Exposure to non-ionizing electromagnetic radiation from mobile telephony and the association with psychiatric symptoms

Exposição a radiações eletromagnéticas não ionizantes da telefonia celular e sintomas psiquiátricos

Exposición a la radiación electromagnética no ionizante de la telefonía móvil y síntomas psiquiátricos

Denize Francisca da Silva [1]
Warley Rocha Barros [2]
Maria da Conceição Chagas de Almeida [1]
Marco Antônio Vasconcelos Rêgo [2]

[1] *Centro de Pesquisas Gonçalo Moniz, Fundação Oswaldo Cruz, Salvador, Brasil.*
[2] *Faculdade de Medicina da Bahia, Universidade Federal da Bahia, Salvador, Brasil.*

Correspondence
D. F. Silva
Rua Belo Horizonte 319, apto. 703, Salvador, BA 40140-380, Brasil.
fsdenize@gmail.com

Abstract

The aim of this study was to investigate the association between exposure to non-ionizing electromagnetic radiation from mobile phone base stations and psychiatric symptoms. In a cross-sectional study in Salvador, Bahia State, Brazil, 440 individuals were interviewed. Psychiatric complaints and diagnoses were the dependent variables and distance from the individual's residence to the base station was considered the main independent variable. Hierarchical logistic regression analysis was conducted to assess confounding. An association was observed between psychiatric symptoms and residential proximity to the base station and different forms of mobile phone use (making calls with weak signal coverage, keeping the mobile phone close to the body, having two or more chips, and never turning off the phone while sleeping), and with the use of other electronic devices. The study concluded that exposure to electromagnetic radiation from mobile phone base stations and other electronic devices was associated with psychiatric symptoms, independently of gender, schooling, and smoking status. The adoption of precautionary measures to reduce such exposure is recommended.

Nonionizing Radiation; Radiation Exposure; Cell Phones; Psychic Symptoms

Resumo

O objetivo desse estudo foi investigar a associação entre exposição a radiações eletromagnéticas não ionizantes da estação radiobase de telefonia celular e sintomas à saúde. Em um estudo transversal realizado em Salvador, Bahia, Brasil, entrevistaram-se 440 indivíduos. Queixas e diagnósticos psiquiátricos constituíram as variáveis dependentes e a distância do domicílio para estação radiobase foi considerada a variável independente principal. Realizou-se análise de regressão logística hierarquizada para avaliação de confundimento e efeito. Observou-se associação entre sintomas psiquiátricos e residir próximo à estação radiobase e formas de uso do telefone celular (sinal de cobertura fraco, perto do corpo, dois ou mais chips *e nunca desligar o celular quando dorme) e com uso de outros eletroeletrônicos. Concluiu-se que a exposição à radiação eletromagnética não ionizante de telefonia celular e a outros eletroeletrônicos foi associada aos sintomas psiquiátricos independente do sexo, escolaridade e tabagismo. Recomenda-se a adoção de medidas precaucionárias no sentido de se reduzir este tipo de exposição.*

Radiação Não Ionizante; Exposição à Radiação; Telefones Celulares; Sintomas Psíquicos

Introduction

The growth in mobile telephony and thus in the number of mobile phone base stations, which establish communications with mobile phones, has increasingly benefited contemporary lifestyle by facilitating communications, offering ease and comfort, providing the opportunity to remain connected to nearby and distant locations, and allowing Internet use for various purposes. However, mobile telephony has raised concerns over the possible health effects for populations exposed to non-ionizing electromagnetic radiation. Such radiation is characterized by its wavelength, frequency, and irradiated energy, and is considered not to carry sufficient energy to alter an atom's physical state [1].

In order for mobile telephony communication to occur, the system is subdivided into cells. Each cell has an mobile phone base stations capable of sending power signals throughout its range. Each mobile phone base stations can serve several telephones at the same time, assigning each of them a narrow range of frequencies [2].

Non-ionizing electromagnetic radiation is absorbed by the skin and by deeper levels of the body, dissipating repeatedly in depth, potentially causing a temperature increase not perceived by the body's natural thermal sensors (located superficially). The heat generated internally depends on exposure time, field intensity, and tissue thickness, and sometimes cannot be offset by the body, thus resulting in biological effects [3]. The depth of penetration of waves around 900MHz frequency used in mobile telephony, in tissues with high water content, like muscle, is 3cm. 2,400MHz waves from microwave ovens penetrate some 1.7cm. In tissues with low water content, like bone, the depths are 17.7cm and 11.2cm, respectively [4].

Most psychiatric disorders appear to originate from some combination of genetic and environmental (biological or psychosocial) factors [5]. One of the most extensively documented observations in epidemiological studies is the increased prevalence of anxiety and depression in women when compared to men [6]. The association between exposure to non-ionizing electromagnetic radiation/mobile telephony and these psychiatric effects has been investigated. Santini et al. [7] indicated more significant symptoms within a radius of 300m from the mobile phone base stations: irritability, depression, memory loss, dizziness, decreased libido, headache, sleep disorders, malaise (200m); and tiredness (300m). Seven symptoms were more significant in women: nausea, loss of appetite, visual disorders, depressive tendency, headache, insomnia, and malaise. Decreased libido was the most common complaint in men. According to Navarro et al. [8] and Bortkiewicz et al. [9], individuals living close to the mobile phone base stations reported circulatory problems, sleep disorders, irritability, depression, blurred vision, and difficulties in concentrating. Meanwhile, Abdel-Rassoul et al. [10] suggested a relationship between living near a mobile phone bases station and neurobehavioral problems like depressive tendency, tremors, dizziness, headache, sleep disorders, and visual disorders, among others. Likewise, Oberfeld et al. [11] found that persons living close to base stations reported more symptoms of irritability, fatigue, headache, nausea, memory loss, visual disturbances, dizziness, and cardiovascular problems, directly proportional to their exposure to microwaves.

Augner et al. [12] studied exposure to mobile phone base stations radiofrequency in three groups of individuals. Each group was exposed to a 900MHz field, with variable exposure times. As exposure intensity increased, there was a significant increase in salivary secretion of cortisol and alpha-amylase (acute metabolic stress proteins); the same effect was not seen in the secretion of immunoglobulin A. The authors thus concluded that exposure to mobile phone base stations radiofrequencies at intensities lower than the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) can cause physiological stress. The guidelines set limits that only consider the acute effects, namely from high non-ionizing electromagnetic radiation levels and short duration (thermal effects), thus overlooking the chronic effects of low levels with long duration (non-thermal effects) [13].

