Replication of Heart Rate Variability (HRV) Provocation Study with 2.4 GHz Cordless Phone

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ABSTRACT: This is a replication of a study to test the effect of radiation from a cordless phone on heart rate variability (HRV) that we previously conducted in Boulder Colorado with 25 subjects. In the current study we tested the response of 75 subjects between the ages of 26 and 80 in both Canada and the United States. Subjects were exposed for 3-minute intervals to radiation generated by a 2.4 GHz cordless phone base station (3 to 8 $\mu W/cm^2$) at levels well below federal guidelines (1000 $\mu W/cm^2$). We also tested the possibility of electromagnetic interference (EMI) and found none. Results were similar to our previous study. A few participants had a severe reaction to the radiation with an increase in heart rate and altered HRV indicative of an alarm response to stress. In this double-blind study approximately one third of the subjects were moderately to highly responsive to the radiation, one third were mildly responsive and the rest were either non-responsive or we were unable to determine their responsiveness based on the data collected. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of electrohypersensitivity (EHS) when they are exposed to electromagnetic emitting devices. The protocol we used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it does not recognize symptoms other than those that affect HRV.

1. Introduction

In 2010 we published a proof-of-concept study [1] that asked a basic questions, "*Does the microwave radiation (2.4 GHz) from a cordless phone affect the heart?*" This study was based on the growing concern that some people have developed sensitivity to electromagnetic energy at various frequencies. Among the symptoms are heart palpitation, tachycardia and/or arrhythmia associated with feelings of anxiety and pain or pressure in the chest. A cordless phone base station was selected for this provocation study because it emits pulsed microwave radiation when the base station is plugged into an electrical outlet, and–unlike a cell phone–subjects are not required to talk and hence there is less human activity that may interfere with heart rate (HR) and heart rate variability (HRV).

In that proof-of-concept study 10 out of 25 subjects (40%) in Colorado responded to the microwave radiation. In these subjects, response and recovery were immediate. The common responses documented were an increase in heart rate (tachycardia), up regulation of the sympathetic nervous system (SNS) and down regulation of the parasympathetic nervous system (PNS) similar to a fight-or-flight stress response. The severe and moderate responders had a much higher LF/HF[1] ratio (SNS/PNS) than those who either did not respond or had a mild reaction to the microwave exposure from the cordless phone.

We repeated this study with an additional 75 subjects from the United States and Canada and report some of our findings here. We also tested for possible interference of the radiation generated by the cordless phone base station with the HRV technology.

2. Material and Methods

The same recruiting method and the same testing protocol for measuring the electromagnetic environment, for monitoring HRV, and for administering the wellness and EHS questionnaire were followed as in the previous study and are provided elsewhere [1]. Only situations specific to this study are provided here.

In this study we tested 75 subjects in six locations during the period October 23, 2008 to February 27, 2009. Testing was done in either a private home or doctor's office in five U.S. cities (San Francisco, California; Tucson, Arizona; Santa Fe, New Mexico; Taylor, Wisconsin; and New York, New York) and one Canadian city (Simcoe, Ontario). Steps were taken to ensure that testing was done in an electromagnetically clean environment with low background values for magnetic fields, dirty electricity, and radio frequency radiation. GS filters were installed where needed to improve power quality. All other exposures were naturally low. The background values for each environment are provided in Table I.

To test for possible electromagnetic interference (EMI) we reasoned that higher levels of radiation should have a greater effect on equipment and moved the base of the cordless phone to within a few cm of the heart and the HRV sensor with both sham and

[1] LF/HF ratio is commonly used to assess HRV responses. LF refers to low frequency and HF to high frequency associated with SNS and PNS respectively. A high LF/HF ratio is indicative or SNS dominance.

real exposure in a blinded study (Fig. 1). The level of radiation at the heart in the original study with the base station about 1 meter from the heart was 2 µW/cm^2 and this increased in the EMI study to 100–200 µW/cm^2.

TABLE I. MEASUREMENT OF THE ELECTROMAGNETIC ENVIRONMENT AT EACH TESTING LOCATION.

