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A Cross-sectional Study on Power Density of Non-ionizing Radiation and the Incidence of Related Adverse Health Effects in Zabol

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Abstract

Introduction: Increased use of wireless devices and networks such as mobile phones has increased exposure to non-ionizing radiation. Since wireless devices are a distinct part of the ongoing technology, the benefits of applications must outweigh the associated risks so that the developments can take place. In this questionnaire-based study, we aimed to evaluate the effects of non-ionizing radiation from mobile phone base transceiver station (BTS) antennae on the Zabol inhabitants' health.

Methods: In this study, 349 volunteers (186 men and 163 women) inhabiting in Zabol, Iran, were asked to complete a standardized questionnaire from April 2019 to June 2021. The questionnaire included information about age, sex, education, time of residence, and the emergence of symptoms such as cardiovascular problems, weight loss, depression, sleep disturbance, nervousness, and hearing disturbances. The power density of non-ionizing radiation in the living place of the volunteers was measured by an Electro Smog Meter (TES-92 TES Instruments Taiwan).

Results: Results showed that the frequency of complaints increased by enhancing the power density for most of the studied symptoms, and in some cases (e.g., irritability, $P<0.05$ and lowering of libido, $P<0.05$), the increase was significant with at least $P<0.05$. The minimum and the maximum measured power densities at the place of residence were 98.3 μW/m^2 and 3400 μW/m^2, respectively. Moreover, increasing the frequency of complaints by about at least one symptom was significantly associated with a power density of >600 μW/m^2 ($P<0.05$).

Conclusion: It is suggested that inhabitants should not live in locations where the power density is higher than 600 μW/^{m2} to minimize the risk of radiation-induced symptoms.

Keywords: Non-ionizing radiation, Power density, Mobile phone base station, Adverse effect

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Introduction

Non-ionizing radiation from mobile phone base transceiver station (BTS) antennae has a low frequency (900 MHz) and energy (5 mW/m^2) and is considered one of the most important sources of radiation to the inhabitants living at distances of up to 300 m from these devices. BTSs emit microwave (MW) radiation in the range of several hundred MHz to several GHz. Although non-ionizing MW radiation does not penetrate deep into the tissues, it has been shown to exert numerous effects upon the mammalian brain,[1] immune functions,[2-4] stimulating hormones,[5,6] and sperm motility and morphology.[7-12]

MWs can have thermal and non-thermal molecular effects on human organs or a combination of these mechanisms. The thermal molecular effect is the most dangerous for the brain, eyes, skin, genitals, stomach, liver, and kidneys. On the other hand, numerous studies have been undertaken on both acute and long-term effects of MW exposure, showing that MW emitted by BTS is at a non-thermal power density level.

Non-ionizing radiation does not break any chemical bond, or it cannot produce any ions or free radicals in matter unlike ionizing radiation. Accordingly, they cannot induce any direct damage to the DNA molecules. On the other hand, some researchers speculate that other mechanisms may cause cancer. For instance, they have found some evidence that melatonin can stop tumor growing, and electromagnetic field exposure in an extremely low frequency range may reduce the level of the hormone.[5,6,13] Therefore non-ionizing radiation cannot be the only cause of cell mutation.

Previous animal studies demonstrated that there is still no direct correlation between MW exposure and cancer incidence.[14-16] The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has considered physical factors for calculation of radiation limit, but vital, mental, and psychological aspects can also be effective in the determination of threshold exposure to radiation. The ICNIRP guidelines provide general recommendations regarding radiofrequency electromagnetic field exposure. These create limitations expressed in terms of the specific absorption rate (SAR, W/kg) for the absorption of energy from radiofrequency electromagnetic fields. Studies have indicated that DNA damages are induced when SAR is 1.2 W/kg for 1800 MHz radiation exposure.[17] In Iran, most of the BTS antennae work at a frequency of 900 MHz. At this frequency, the reported limit for general public exposure is set to 4.5 mW/m^2.[18]