Lakimenko et al. [14] reproduced in cells the non-thermal effects of mobile phone base stations radiation using low-intensity radiofrequencies for long exposure times, demonstrating increased denaturation of various cytoplasmic proteins, increased formation of reactive oxygen species, increased intracellular Ca^{2+}, DNA damage, and inhibition of DNA repair, alterations that can lead to metabolic disturbances. The study concluded that it is a mistake to explain the damage caused by this radiation, based exclusively on the thermal factor. Other effects of exposure to non-ionizing electromagnetic radiation/mobile telephony such as neoplasms (ovary, breast, lung), sleep disorders, headache, infertility, and others have been reported in the literature [15,16,17].

However, some studies [18] have failed to identify negative health effects in populations exposed to non-ionizing electromagnetic radiation. Blettner et al. [19] found no association between living close to mobile phone base station and in-

creased cancer incidence, concluding that non-ionizing electromagnetic radiation emissions were not related to adverse health outcomes. According to Saravi [20], the data do not suggest that non-ionizing electromagnetic radiation/mobile phone base stations pose health risks; even so, they find that even though the results are conflicting, there appears to be a clear need for new studies on this and other electromagnetic sources such as radio and television.

Thus, the relationship between exposure to non-ionizing electromagnetic radiation and increased incidence of human health problems is a controversial topic, requiring further in-depth investigation in epidemiological studies. In this sense, in response to public and government concern, the World Health Organization developed a project in 1996 to assess the scientific evidence for possible adverse health effects related to non-ionizing electromagnetic radiation. In 2011, the World Health Organization (WHO) took a stance when the International Agency for Research on Cancer (IARC) [21] classified exposure to radiofrequencies as belonging to group 2B, the category that classifies agents as possible carcinogens. Given the above, the current study aimed to investigate the association between exposure to non-ionizing electromagnetic radiation from mobile phone base stations and psychiatric symptoms.

Methodology

This was a cross-sectional epidemiological study in two neighborhoods in Salvador, Bahia State, Brazil. By mapping the mobile phone base stations in this city [22], a study area was defined based on the existence of at least one mobile phone base stations surrounded by urban occupation up to and beyond a 300m radius, as proposed by Santini et al. [7]. Since they met the established criteria, two adjoining neighborhoods in Salvador were selected for the study: individuals living in the neighborhoods of Bonfim and Monte Serrat, up to versus greater than 300m from mobile phone base stations, respectively. The mobile phone base stations reported in the study had been licensed for installation since 2004, operating with GSM transmission antennas, at a frequency of 1,800MHz, shared by three more operators in 2004, 2006, and 2008.

Sample size was calculated (n = 474) using the following parameters: α = 5%; frequency of the health problem in the unexposed = 5%: prevalence ratio = 2; study power = 80%, and exposed/unexposed ratio 1:1. However, due to difficulty in access and the exclusion of interviews held in households outside the established geographic limits, a total of 440 interviews were considered valid for analysis.

The following exclusion criteria were used for households: exclusively commercial buildings or institutions; households in which only individuals less than 18 years of age were home at the time of the intended interview; and homes exposed to non-ionizing electromagnetic radiation from other base stations.

A systematic random sample was taken. The first household was picked, after which every other household was selected. After the household was picked a resident 18 years or older was selected randomly for a face-to-face interview, conducted by trained interviewers. In addition to the instrument produced specifically for this study, a questionnaire was applied, previously validated for Brazil [23], for screening symptoms of depression, namely the *Center for Epidemiological Studies Depression Scale* (CES-D). The scale is widely used to facilitate diagnosis in non-psychiatric outpatient clinics, and especially in research. However, the scale's sensitivity and specificity vary in the literature. Risk of depression was defined as a CES-D score greater than or equal to 16 [23].

The dependent variables were evaluated by means of interviewees' self-reporting, including complaints of irritability, anxiety, decreased libido, palpitation, depressive tendency, and physician diagnoses of depression and anxiety and depressive symptoms (CES-D $\geq$ 16). The principal independent variable was exposure to non-ionizing electromagnetic radiation from mobile phone base stations. Based on existing knowledge on exposure to non-ionizing electromagnetic radiation/mobile telephony and health effects, the following secondary variables were selected: exposure to non-ionizing electromagnetic radiation from mobile phones (years of use, number of mobile phones, number of chips, use with weak signal coverage, duration of calls, keeping the device close to the body, and never turning off the phone), electronic devices (microwave oven, landline telephone, router, devices kept in the bedroom), age, sex, income, schooling, alcohol consumption, and smoking.

After descriptive analyses, a hierarchical logistic regression model was used. We initially verified any association between independent variables using the chi-square test. Thus, the covariates age, alcohol consumption, income, years of mobile phone use, use of microwave oven, duration of mobile phone calls, and use of landline telephone were excluded because they showed strong associations between each other ($p \leq 0.05$). We then structured hierarchical models,

preselecting variables whose association with the dependent variable showed $p \leq 0.25$. The strategy for entering variables into the model was hierarchical, as proposed by Greenland [24] and Fuchs et al. [25], maintaining at each level the variables with $p \leq 0.10$ [26].

The first level included macro-social and lifestyle variables: sex, schooling (primary/secondary versus university/graduate school) and smoking. The second level included exposure to electronic devices: presence of devices in the bedroom (mobile phones, videogames, notebook, alarm clock/radio, computer); and router use in the home. The third level included exposure to non-ionizing electromagnetic radiation resulting from subjects' behavior in mobile phone use, that is, whether the individual: made mobile phone calls with weak signal coverage; used more than one mobile phone or more than one chip; turned the mobile phone off when asleep; kept the mobile phone close to the body. For inclusion in the fourth level, pertaining to exposure to non-ionizing electromagnetic radiation/mobile phone base stations, three models were constructed based on distance from the households and to the mobile phone base stations: 0-100; 101 to 200m; and > 200m from the mobile phone base stations; ≤ 300m versus > 300m from the mobile phone base stations; and ≤ 400 versus > 400m from the mobile phone base stations. These models were constructed because the antennas installed in the mobile phone base stations are tilted towards the ground in relation to the tower. Thus, at a given distance from the tower, the electromagnetic waves reach the ground with maximum intensity. Before and after this distance, the waves display significantly lower intensities [27]. In addition to distance, time residing in the vicinity (≤ 10 versus > 10 years) and time spent at home (8 to 16 versus 16.1 to 24 hours/day) were also incorporated at this level. The data were analyzed in Stata 10 (StataCorp LP, Colege Station, USA). The Hosmer-Lemeshow statistic [28] was used to test the model's goodness-of-fit.

The research project complies with *Resolution n. 196/96* of the Brazilian National Health Council and was approved by the Ethics Research Committee of the Gonçalo Moniz Research Center, Oswaldo Cruz Foundation (CPqGM/Fiocruz), filed under protocol n. 358/2011 and final ruling n. 245/2011. All subjects signed a Free and Informed Consent Form.