Location	Date of Testing	Subjects Tested #	Background Levels: Magnetic Field *mG*	Dirty Electricity *GS units*	Radio Frequency Radiation *µW/cm2*
Arizona	12/20/08	9	0.8	60	0.05
California	10/23-24/08	21	0.5	30	<0.004
New Mexico	12/21/08	11	0.6	42	<0.004
New York	2/26 to 3/1 2009	17	1.5	90-110	0.01
Ontario	11/15/08	7	0.4	60	<0.004
Wisconsin	11/24/08	10	0.2	48	<0.004

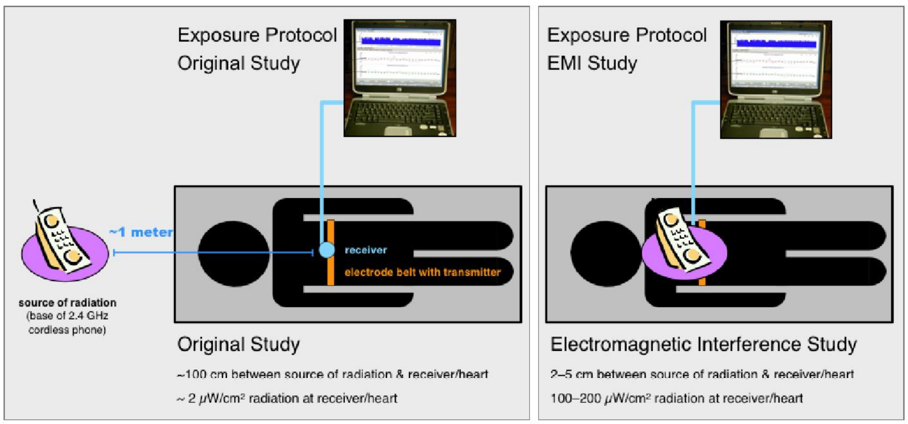


Figure 1. Exposure protocol for testing electromagnetic interference (EMI).

3. RESULTS AND DISCUSSION

A. Test of EMI with HRV Technology of the Radiation from the Cordless Phone Base Station

When the base station of the cordless phone (source of radiation) was placed close to the receiver and the heart of a subject who was a "non-reactor" there were no changes in heart rate, HRV, sympathetic activity or in the HF/LF ratio. A slight down regulation of the parasympathetic nervous system was observed that may have been due to the subject reacting to the higher levels of radiation to which she was now exposed (100–200 µW/cm^2 rather than 2 µW/cm^2). These data are summarized in Fig. 2 along with example of a highly reactive individual (Fig 3) from our original study [1] for comparison. The changes we documented in the original study and in this one are due to altered HRV activity and not EMI.

B. Test Subjects

Most of the participants were female (73%) and ranged in age from 26 to 80 with 82% between the ages of 40 to 70 (Table II). Heart disease is associated with body mass index (BMI) and elevated blood pressure. In this population 64% had normal BMI, 21% were overweight, and 8% were obese. Fifty-seven percent had normal blood pressure, 33% were pre-hypertensive, and 8% had high blood pressure. Electrohypersensitivity is often associated with mercury in the body and 48% of the subjects had mercury fillings. Twelve percent had metal objects in their body and metal is known to reradiate radio frequency radiation.

C. Electromagnetic Exposure in Test Environment

All the environments had low background levels of anthropogenic electromagnetic exposure (Table I). Extremely low frequency magnetic fields (ELF MF) ranged between 0.2 mG (Taylor, WI) and 1.5 mG (New York, NY). Power quality was between 30 GS units (San Francisco, CA) and 109 GS units (New York, NY). Radio frequency radiation was undetected (less than 0.004 µW/cm^2) in all but two environments where levels were low (0.01 to 0.05 µW/cm^2 in Tucson, AZ and New York, NY respectively).

Exposure to the base of the cordless phone was between 3 and 8 $\mu W/cm^2$ at the head of each test subject while subject was lying down during the provocation portion of this study. Exposures (real and sham) were for periods of 3-minutes and were randomized.