Nittby et al have found that elevated levels of albumin in rats are due to exposure to 12 mW/kg SAR cell phones.[1] Many recent studies have also shown that the effect of radiation on living organisms is less than that of the mentioned value. The effect of radio waves on immune function has also been documented.[19-21]

Two questionnaire-based studies were conducted by researchers to investigate some adverse effects of MW on inhabitants living near BTS antennae. Similar symptoms such as nausea, headache, nervousness, depression, sleep disturbance, memory loss, and lowering of libido were almost investigated in both studies. The results displayed that complaint frequency with many symptoms decreased by increasing the distance from BTS, so an increase in the frequency of complaints was not significant for more than 300 m.

In Iran, a questionnaire-based study was conducted on people living near BTS antennae. The results indicated that some symptoms such as nausea, headache, nervousness, depression, sleep disturbance, memory loss, and lowering of libido are statistically significant in the inhabitants living near the BTS antenna (< 300 m distances) compared to those living far from it (> 300 m).[22] Considering the results of the present study, it is necessary to obtain a power density threshold for public exposure to the reported symptoms.

In similar accomplished studies, distance from BTS was a determining variable, but the behavior of power density was not considered. Measurements and calculations indicated that the prediction of the change in power density caused by the BTS depends on various variables such as distance, antenna type, and its angle and height from the ground.[23] Accordingly, the distance variable is not sufficient to investigate the complications.

This questionnaire-based study aimed to determine the effects of non-ionizing radiation in the high frequency ranges mainly caused by mobile phone BTS antennae. Furthermore, it evaluated the effect of other sources of radio frequencies such as wireless devices and radio transmitters on the Zabol inhabitants' health. Finally, based on the recorded symptoms, a dose limit was determined for general public MW exposure to these devices.

Materials and Methods

In this study, Zabol inhabitants (186 men and 163 women) were randomly selected to be included in the study. Each volunteer was requested to complete a standardized questionnaire. The study sample size was estimated using the Cochran formula based on a similar study conducted by Shahbazi-Gahrouei et al.[22] To avoid the interference of ultra-low frequency dose in the measurement, people living less than 50 m from high voltage power lines or less than 10 m from the power transformers were excluded from the study.

The inhabitants were divided into five groups: non-exposed, exposed 1, exposed 2, exposed 3, and exposed 4. The non-exposed group was the volunteers whose power density levels in their living areas were lower than the limit. The limit value was determined as the maximum power density that does not cause a noticeable change in the frequency of any symptoms. The intervals between the remaining four groups were chosen exponentially.

Questionnaire

The questionnaire included information about age, sex, education, time of residence, and the frequency and severity of symptoms such as cardiovascular problems, visual disturbances, dizziness, weight loss, depression, sleep disturbance, nervousness, hearing disturbances, nausea, headaches, memory loss, irritability, lowering of libido, and feeling of discomfort. Questions about the frequency of symptoms were ranked as "never", "sometimes", "often", and "very often".

Symptoms and disorders within the questionnaire were described by the questioner to all candidates, and the interviewer completed the questionnaire. Moreover, to avoid bias, the questioner did not know about the power density when filling out the questionnaire. All the questions were explained to the volunteers by the questioner. For example, the questioner explained that cardiovascular problem was staged from irregular heartbeat feeling to a heart attack.

Dosimeter

The power density of non-ionizing radiation in the living place of the volunteers was also measured and recorded. This measurement was performed using the Electro Smog Meter (TES-92, TES Instruments Taiwan) dosimeter. The device can measure the intensity of electromagnetic waves in the frequency range of 50 to 50 000 MHz. This dosimeter has no sensitivity to low-frequency range (< 50 MHz) such as power lines or power transformers. The average power density was recorded in the questionnaires in terms of micro watt per square meter (μW/m²) as recommended by Hu et al.[24] Then, the power density measurement was done separately to obtain the power density map. Each power density measurement was performed at a height of approximately 1.2 meters above the ground, and the location of volunteers was recorded by the questioner to estimate power density.