Results

The final study population consisted of 440 individuals, with a mean age of 48.4 years (range 18 to 87). Most were females (59.3%), and brown was the most common self-reported skin color (51.4%). More than half (60.2%) had finished secondary school and 39.8% had university or graduate degrees. One-fourth earned between one and two minimum wages, 9.1% smoked, and 40.7% consumed alcoholic beverages.

Most subjects had lived in the vicinity for more than ten years, with an average of 21.3 years, and 61.8% stayed at home between 8 and 16 hours a day. Some 40% lived at a distance of up to 300m from the mobile phone base stations, while the rest lived more than 300 meters away. In relation to mobile phone exposure, 90.9% were users, 31.3% had used mobile phones for more than ten years, had at least two chips (56.5%), were used to carrying their mobile phones close to the body (67.4%), never turned their mobile phones off while sleeping (82.5%), made calls totaling more than 30 minutes a day (28.6%), and used their mobile phone even with weak signal coverage (89.2%).

As for electronic equipment, 50.8% had a landline phone with a wireless receiver, kept electronic devices in the bedroom (80%), used a router at home (52.5%), and used a microwave oven (65.7%). Distribution according to these different variables was similar in the two neighborhoods (≤ 300m and > 300m from the mobile phone base stations) (Table 1).

As for psychiatric symptoms, there were no significant differences between those living up to 300m versus more than 300m from the mobile phone base stations, in the crude analysis (Table 2). An association was observed between living 100 to 200m from the mobile phone base stations and a diagnosis of anxiety (OR = 2.39; 90%CI: 1.09-5.26) (Table 3) or depression (OR = 3.25; 90%CI: 1.63-6.45) (Table 3). For individuals living up to 300m from the mobile phone base stations, it was associated with depressive symptoms (CES-D ≥ 16) (OR = 0.50; 90%CI: 0.32-0.80) (Table 3). Living up to 400m from the mobile phone base stations was associated with depressive tendency (OR = 1.55; 90%CI: 1.04-2.33) (Table 4) and depressive symptoms (CES-D ≥ 16) (OR = 1.66; 90%CI: 1.08-2.55) (Table 3). Staying at home 16.1 to 24 hours a day showed an association with decreased libido (OR = 1.61; 90%CI: 1.01-2.59) (Table 4) and depressive symptoms (CES-D ≥ 16) (OR = 1.67; 90%CI: 1.06-2.61) (Table 3).

For variables pertaining to exposure to non-ionizing electromagnetic radiation from mobile phone use, an association was observed between having more than one mobile phone and depressive symptoms (CES-D ≥ 16) (OR = 1.63; 90%CI: 1.03-2.56) (Table 3). Using two or more chips and never turning off the mobile phone while sleep-

Table 1

Distribution of individuals according to macro-social and lifestyle variables and exposure to non-ionizing electromagnetic radiation/mobile telephony. Salvador, Bahia State, Brazil, 2014.

Variables	Total	%	Exposure				p-value
			≤ 300m		> 300m		
			n	%	n	%	
Age (years)							
18 to 50	237	53.9	93	53.1	144	54.3	0.882
> 50	203	46.1	82	46.9	121	45.7	
Sex							
Male	179	40.7	69	39.4	110	41.5	0.737
Female	261	59.3	106	60.6	155	58.5	
Schooling							
Primary and Secondary	265	60.2	100	57.1	165	62.3	0.330
University and graduate	175	39.8	75	42.9	100	37.7	
Current occupation							
Retirees, pensioners, housewives	136	30.9	51	29.1	85	32.1	0.135
Working	238	54.1	105	60.0	133	50.2	
Students	33	7.5	9	5.1	24	9.1	
Unemployed	33	7.5	10	5.7	23	8.7	
Smoking							
No	400	90.9	159	90.9	241	90.9	1.000
Yes	40	9.1	16	9.1	24	9.1	
Alcohol consumption							
No	261	59.3	105	60,0	156	58.9	0.891
Yes	179	40.7	70	40,0	109	41.1	
Devices in the bedroom							
No	88	20.0	32	18.3	56	21.1	0.543
Yes	352	80.0	143	81.7	209	78.9	
Uses router in the home							
No	209	47.5	81	46.3	128	48.3	0.751
Yes	231	52.5	94	53.7	137	51.7	
Uses microwave oven							
No	151	34.3	51	29.1	100	37.7	0.079
Yes	289	65.7	124	70.9	165	62.3	
Uses landline phone with wireless receiver							
No	213	49.2	85	49.1	128	49.2	1.000
Yes	220	50.8	88	50.9	132	50.8	
Years of mobile phone use							
≤ 10	264	68.8	100	64.5	164	71.6	0.174
> 10	120	31.3	55	35.5	65	28.4	
Uses how many mobile phones							
1	287	71.9	111	69.4	176	73.6	0.415
> 1	112	28.1	43	30.6	63	26.4	
Uses how many chips							
1	174	43.5	66	41.3	108	45.0	0.523
≥ 2	226	56.5	94	58.8	132	55.0	
Turns mobile phone off while asleep							
Always	66	17.3	33	21.4	33	14.5	0.104
Never	316	82.7	121	78.6	195	85.5	

(continues)

Table 1 (continued)

Variables	Total	%	Exposure				p-value
			≤ 300m		> 300m		
			n	%	n	%	
Keeps mobile phone							
Far from the body	130	32.6	55	34.4	75	31.4	0.606
Close to the body	269	67.4	105	65.6	164	68.6	
Duration of mobile phone calls (minutes/day)							
≤ 30	280	71.4	109	69.4	171	72.8	0.546
> 30	112	28.6	48	30.6	64	27.2	
Weak signal coverage							
No	43	10.8	23	14.4	20	8.4	0.083
Yes	356	89.2	137	85.6	219	91.6	
Time living in the vicinity (years)							
≤ 10	165	37.5	65	37.1	100	37.7	0.980
> 10	275	62.5	110	62.9	165	62.3	
Time spent at home (hours/day)							
8-16	273	68.0	119	68.0	154	58.1	0.046
16.1-24	167	32.0	56	32.0	111	41.9	

Table 2

Prevalence ratios (PR) for exposure to non-ionizing electromagnetic radiation/mobile telephony and psychiatric symptoms. Salvador, Bahia State, Brazil, 2014.