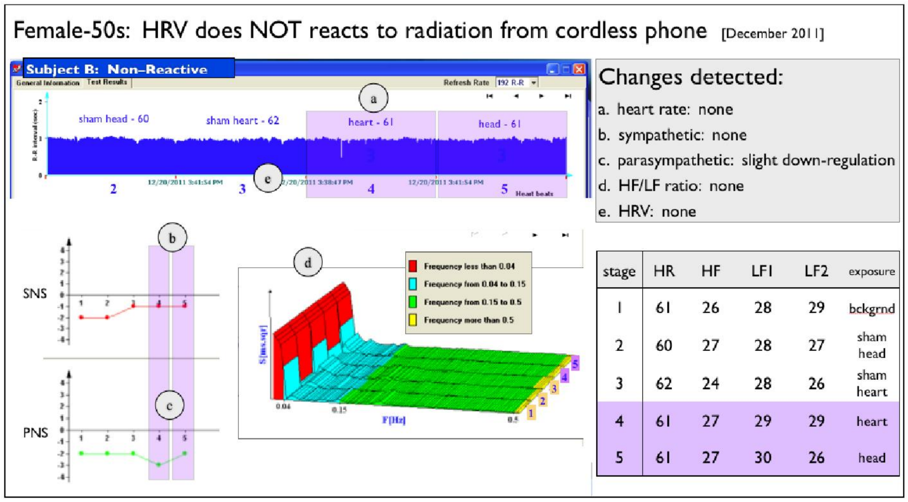


Figure 2. A non-responsive subject was exposed to radiation from a cordless phone. The base station of the phone was placed near the head and near the heart resulting in higher levels of exposure (see Fig.1). Note: there are no changes in (a) heart rate; (b) sympathetic nervous system response; (d) HF/LF ratio; or in (e) R-R interval. The only change detected is a one unit down regulation of the parasympathetic nervous system. Compare this to Fig. 3.

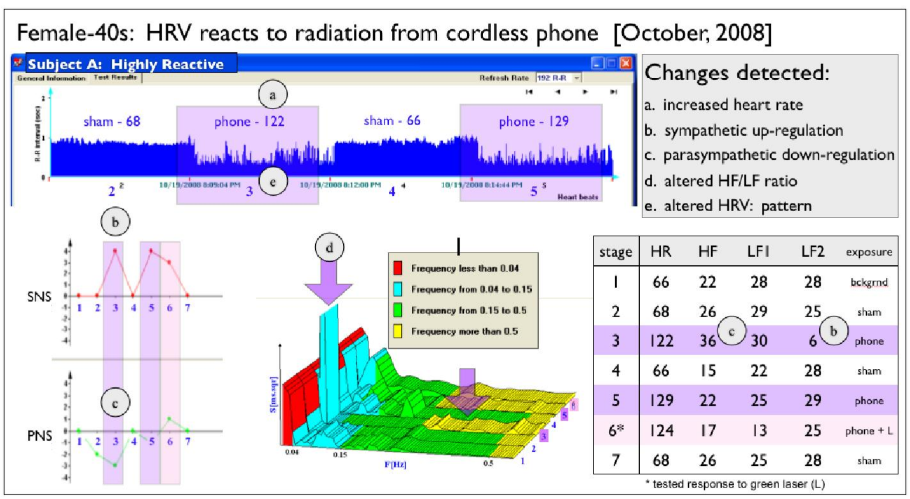


Figure 3. Response of a highly reactive subject to radiation generated by a cordless phone. Note the inrease in (a) heart rate; (b) upregulation of the sympathetic nervous system; (c) down regulation of the parasympathetic nervous system; (d) altered HF/LF ratio, and (e) altered HRV pattern as shown in the R-R interval. The cordless phone was placed near the head of this subject and resulted in an exposure of 3-5 $\mu W/cm^2$ at the head. Data from [1].

D. Wellness and Electrosensitivity (Questionnaire)

Approximately half of the subjects (55%) classified themselves as being "a little" to "extremely" sensitive with 30% in the "extreme" category. Most of the remaining subjects (43%) did not know if they were sensitive to electromagnetic radiation (Fig. 4). When asked how debilitated they are when exposed to electrosmog, 12% were severely debilitated and 40% were moderately to slightly debilitated.

In the current study, in order to detect a response, individuals had to respond immediately to a provocation. According to the questionnaire, only 45% of self-proclaimed EHZ subjects responded immediately and only 8% recovered immediately (Fig. 5). Time of response is crucial for this study and delayed responders cannot be identified according to our protocol. The protocol can be altered to take into account delayed responders.

TABLE II. INFORMATION ABOUT PARTICIPANTS.

		#	%
Gender	Male	20	27%
	Female	55	73%
Age	20s	4	5%
	30s	3	4%
	40s	18	24%
	50s	26	35%
	60s	17	23%
	70s	5	7%
	80s	1	1%
	nd	1	1%
BMI*	obese	6	8%
	over weight	16	21%
	normal	48	64%
	under weight	2	3%
Resting Heart Rate	mean & range	70.4 bpm	42 – 118 bpm
Blood Pressure**	normal	43	57%
	pre-hypertension	25	33%
	high blood pressure	6	8%
	no data	1	1%
Metal in Body	mercury fillings	36	48%
	other metal	9	12%

* BMI = body mass index based on height and weight [2]; ** Blood Pressure according to National Heart and Lung and Blood Institute [3]