Statistical Methods

The results were analyzed using SPSS version 21 and the chi-square statistical test. *P* values less than 0.05 were considered significant

Results

The lowest measured power density at the place of inhabitants was 98.3 μW/m², and the maximum was 3400 μW/m² (Table 1). The non-exposed group were those whose power density in their place of residence was less than 600 microwatt per square meter. In the non-exposed group, no statistically significant complication was reported. As observed in Table 1, about half of the participants (63.8% women and 36.2% men) lived at the non-exposed level (177). Further, 91 participants lived in Exposed 1, 56 participants lived in exposed 2, 8 participants lived in exposed 3, and 17 participants were lived in exposed 4 groups.

The obtained results were analyzed concerning the frequency of the complaints experienced in relation to responses with never. The results of 349 participating volunteers in this study showed that the frequency of complaints increases by increasing the power density for most of the studied symptoms, and in seven symptoms (Visual disturbances, nervousness, hearing disturbances, nausea, irritability, lowering of libido, and feeling of discomfort), the increase was significant with at least $P<0.05$. However, this study did not show any significant change in the frequency of complaints regarding age, level of education, and length of living time.

Table 2 depicts the frequency of complaints of symptoms for men and women. As observed, the complaint rate of memory loss increased significantly in the men group ($P<0.05$). Further, this study did not show any significant change in the frequency of complaints regarding age, level of education, and duration of residence.

Tables 3 and 4 present residents' complaints frequency for different power densities. Table 3 illustrates that the frequency of complaints for most symptoms increased with increasing power density. Compared to the non-irradiated group, the increase in some symptoms such as visual disturbances was statistically significant ($P<0.05$), as depicted in Table 4.

Discussion

In this study, 349 inhabitants who were living near BTS antennae in Zabol were selected to investigate their physical and psychological symptoms using a standard questionnaire. The results were analyzed based on the measured MW power density at the living place of the volunteers.

According to the results in Table 3, increasing the frequency of complaints for at least one of the symptoms was significant for the power density of above 600 μW/m². Moreover, the frequency of the symptoms significantly increased with increasing doses, especially for symptoms such as irritability ($P<0.05$) and lowering of libido ($P<0.05$). Those who were living below 600μW/m² were selected as non-exposed (reference group), and no symptoms were significantly observed at intensities less than 600 μW/m². Based on Table 1, about 50.7% of the subjects were exposed to the power density of radiation above 600 μW/m².

It should be noted that the measured power density also included the radiation from radio and television transmitting stations and cosmic sources. This study did not reveal any significant change in the frequency of complaints regarding age, level of education, and length of time living near BTS antennae.

Table 4 showed that the gender of the volunteer can

Table 1. The Distribution of Inhabitants in the Studied Exposure Levels

Group	Total	Men (n = 186)	Women (n = 163)
Non-exposed	177	64 (36.2)	113 (63.8)
Exposed 1	91	82 (90.1)	9 (9.9)
Exposed 2	56	21 (37.5)	35 (62.5)
Exposed 3	8	4 (50.0)	4 (50.0)
Exposed 4	17	15 (88.2)	2 (11.8)

Note. The non-exposed group was defined as power density between 98.3-600, Exposed 1 power density between 600-800, Exposed 2 power density between 800-1200, Exposed 3 power density between 1200-2500, and Exposed 4 power density between 2500-3400 (μW/m²). Values are presented as n (%).

Table 2. The Frequency of Complaints for Each Studied Symptom among Men and Women

	Men	Women	*P* Value
Cardiovascular problem (%)	41.9	38.4	0.665
Dizziness (%)	35.4	37	0.472
Weight loss (%)	23.7	27.4	0.472
Depression (%)	31.9	33.6	0.240
Sleep disturbance (%)	41.2	44.4	0.378
Nervousness (%)	35.7	36.6	0.754
Hearing disturbances (%)	34.6	33.3	0.202
Nausea (%)	34.4	38.4	0.551
Headaches (%)	43.5	50.9	0.053
Memory loss (%)	41.7*	37.1	0.001
Irritability (%)	39.1	39.4	0.407
Lowering of libido (%)	25.11	27.8	0. 800
Feeling of discomfort (%)	42.3	45.0	0.447

Note. * Statistical significant variables ($P<0.05$).