Variables	Total		Exposure				PR (95%CI)
			≤ 300m		> 300m		
	n	%	n	%	n	%	
Irritability							
Yes	148	66.4	57	32.6	91	34.3	0.95 (0.72-1.24)
No	242	33.6	118	67.4	174	65.7	
Anxiety							
Yes	212	48.3	82	46.9	130	49.2	0.95 (0.75-1.16)
No	227	51.7	93	53.1	134	50.8	
Palpitation							
Yes	77	17.5	26	14.9	51	19.2	0.77 (0.50-1.19)
No	363	82.5	149	85.1	214	80.8	
Decreased libido							
No	89	20.3	30	17.1	59	22.4	0.76 (0.51-1.34)
Yes	349	79.7	145	82.9	204	77.6	
Depressive tendency							
Yes	101	23.0	34	19.4	67	25.4	0.77 (0.53-1.10)
No	338	77.0	141	80.6	197	74.6	
Diagnosis of depression							
Yes	56	12.7	20	11.4	36	13.6	0.84 (0.50-1.40)
No	384	87.3	155	88.6	229	86.4	
Diagnosis of anxiety							
Yes	50	11.4	18	10.3	32	12.1	0.85 (0.49-1.47)
No	390	88.6	157	89.7	233	87.9	
CES-D							
Positive	95	24.9	27	18.0	68	29.4	0.61 (0.41-0.91)
Negative	286	75.1	123	82.0	163	70.6	

95%CI: 95% confidence interval; CES-D: *Centre For Epidemiological Studies Depression Scale*.

Table 3

Hierarchical logistic regression model for variables associated with diagnoses of anxiety and depression and depressive symptoms (*Center for Epidemiological Studies Depression Scale* – CES-D ≥ 16) and exposure to non-ionizing electromagnetic radiation/mobile telephony, odds ratios (OR), and 90% confidence intervals (90%CI). Salvador, Bahia State, Brazil, 2014.

Variables	OR	OR adjusted (90%CI)					
	crude (90%CI)	Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Diagnosis of anxiety							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	2.18 (1.20-3.98)	2.37 (1.29-4.36)	2.45 (1.32-4.55)	2.74 (1.46-5.15)	**2.70 (1.43-5.10)**	**2.74 (1.46-5.15)**	**2.80 (1.48-5.29)**
Smoking							
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.06 (0.97-4.34)	2.43 (1.13-5.23)	2.61 (1.19-5.72)	3.01 (1.35-6.74)	**3.13 (1.93-7.03)**	**3.02 (1.35-6.75)**	**3.01 (1.35-6.73)**
Exposure to electronic devices radiation							
Devices in the bedroom							
No	1.00		1.00	1.00	1.00	1.00	1.00
Yes	9.07 (1.69-48.64)		9.54 (1.77-51.50)	10.14 (1.87-55.10)	**9.57 (1.76-51.99)**	**10.15 (1.87-55.13)**	**10.17 (1.87-55.25)**
Exposure to mobile telephony radiation							
Weak signal coverage							
No	1.00			1.00	1.00	1.00	1.00
Yes	2.74 (0.81-9.30)			3.58 (1.03-12.42)	**3.82 (1.10-13.28)**	**3.58 (1.02-12.40)**	**3.69 (1.06-12.90)**
Exposure to mobile phone base station radiation							
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	2.31 (1.09-4.90)				**2.39 (1.09-5.26)**		
> 300	1.00					1.00	
≤ 300	0.94 (0.55-1.61)					0.97 (0.56-1.69)	
> 400	1.00						1.00
≤ 400	0.97 (0.57-1.66)						0.86 (0.49-1.50)

(continues)

Table 3 (continued)

Variables	OR crude (90%CI)	OR adjusted (90%CI) Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Diagnosis of depression							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00			1.00	1.00	1.00
Female	2.42 (1.23-4.78)	2.42 (1.23-4.78)			2.40 (1.21-4.76)	2.43 (1.23-4.81)	2.36 (1.19-4.68)
Exposure to mobile phone base station radiation							
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	3.30 (1.48-7.40)				3.25 (1.63-6.45)		
> 300	1.00					1.00	
≤ 300	0.72 (0.79-2.56)					0.71 (0.38-1.13)	
> 400	1.00						1.00
≤ 400	1.42 (0.79-2.56)						1.33 (0.73-2.41)
Depressive symptoms (CES-D ≥ 16)							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	3.61 (2.19-5.96)	**3.61 (2.19-5.96)**	**3.58 (2.17-5.91)**	**3.71 (2.24-6.14)**	**3.44 (2.08-5.72)**	**3.53 (2.11-5.90)**	**3.34 (2.01-5.58)**
Exposure to electronic devices radiation							
Router							
No	1.00						
Yes	0.71 (0.47-1.07)						
Exposure to mobile telephony radiation							
Number of mobile phones							
No	1.00			1.00	1.00	1.00	1.00
Yes	1.52 (0.98-2.35)			**1.63 (1.03-2.56)**	**1.89 (1.13-2.89)**	**2.70 (1.40-5.23)**	**2.63 (1.36-5.09)**

(continues)

Table 3 (continued)

Variables	OR crude (90%CI)	OR adjusted (90%CI)					
		Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Exposure to mobile phone base station radiation							
Time spent at home (hours/day)							
8-16	1.00				1.00	1.00	1.00
16.1-24	1.80 (1.18-2.74)				**1.67 (1.06-2.61)**	**1.56 (0.99-2.46)**	**1.63 (1.04-2.56)**
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	0.79 (0.36-1.72)				0.70 (0.31-1.58)		
> 300	1.00					1.00	
≤ 300	0.52 (0.33-0.81)					**0.50 (0.32-0.80)**	
> 400	1.00						1.00
≤ 400	1.73 (1.14-2.61)						**1.66 (1.08-2.55)**

MPBS100-200: distance between 100 and 200m from the households and the mobile phone base stations; MPBS300: distance of 300m from the households and the mobile phone base stations; MPBS400: distance of 400m from the households and the mobile phone base stations.

* Contextual variables;

** Selected variables from level I and variables related to exposure to non-ionizing electromagnetic radiation from electronic devices;

*** Selected variables from levels I and II and variables related to non-ionizing electromagnetic radiation from mobile phones;

Selected variables from levels I, II, and III and variables related to exposure to non-ionizing electromagnetic radiation/mobile phone base stations.

ing was associated with anxiety (Table 4). Keeping the mobile phone close to the body was associated with palpitation (Table 5). Using the mobile phone with weak signal coverage was associated with irritability (Table 5) and diagnosis of anxiety (Table 3). As for covariates related to exposure to electronic equipment, "keeping devices in the bedroom" was associated with irritability (Table 5) and diagnosis of anxiety (Table 3), while palpitation was significantly less common among individuals with a router at home (Table 5).

An association was observed between female gender and eight psychiatric symptoms (irritability, palpitation, anxiety, depressive tendency, decreased libido, diagnosis of anxiety and depression, and depressive symptoms, CES-D ≥ 16) (Tables, 3, 4, and 5).

Discussion

The relationship between exposure to non-ionizing electromagnetic radiation/mobile telephony and health effects has raised concern in the scientific community, as well as among policymakers, specifically related to populations around mobile phone base stations and mobile phone users.

