yes	6	20.0	1	3.3		
No	18	60.0	25	83.3	2.85	0.12
Sometimes	6	20.0	4	13.4		
Palpitation on mild to moderate. exertion:						
Yes	3	10.0	2	6.7		
No	24	80.0	28	93.3	1.83	0.26
Sometimes	3	10.0	0	0.0		

Table (2): continue

Variables	Before program		After program		X^2	P
	no.	%	no.	%		
Epigastric pain:						
Yes	5	16.7	3	10.0		
No	19	63.3	23	76.7	2.98	0.103
Sometimes	6	20.0	4	13.3		
Hurt burn:						
Yes	3	10.0	2	6.7		
No	24	80.0	26	86.7	1.25	0.29
Sometimes	3	10.0	2	6.7		
Distension and flatulence:						
Yes	11	36.7	8	26.7		
No	18	60.0	20	66.7	1.28	0.35
Sometimes	1	3.3	2	6.7		
Attacks of diarrhea:						
Yes	5	16.7	3	10.0		
No	23	76.7	25	83.3	0.98	0.58
Sometimes	2	6.7	2	6.7		
Attacks of constipation:						
Yes	2	6.7	2	6.7		
No	25	83.3	27	90.0	0.89	0.61
Sometimes	3	10.0	1	3.3		

* Significant at 0.05 level

Table 3: Some quantitative measures among the studied sample with before and after the PAP percent change

Variables	Before program		After program		T	P	Mean % change
	Mean	S.D	Mean	S.D			
Work satisfaction@	8.29	1.24	9.52	1.65	2.03	0.038*	12.9
Health satisfaction@	7.61	2.17	8.98	1.09	1.98	0.041*	15.3
Wt (Kg)	86.16	12.89	80.3	9.25	2.03	0.004*	-7.3
BMI (Kg/m^2)	27.69	1.49	26.31	3.34	2.48	0.019*	-5.2
Sleep hours	7.00	2.13	8.06	1.98	1.56	0.11	13.2

* significant at 0.05 level.

@ score from 0-10, where zero is no satisfaction at all and 10 is full satisfaction.

Table (4) : Cardiovascular measures among the studied sample with before and after the PAP percent change.

Variables	Before PAP		After PAP		T	P	Mean % change
	Mean	S.D	Mean	S.D			
HR (beat/min)	64.37	9.05	55.30	6.22	5.98	0.0000*	-16.4
SBP (mmHg)	127.17	10.96	121.00	10.54	2.41	0.0151*	-5.1
DBP (mmHg)	79.67	5.40	77.67	13.50	0.98	0.2280	-2.6
Sokolow index (mm)	22.83	6.41	21.67	5.60	0.89	0.2279	-5.4
R-R max (mm)	26.73	3.68	31.20	3.56	6.98	0.0000*	14.3
R-R min (mm)	20.87	3.66	23.60	2.62	4.65	0.0008*	11.6

* Significant at 0.05 level

Table (5): Serum total cholesterol and complete blood count among the studied sample with before and after the PAP percent change

Variables	Before PAP		After PAP		T	P	Mean % change
	Mean	S.D	Mean	S.D			
Total cholesterol mg/dl	173.07	32.84	180.40	30.25	0.98	0.1883	4.1
Hb gm/dl	13.84	3.93	13.95	3.25	0.98	0.42	0.8
RBC (10^6/cc)	6.79	2.46	5.80	2.28	1.25	0.0547	-17.1%
PCV %	39.74	3.21	39.62	12.08	0.85	0.4791	-0.3%
Platelets (10^3/cc)	334.03	142.32	305.70	70.58	1.01	0.1671	-9.3%
WBC (10^3/cc)	7.58	2.02	5.37	1.89	1.84	0.041*	-41.2%
Basophils %	0.59	0.14	0.13	0.35	1.99	0.039*	-53.8%
Eosinophils%	1.47	0.73	3.70	2.37	7.98	0.0000*	60.3
Neutrophils %	67.50	7.74	51.07	16.78	6.25	0.0000*	-32.2
Lymphocytes %	46.37	13.27	29.03	5.04	7.52	0.0000*	-59.7
Monocytes %	2.83	0.83	2.10	0.96	4.68	0.0013*	-34.8

Significant at 0.05 level

Discussion

The study sample was representative for workers exposed to low frequency EMF in an electrical utility. The exposure level was within the permissible limits. [22] The subjective symptoms reported by the studied sample before the PAP were high regarding sleep difficulties, headache and sense of easy fatigability. Answers ranged from yes to sometimes in almost more than half of the studied sample for all the tested parameters; meanwhile, cardiovascular and gastrointestinal symptoms were less frequently complained. However, subjective findings have been criticized for the lack of precision and the difficulty to establish a cause – effect relationship. [2, 5] It may be related to psychological aspect due to phobia from threats of exposure. The outcome of the PAP was for the favor of reduction of the frequently complained subjective symptoms. This may be attributed to the beneficial effect of physical activity on fitness, morals and general health. Similar results were found in other studies evaluating the possible effects of interventions with physical activity in health problems. [15, 16] The significant reporting of increase in health and work satisfaction after the PAP in our study is elucidating the general positive effects of physical activity.

Workers exposed to EMF in the present study were overweight and obese according to their baseline mean BMI (above 25 kg/m2)[17] and the PAP contributed significantly for their weight reduction. In the current study, a standardized PAP was administered to the workers and objective fitness outcomes were observed specially in the form of significant reduction in heat rate and increase in both R-R max and R-R min. These measures of heart rate variability pointed out to the favorable effect of this program to readjust the cardiac parasympathetic autonomic drive to take hand.

It has been previously reported that low

frequency EMF may increase the action of sympathetic nervous system on cardiovascular responses. [12, 13, 23] Based on our results, a PAP could be considered as a counteracting mechanism to the deleterious effects of low frequency EMF on cardiac autonomic control. This finding could be considered advantageous for the overall fitness of the worker, [16] as well as to reduce cardiovascular risk. [3]

Other risk factors that were studied in the present research were, SBP which showed significant reduction with the PAP; meanwhile, Sokolow index for LVM and serum total cholesterol were not affected. This may be attributed to the fact that SBP is a short term reactive parameter; while, other factors need longer programs of physical activity than what used in the present situation. In order to optimize benefits of the PAP, it should be coupled with nutritional program. [16]

It was previously reported that EMF may produce some changes in the different blood indices. [6] Hematological changes observed in this research with the PAP induced reductions in WBC total and differential counts need further studies.

Conclusion and Recommendations

Physical activity program for workers exposed to EMF may be a good tool to improve their fitness and to ameliorate some health risks.

Therefore, it is recommended to include standardized PAPs in preventive measures for this sector of workers with before and after assessments.

Similar studies are needed to extend for other occupational groups at risk.

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