Table 3. The Frequency of Residents' Complaints for Different Power Densities

Power Density	Non-exposed	Exposed 1		Exposed 2		Exposed 3		Exposed 4	
		%	P	%	P	%	P	%	P
Cardiovascular Problem	37.4	45.0	0.181	38.7	0.626	41.7	0.644	49.0	0.509
Visual disturbances	27.3	29.1	0.980	23.4*	0.025	30.1	0.114	30.8	0.066
Dizziness	35.2	35.9	0.864	34.5	0.111	45.8	0.751	49.0	0.240
Weight Loss	25.4	23.4	0.916	25.6	0.935	37.5	0.239	29.4	0.519
Depression	33.3	33.7	0.635	33.3	0.626	45.8	0.269	41.2	0.684
Sleep disturbance	41.0	38.8	0.157	50.6	0.99	62.5	0.149	45.1	0.820
Nervousness	37.4	35.9	0.499	39.3	0.620	45.8	0.433	47.1*	0.01
Hearing disturbances	32.2	33.0	0.714	35.8	0.814	50.0	0.132	45.1*	0.047
Nausea	36.1	37.0	0.724	33.3*	0.038	41.7	0.228	41.2	0.512
Headaches	45.2	45.4	0.263	51.2	0.484	54.2	0.915	49.1	0.086
Memory loss	38.0	44.0	0.073	37.5	0.703	54.2	0.512	51.0	0.403
Irritability	30.5	40.3*	0.01	48.8*	0.01	45.8*	0.019	49.0*	0.015
Lowering of libido	24.5	23.8	0.895	26.2	0.411	33.3*	0.009	35.3*	0.04
Feeling of discomfort	41.8	45.1	0.843	45.2	0.573	66.7*	0.04	56.9	0.182

Note. * $P<0.05$ compared with non-exposed.

Table 4. The Frequency of Symptoms for Both Men and Women with Different Power Densities

Power Density Rank		Non-ex.	Ex. 1	P	Ex. 2	P	Ex. 3	P	Ex. 4	P
Cardiovascular problem	Men	38.5	47.0	0.411	36.5	0.557	8.3	0.381	44.4	0.995
	Women	36.9	25	0.575	40	0.938	75*	0.019	83.3	0.244
Visual disturbances	Men	35.9	38.0	0.635	39.7	0.602	50	0.130	55.5	0.151
	Women	38.1	37.0	0.861	43.8*	0.039	50	0.568	33.3	0.786
Dizziness	Men	33.3	37.0*	0.041	31.7	0.220	25	0.334	44.4	0.746
	Women	36.3	25.9	0.321	36.2	0.285	66.7*	0.027	83.3*	0.041
Weight Loss	Men	20.8	22.8	0.838	30.2*	0.032	25.0	0.674	31.1	0.543
	Women	28.0	29.6	0.894	22.9	0.750	50	0.333	16.7	0.961
Depression	Men	29.7	32.1	0.534	28.6	0.646	33.3	0.932	44.4	0.281
	Women	35.4	48.1	0.453	36.2	0.823	58.3	0.130	16.7	0.824
Sleep disturbance	Men	41.1	38.6	0.536	42.3	0.990	75*	0.046	44.4	0.865
	Women	41	40.7	0.748	55.2*	0.041	50	0.791	50	0.931
Nervousness	Men	37.5	36.2	0.189	38.1	0.659	16.7	0.107	51.1*	0.012
	Women	37.4	33.3	0.989	40	0.755	75	0.501	16.7	0.771
Hearing disturbances	Men	28.6	35.8	0.151	36.5*	0.048	41.7	0.349	48.9*	0.039
	Women	34.2	7.4*	0.013	35.2	0.317	58.3	0.105	16.7	0.822
Nausea	Men	32.3	32.3	0.532	28.6	0.204	8.3	0.334	44.4	0.204
	Women	38.3	37.0	0.781	36.2	0.206	75*	0.035	16.7	0.749
Headaches	Men	42.2	44.7	0.637	41.3	0.805	33.3	0.884	48.9	0.093
	Women	48.1	51.9	0.821	57.1	0.509	75	0.517	50	0.363
Memory loss	Men	38	44.7	0.638	34.9	0.900	41.7	0.474	51	0.291
	Women	38	37	0.744	39	0.544	66.7	0.199	50	0.786
Irritability	Men	31.7	41.9*	0.046	42.9	0.178	25	0.823	48.9*	0.044
	Women	29.8	25.9	0.432	52.4*	0.010	66.7*	0.046	50	0.534
Lowering of libido	Men	19.8	24.0	0.727	22.2	0.517	16.7*	0.049	35.6*	0.002
	Women	27.1	22.2	0.127	28.6	0.190	50*	0.027	33.3	0.325
Feeling of discomfort	Men	33.9	44.7	0.561	41.2	0.948	58.3	0.240	62.2*	0.002
	Women	46.3	48.1	0.993	47.6	0.680	75	0.287	16.7	0.924