The theme is highly relevant for public health and appears in the literature with conflicting results. This calls for adoption of the precautionary principle, a decision made when scientific information is insufficient, inconclusive, or uncertain and there are indications that the possible effects for the environment, human and animal health, or plant protection may be potentially hazardous and inconsistent with the chosen level of protection [29].

The current study showed an association between exposure to non-ionizing electromagnetic radiation/mobile phone base stations for individuals living between 100 and 200m from the mobile phone base stations and diagnoses of anxiety and depression; those living up to 300m from the mobile phone base stations showed a significantly lower association with depressive symptoms (CES-D ≥ 16); and living up to 400m from the mobile phone base stations was asso-

Table 4

Hierarchical logistic regression model for variables associated with anxiety, depressive tendency, and decreased libido and exposure to non-ionizing electromagnetic radiation/mobile telephony, odds ratios (OR), and 90% confidence intervals (90%CI). Salvador, Bahia State, Brazil, 2014.

Variables	OR crude (90%CI)	OR adjusted (90%CI)					
		Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Anxiety							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00		1.00	1.00	1.00	1.00
Female	1.79 (1.27-2.51)	1.69 (1.19-2.40)		1.69 (1.19-2.40)	**1.68 (1.18-2.40)**	**1.69 (1.19-2.41)**	**1.67 (1.17-237)**
Exposure to mobile phone							
Chips							
1	1.00			1.00	1.00	1.00	1.00
≥ 2	1.49 (1.07-2.08)			1.43 (1.01-2.02)	**1.44 (1.02-2.04)**	1.44 (0.95-2.18)	**1.44 (1.02-2.04)**
Turns mobile phone off when asleep							
Always	1.00			1.00	1.00	1.00	1.00
Never	2.08 (1.31-3.31)			1.94 (1.21-3.10)	**1.95 (1.22-3.12)**	**1.90 (1.19-3.05)**	**1.90 (1.18-3.04)**
Exposure to mobile phone base station radiation							
Distance (m)	1.00				1.00		
0-100; > 200	1.48 (0.82-2.70)				1.45 (0.78-2.70)		
101-200	1.00					1.00	
> 300	0.89 (0.64-1.25)					0.84 (0.59-1.20)	
≤ 300							1.00
> 400							1.18 (0.83-1.68)
Depressive tendence							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00			1.00	1.00	1.00
Female	3.26 (2.05-5.19)	3.26 (2.05-5.19)			**3.08 (1.92-4.93)**	**3.29 (2.07-5.24)**	**2.98 (1.86-4.80)**
Exposure to mobile phone base station radiation							
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	1.03 (0.51-2.06)				0.92 (0.45-1.88)		
> 300	1.00					1.00	
≤ 300	0.86 (0.44-1.00)					0.65 (0.42-0.99)	
> 400	1.00						1.00
Exposure to mobile phone base station radiation	1.65 (2.05-2.45)						**1.55 (1.04-2.33)**
Years living in vicinity							
≤ 10	1.00				1.00	1.00	1.00
> 10	0.72 (0.49-1.07)				0.71 (0.48-1.06)	0.73 (0.49-1.08)	0.71 (0.47-1.07)
Time spent at home (hours/day)							
8-16	1.00				1.00		1.00
16.1-24	1.64 (1.10-2.46)				1.34 (0.88-2.04)		1.33 (0.88-2.03)

MPBS100-200: distance between 100 and 200m from the households and the mobile phone base stations; MPBS300: distance of 300m from the households and the mobile phone base stations; MPBS400: distance of 400m from the households and the mobile phone base stations.

* Contextual variables;

** Selected variables from level I and variables related to exposure to non-ionizing electromagnetic radiation from electronic devices;

*** Selected variables from levels I and II and variables related to non-ionizing electromagnetic radiation from mobile phones;

Selected variables from levels I, II, and III and variables related to exposure to non-ionizing electromagnetic radiation/mobile phone base stations.

Table 5

Hierarchical logistic regression model for variables associated with irritability and palpitation and exposure to non-ionizing electromagnetic radiation/mobile telephony, odds ratios (OR), and confidence intervals (90%CI). Salvador, Bahia State, Brazil, 2014.

Variables	OR crude (90%CI)	OR adjusted (90%CI)					
		Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Irritability							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	2.33 (1.61-3.34)	2.32 (1.60-3.38)	2.35 (1.62-3.42)	2.51 (1.72-3.68)	2.50 (1.71-3.66)	2.51 (1.72-3.68)	2.46 (1.68-3.60)
Schooling							
Primary and Secondary	1.00	1.00					
University and Graduate	1.40 (0.98-1.97)	1.39 (0.97-1.98)					
Exposure to electronic devices radiation							
Devices in the bedroom							
No	1.00		1.00	1.00	1.00	1.00	1.00
Yes	2.36 (1.37-4.05)		2.40 (1.38-4.17)	2.43 (1.40-4.24)	2.39 (1.37-4.16)	2.43 (1.40-4.24)	2.44 (1.40-4.25)
Exposure to mobile telephony radiation							
Weak signal coverage							
No	1.00			1.00	1.00	1.00	1.00
Yes	2.20 (1.16-4.18)			2.72 (1.41-5.26)	2.89 (1.49-5.60)	2.70 (1.40-5.23)	2.63 (1.36-5.09)
Exposure to mobile phone base station radiation							
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	1.74 (0.85-3.48)				1.83 (0.97-3.43)		
> 300	1.00					1.00	
≤ 300	0.90 (0.63-1.28)					0.95 (0.66-1.37)	
> 400	1.00						1.00
≤ 400	1.40 (0.92-2.12)						1.25 (0.87-1.79)
Palpitation							
Macro-social and lifestyle							
Sex							
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	2.10 (1.29-3.42)	2.10 (1.29-3.42)	2.04 (1.25-3.33)	2.21 (1.34-3.63)	2.23 (1.36-3.67)	2.22 (1.35-3.66)	2.18 (1.33-3.59)
Exposure to electronic devices radiation							
Router							
No	1.00		1.00	1.00	1.00	1.00	1.00
Yes	0.58 (0.37-0.90)		0.60 (0.38-0.93)	0.58 (0.37-0.91)	0.57 (0.37-0.90)	0.60 (0.37-0.91)	0.58 (0.37-0.91)

(continues)

Table 5 (continued)

Variables	OR crude (90%CI)	OR adjusted (90%CI)					
		Level I *	Level II **	Level III ***	Level IV # MPBS100-200	Level IV # MPBS300	Level IV # MPBS400
Exposure to mobile telephony radiation							
Keeps mobile phone							
Far from the body	1.00			1.00	1.00	1.00	1.00
Close to the body	2.08 (1.23-3.53)			2.34 (1.37-4.00)	2.33 (1.36-3.40)	2.34 (1.36-4.01)	2.35 (1.37-4.03)
Exposure to mobile phone base station radiation							
Distance (m)							
0-100; > 200	1.00				1.00		
101-200	0.63 (0.26-1.55)				0.59 (0.23-1.47)		
> 300	1.00					1.00	
≤ 300	0.67 (0.42-1.07)					0.67 (0.42-1.07)	
> 400	1.00						1.00
≤ 400	1.14 (0.73-1.77)						1.13 (0.71-177)

MPBS100-200: distance between 100 and 200m from the households and the mobile phone base stations; MPBS300: distance of 300m from the households and the mobile phone base stations; MPBS400: distance of 400m from the households and the mobile phone base stations.

* Contextual variables;

** Selected variables from level I and variables related to exposure to non-ionizing electromagnetic radiation from electronic devices;

*** Selected variables from levels I and II and variables related to non-ionizing electromagnetic radiation from mobile phones;

Selected variables from levels I, II, and III and variables related to exposure to non-ionizing electromagnetic radiation/mobile phone base stations.

ciated with depressive tendency and depressive symptoms (CES-D ≥ 16). Staying at home from 16.1 to 24 hours a day was associated with decreased libido in individuals living 100 to 200m from the mobile phone base stations. These findings are similar to those of other studies published in the literature. A French study [7] focused on 530 individuals living within a radius of 300m from the mobile phone base stations, and the significant symptoms according to distance from the source were: irritability, depression, memory loss, dizziness, decreased libido (100m); headache, sleep disturbance, malaise (200m), and tiredness (300m). Navarro et al. [8] indicated an association between exposure and depressive symptoms in the population 150m from the mobile phone base stations. Likewise, Bortkievicz et al. [9], Abdel-Rassoul et al. [10], and Hutter et al. [30] found more neurobehavioral effects in populations living near the mobile phone base stations when compared to those living more than 300m or 400m from the mobile phone base stations.

Eger et al. [16] found that five years or more after installation and operation of the mobile phone base stations, the risk of developing cancer tripled for residents within less than 400m from the source, the main beam of which touched the ground at a horizontal distance of 350m. Wolf & Wolf [15] also indicated a fourfold increase in cancer incidence in residents within 350m from the mobile phone base stations.

Antennas in mobile phone base stations are installed such that radiation emission is maximal when perpendicular to the antenna [27]. In relation to the tower, the antennas are tilted towards the ground, such that at a given distance from the tower the waves reach the ground with maximum intensity. Before and after this distance, the waves display significantly lower intensities. The terrain's topography, tower height, antennas' tilt, irradiated energy, and distance from the tower to the households are also preponderant factors in determining the region with the highest incidence of waves emitted by the mobile phone base stations, since the waves bounce off natural obstacles and buildings. Thus, households located between 100 to 200m from the tower show higher risk when compared to those located nearer (0 to 100m) and farther (> 200m) from the mobile phone base stations [27,31].

One problem with exposure to non-ionizing electromagnetic radiation/mobile phone base stations has been the distance from the source to the households. For example, at 150m from a mobile phone base stations, typical values for an electric field (0.5 to 2V/m) [32] are considered low, but they represent continuous exposure. High radiation levels have been found [16] in areas around

where the principal beam it reaches the ground, and in combination with local reflection, from that point onward; the intensity of the radiation decreases with the square of the distance from the point of the antenna feed. In addition, the principal radiation lobe is in the direction determined by the tilt's angle, while there are also side lobes arranged at other angles, thereby scattering the radiation.

Hardell et al. [33] found an association between mobile phone use and risk of brain tumors. According to the authors, the results indicate that risk of exposure to non-ionizing electromagnetic radiation from mobile phones is lower in areas at a short distance from the mobile phone base stations, due to adaptive power control (APC). This corroborates the findings presented in other studies, by Lönn et al. [34] and Hillert et al. [35], who demonstrated that APC in cellular phones is regulated by the distance between the mobile phone base stations. Thus, in areas with a long distance between mobile phone base stations (generally rural), the output power level is higher when compared to urban areas, where the distance between mobile phone base stations is shorter.

In this sense, a possible explanation for the current study's findings, for example OR > 1 when evaluating psychiatric symptoms at distances between 100 and 200m, may be the exposure to non-ionizing electromagnetic radiation/mobile phone base stations. At a distance of 300m, the risk is expected to decrease, since there is less exposure to non-ionizing electromagnetic radiation/mobile phone base stations . This can be explained by the automatic control of gain or power irradiated by mobile phone devices, which decrease as they approach the mobile phone base stations, in agreement with some studies [33,34,35]. The risk increases again after 400m, possibly due to exposure to non-ionizing electromagnetic radiation from mobile phones which intensifies when the devices are farther from the mobile phone base stations (weak signal coverage). Automatic gain adjustment results in higher power and thus greater exposure of the user's head, resulting in higher OR, due to exposure to non-ionizing electromagnetic radiation from the mobile phone, not from the mobile phone base stations.

One way to estimate protective spacing of homes in neighborhoods around mobile phone base stations is to use the Friis equation to calculate exclusion zones, or areas in which the estimated level of the electric field may exceed the guidelines, considering not only the effects of high levels and short exposure times, like the ICNIRP standards, but also those that consider the effects of low levels and long exposure times. This procedure shows the region with reduction of possible risks of exposure from non-ionizing electromagnetic radiation/mobile phone base stations for the health of individuals living or working outside this region [36].

For variables related to exposure to non-ionizing electromagnetic radiation from mobile phones, having more than one mobile phone device was associated with depressive symptoms (CES-D ≥ 16), and using two or more chips and never turning the mobile phone off when asleep were associated with anxiety. Using the mobile phone with weak signal coverage was associated with diagnosis of anxiety and irritability. Coureau et al. [37] found a statistically significant association between using the mobile phone for more than two hours a day and brain tumors, concluding that the data reinforce the results of previous studies on intensive use of mobile phones and such tumors. Martin et al. [38] conducted measurements of the spectra of non-ionizing electromagnetic radiations in São José dos Campos and Taubaté, São Paulo State, Brazil, indicating that the sources with the heaviest pollution in frequencies ranging from 1MHz to 9.4GHz were mobile phones and VHF. Kuster & Kuhn [39] indicated that mobile phones are the strongest source of the brain's exposure to electromagnetic fields, and that exposure is influenced by the user's behavior and choice of the device. Important factors include the device's design and the use of earphones (which reduces exposure by ten times).

Other studies [40,41] have associated excessive and intensive use of wireless communication technologies with psychiatric effects.

From the physical point of view, when comparing the results of exposure to non-ionizing electromagnetic radiation from mobile phone base stations with that of mobile phones themselves, the individual's mobile phone behavior can certainly favor greater exposure. Using two or more chips, never turning the device off, keeping it close to the body, and using it in places with weak signal coverage can lead to greater exposure to non-ionizing electromagnetic radiation, when compared to exposure to radiation from mobile phone base stations.