Note. Ex: Exposed; * $P<0.05$ compared with non-exposed. Values are presented as %.

also affect the frequency of some symptoms at least with $P<0.046$. In some cases, the severity of the symptoms appeared faster in men than in women such as dizziness ($P<0.05$), weight loss ($P<0.05$), nervousness ($P<0.05$), and feeling of discomfort ($P=0.002$). This is especially important in the context in which centers were dedicated to a specific gender.

A study by Shahbazi-Gahrouei et al explored the risk of living in the vicinity of cellular phone base stations.[22] They studied the occurrence of complications due to distance from the cellular phone base stations antenna. They did not report any significant side effects for residents living more than 300 meters from the cellular phone BTS.[22] Other similar studies were carried out to reveal a significant correlation, as expected, between frequency and severity of complications with distance from the antenna.[25-29]

It should be noted that, in addition to the distance, the intensity of radiofrequency (RF) radiation in front of a BTS antenna is mainly related to the position and installation height of the antenna to the inhabitant's place of living.[23] Changes in the intensity of radiated electromagnetic waves from the antenna at a distance of fewer than 300 meters are not merely decreasing, and in some regions, the power density increases with distance. In fact, the maximum intensity of the wave does not occur at a distance close to the antenna. In the present study, the value of 600 $\mu W/m^2$ was selected as the limit, which based on the calculations can occur at a distance of 150 to 300 meters from the antenna provided that the effect of other antennas is not considered.[23,30]

Due to the increasing prevalence of complications in residential areas, with increasing power density, it is necessary to obtain a power density distribution map of RF radiation in residential areas. Knowing this information can be helpful to protect vulnerable groups in the community, especially when determining the location of hospitals, schools, and nursing homes.

Based on the results, the impression of non-ionizing radiation differs in gender. For example, lowering of libido and feeling of discomfort in the exposed 4 group and weight loss in the exposed 2 group is higher for men. On the contrary, cardiovascular problems and dizziness in the exposed 3 group and irritability in the exposed 1 group are greater for women.

Although non-ionizing radiation does not require energy to change the molecular structure of DNA, some researchers believe that changes in some hormones such as melatonin can lead to cancer.[5,6,13]

Although no significant correlation was found between the intensity of MW radiation and cancer,[14-16] due to the increasing use of mobile phones, 5G internet, and internet of things that are thirsty for wireless communication, more follow-up studies are necessary to find a power density threshold to minimize exposure to non-ionizing radiation and the RF-induced symptoms of neighbors. It also seems essential to prepare a map based on the power density for each city. Having such information helps protect buildings located in high-risk areas.

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Competing Interests

None.

Ethical Approval

This study was approved by the ethics committee of Zabol University of Medical Sciences with the code of IR.ZBMU.REC.1397.198.

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