The amount of energy one receives when talking for six seconds on a mobile phone [42] is equivalent to being exposed for 24 hours to a mobile phone base station at 100m, and when one holds a mobile phone device very close to the ear, the power level received is greater than when holding the device farther away. However, when signal coverage is poor, individuals tend to hold the device as close as possible, without realizing that this behavior increases the absorption of radiation. Using a mobile phone with weak signal coverage, a habit reported by most of our

interviewees, is worrisome, since the reduced number of available channels due to overcrowding of users involves a higher field level and thus higher power in the device, which increases automatically in the attempt to locate another mobile phone base stations to keep the call going. Several studies [7,8,17] have indicated an association between exposure to non-ionizing electromagnetic radiation/ mobile phone base stations and health effects, only considering exposure to mobile phone base stations and overlooking exposure to non-ionizing electromagnetic radiation resulting from mobile phones use and thus APC.

Electronic devices in the bedroom (mobile phone, notebook, router, TV, etc.) can increase the risk of exposure to non-ionizing electromagnetic radiation, and in this study they were associated with irritability and diagnosis of anxiety. Palpitations were significantly less frequent in individuals that used a router in the home. For a distance up to 5m from the source (router), a low electric field is found (0.1 to 0.2V/m) [32].

In this sense, despite the lack of a convincing explanation as to the biological plausibility of psychiatric effects from exposure to non-ionizing electromagnetic radiation, these findings should serve as a warning, especially due to the intensive use of mobile phone devices, where the electric field levels are much higher (10 to 150 /m, close to the head) [32] when compared to those from mobile phone base stations, which are located far from the individual's body. In addition, the results on exposure to non-ionizing electromagnetic radiation and depressive symptoms (CES-D ≥ 16) reinforce the findings, since CES-D has been validated in Brazil [23]. Nevertheless, the current study's findings should be viewed with caution, since this was a cross-sectional study, subject to reverse causality bias, given that information on exposure and outcome was obtained simultaneously. For example, do individuals that use mobile phones more tend to become more anxious, or does anxiety lead to greater use of the mobile phone? This reasoning can also be applied to other associations described above.

Despite adjustment, one cannot entirely rule out confounding. An example is possible confounding in the association between decreased libido and staying longer at home. Although the majority (54.1%) of the individuals were working, 7.5% were studying and 7.5% were unemployed (Table 1), and it is important to note that because they spend more time at home, they may have some clinical illness that causes limitations, or they may be on some medication, both of which are factors that can alter libido. It is important to identify the degree of difficulty in generalizing the findings to other populations, even within the city of Salvador. The two neighborhoods were not selected randomly, but as a convenience sample, since they displayed the necessary logistic and methodological conditions for conducting the research. Notwithstanding the important formal requisites of statistics, one can raise the hypothesis that the study's findings may be valid for similar populations, especially from the socioeconomic point of view. Important well-known associations, for example between smoking and lung cancer or between ionizing radiation and leukemia, were found in specific populations, but are valid for all human beings, due to a species issue, while respecting the various possibilities of effect modification. In addition, studies on distances from mobile phone base stations and especially the exposure to non-ionizing electromagnetic radiation from mobile phone devices should be conducted in the future, since the effects of non-ionizing electromagnetic radiation depend on the exposure field's characteristics.

Conclusions

Exposure to non-ionizing electromagnetic radiation related to living between 100 and 200m from a mobile phone base stations and individual behavior in the use of mobile phones and other electronic devices were associated with some psychiatric symptoms, after adjusting for various other potential confounding variables, especially gender. Despite the study's limitations and considering the controversies on the issue, described for the first time in Brazil based on a household survey and using a random sample, we recommend the adoption of precautionary measures to reduce the absorption of radiation from this type of exposure, especially in young people, namely: reduce the time per day spent on mobile phone calls, avoid using the mobile phone with weak signal coverage, refrain from keeping the mobile phone close to the body, use earphones or pop phones, avoid mobile phone use by children, whenever possible use the hardwire landline phone, and avoid residing or working within 200m of mobile phone base stations. The results can help improve public policies, in the sense of informing decision-making on risk evaluation, management, and communication aimed at individual health promotion.

Resumen

El objetivo de este estudio fue investigar la asociación entre la exposición a la radiación electromagnética no ionizante de una estación base telefonía móvil y sus efectos sobre la salud. Se trata de un estudio transversal en Salvador, Bahía, Brasil, donde se entrevistaron a 440 personas. Las quejas y diagnósticos psiquiátricos fueron las variables dependientes y la distancia del hogar a la estación base se consideró como la variable independiente principal. Se realizó un análisis de regresión logística jerárquica para evaluar la confusión y modificación de los efectos. Se observó una asociación entre los efectos psiquiátricos y residir cerca de una estación base y formas de uso del teléfono celular (débil cobertura de la señal, cerca del cuerpo dos o más chips *y nunca apagar el teléfono cuando se duerme) y uso de otros aparatos electrónicos. Se concluyó que la exposición a radiación no ionizante de la telefonía móvil y otros aparatos electrónicos se asoció con efectos psiquiátricos, independiente de sexo, la educación y el tabaquismo. Se recomienda la adopción de medidas de precaución, con el fin de reducir la exposición.*

Radiación No Ionizante; Exposición a la Radiación; Teléfonos Celulares; Síntomas Psíquicos

Contributors

D. F. Silva participated on the conceptualization, field research (interviews), elaboration/construction/keying-in of the database, data analysis and interpretation, writing of the article, relevant critical revision of the intellectual content, revision and approval of the final version for publication. W. R. Barros collaborated on the discussion of the questionnaire, data collection in the field (conducting interviews), participation in construction of the database, and approval of the final version for publication. M. C. C. Almeida and M. A. V. Rêgo contributted on the conceptualization, elaboration of the questionnaire, elaboration of the database, data analysis and interpretation, relevant critical revision of the intellectual content, revision and approval of the final version for publication.

Acknowledgments

This article is part of the PhD thesis by Denize Francisca da Silva under the Graduate Studies Program in Health Biotechnology and Investigational Medicine at the CPqGM/Fiocruz. The authors wish to acknowledge the logistic support from the First and Second Offices of the Public Prosecutors for the Environment in Salvador, Bahia State, and the Capes research funding agency for a scholarship awarded to the above-mentioned PhD student.

References

1. Okuno E, Vilela MAC. Radiação ultravioleta: características e efeitos. São Paulo: Editora Livraria da Física; 2005. (Coleção Temas Atuais de Física).
2. Carvalho RP. Microondas. São Paulo: Editora Livraria da Física; 2005. (Coleção Temas Atuais de Física).
3. Salles AAA, Fernández CER. O impacto das radiações não ionizantes da telefonia móvel e o princípio da precaução. Florianópolis: Ministério Público do Estado de Santa Catarina; 2005. (Caderno Temático).
4. Okuno E, Yoshimura E. Física das radiações. São Paulo: Editora Livraria da Física; 2010.
5. Kapezinski IF, Quevedo J, Izquierdo I. Bases biológicas de transtornos psiquiátricos: uma abordagem translacional. Porto Alegre: Editora Artmed; 2011.
6. Andrade LHSG, Viana MC, Silveira CM. Epidemiologia dos transtornos psiquiátricos na mulher. Rev Psiquiatr Clín 2006; 33:43-54.
7. Santini R, Santini P, Danze JM, Le Ruz P, Seigne M. Enquete sur la sante de riverains de stations relais de telephonie mobile: II. Incidences de l'age des sujets, de la duree de leur exposition et de leur position par rapport aux antennes et autres sources electromagnetiques. Pathol Biol (Paris) 2002; 51:412-5.
8. Navarro EA, Segura J, Portolés M, Mateo CG. The microwave syndrome: a preliminary study in Spain. Electromagn Biol Med 2003; 22:161-9.
9. Bortkiewicz A, Gadzicka E, Szyjkowska A, Politański P, Mamrot P, Szymczak W, et al. Subjective complaints of people living near mobile phone base/stations in Poland. Int J Occup Med Environ Health 2012; 25:31-40.
10. Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, et al. Neurobehavioral effects among inhabitants around mobile phone base/stations. Neurotoxicology 2006; 28:434-40.

11. Oberfeld G, Navarro AE, Portoles M, Maestu C, Gomes-Perretta C. The microwave syndrome: further aspects of a Spanish study. http://www.mindfully.org/Technology/2004/Microwave-Syndrome-Oberfeld1may04.htm (accessed on 08/Apr/2010).
12. Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J, et al. Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed Environ Sci 2010; 23:199-207.
13. International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300GHz), USA. Health Phys 1998; 74:494-522.
14. Iakimenko IL, Sidorik EP, Tsybulin AS. Metabolic changes in cells under electromagnetic radiation of mobile communication systems. Ukr Biokhim Zh (1999) 2011; 83:20-8.
15. Wolf D, Wolf R. Increased incidence of cancer near a cell-phone transmitter station. Int J Canc Prev 2004; 1:1-19.
16. Eger H, Hagen KU, Lucas B, Vogel P, Voit H. Influence of proximity to cell towers on cancer incidence. Umwelt Medizin Gesellschaft 2004; 17:326.
17. Dode AC, Leão MM, Tejo FA, Gomes AC, Dode DC, Dode MC, et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte Municipality, Minas Gerais State, Brazil. Sci Total Environ 2011; 409:3649-65.
18. Berg-Beckhoff G, Blettner M, Kowall B, Breckenkamp J, Schlehofer B, Schmiedel S, et al. Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup Environ Med 2009; 66:124-30.
19. Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, et al. Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. Occup Environ Med 2009; 66:118-23.
20. Saravi FD. Telefonía móvil (celular) y salud humana. Revista Médica Universitária 2007; 3:29-32.
21. International Agency for Research on Cancer. Classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. http://www.iarc.fr/en/mediacentre/pr/2011/pdfs/pr208_E.pdf (accessed on 20/Jun/2011).
22. Silva DF. Análise dos condicionantes para licenciamento das estações radiobase de telefonia celular no município de Salvador – BA [Masters Thesis]. Salvador: Escola Politécnica, Universidade Federal da Bahia; 2009.
23. Schestatsky G. Desempenho de uma escala de rastreamento de depressão (CES-D) em usuários de um serviço de cuidados primários de saúde de Porto Alegre [Masters Thesis]. Porto Alegre: Faculdade de Medicina, Universidade Federal do Rio Grande do Sul; 2002.
24. Greenland S. Hierarchical regression for epidemiologic analyses of multiple exposures. Environ Health Perspect 1984; 102 Suppl 8:33-9.
25. Fuchs SC, Victora CG, Fachel J. Modelo hierarquizado: uma proposta de modelagem aplicada à investigação de fatores de risco para diarreia grave. Rev Saúde Pública 1996; 30:168-78.
26. Dancey CP, Reidy J. Estatística sem matemática para psicólogos: questões de significância. Porto Alegre: Editora Penso Ltda.; 2011.
27. Hayt W, Buck A. Eletromagnetismo. São Paulo: McGraw Hill; 2008.
28. Field A. Descobrindo a estatística usando o SPSS. Porto Alegre: Editora Artmed; 2009.
29. Machado PAL. Direito ambiental. São Paulo: Editora Malheiros; 2006.
30. Hutter H, Moshammer H, Wallner P, Kundi M. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med 2006; 63:307-13.
31. Terada MAB. Propriedades direcionais de irradiação de antenas rádio-base. Telecomunicações 2007; 9:13-8.
32. Powerwatch. RF ("microwave" EMFs): WiFi and health. http://www.powerwatch.org.uk/rf/wifi.asp (accessed on 08/Mar/2013).
33. Hardell L, Calberg M, Hansson KM. Use of cellular telephones and brain tumour risk in urban and rural areas. Occup Environ Med 2005; 62:390-4.
34. Lönn S, Forssén U, Vecchia P, Ahlbom A, Feychting M. Output power levels from mobile phones in different geographical areas; implications for exposure assessment. Occup Environ Med 2004; 61:769-72.
35. Hillert L, Ahlbom A, Neasham D, Feychting M, Järup L, Navin R, et al. Call-related factors influencing output power from mobile phones. J Expo Sci Environ Epidemiol 2006; 16:507-14.
36. Salles AAA, Fernández CHR. Exclusion zones close to wireless communication transmitters aiming to reduce human health risks. Electromagn Biol Med 2006; 25:339-47.
37. Coreau E, Bouvier G, Lebailly P. Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med 2014; 71:514-22.
38. Martin M, Gomes MP, Alves MA. Medidas dos espectros das radiações não ionizantes de São José dos Campos e Taubaté, SP, Brasil. Telecomunicações 2013; 15:7-10.
39. Kuster N, Kühn S. Kumulative exposition des zentralen Nervensystems im Zeit und Frequenzbereich. http://www.pnr57.ch (accessed on 05/Jun/2011).
40. Rosen LP. iDisorder: understanding our obsession with technology and overcoming its hold on US. London: Palgrave Macmillan; 2012.
41. Young KS, Abreu C. Dependência de internet: manual e guia de avaliação e tratamento. Porto Alegre: Editora Artmed; 2011.
42. Statens Stralskyddsinstitut. Swedish Radiation Protection Institute. http://www.eu-decom.be/contacts/sweden/profile-ssi.pdf (accessed on Mar/2013).

Submitted on 10/Jul/2014
Final version resubmitted on 04/Mar/2015
Approved on 30/Mar/2015