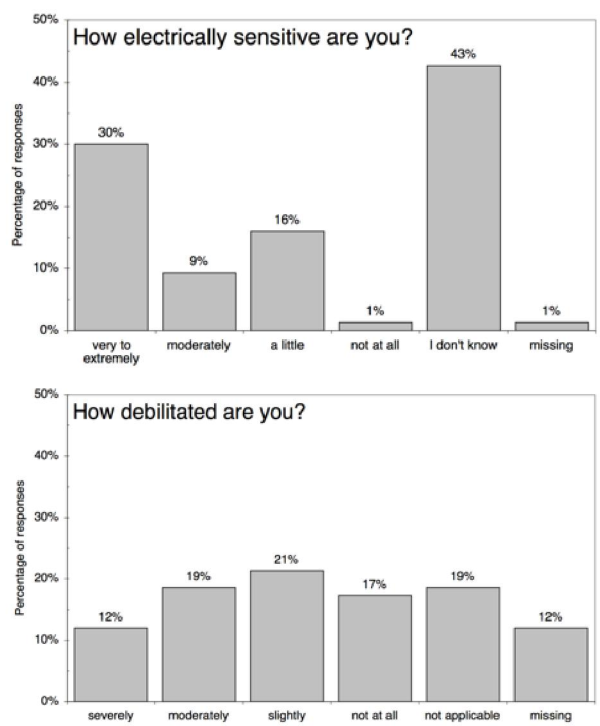


Figure 4. Self-proclaimed electrosensitivity of participants (n=75)

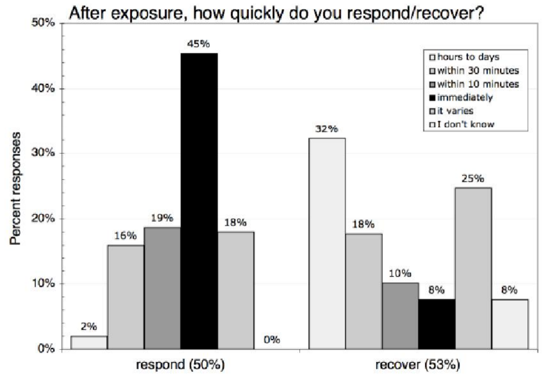


Figure 5. Response and recovery time following exposure to electrosmog for those who are self-proclaimed sensitivities (n=38 & 40). Note: half of the participants (n=75) claim to be responsive.

Severity and frequency of symptoms is provided in Fig. 6. The most common symptoms are headaches, sleep disorders, difficulty concentrating, chronic fatigue, feeling unwell and poor short-term memory. Heart palpitations and rapid heart rate are 11th and 13th on this list of 26 symptoms with 30% of the subjects having mild to severe reactions. Arrhythmia and slower heart beat are less common.

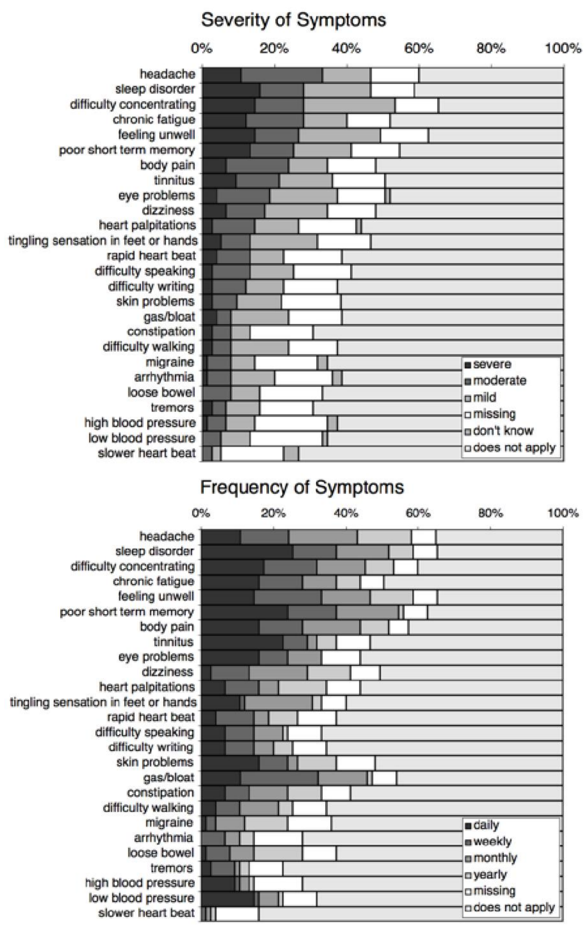


Figure 6. Severity and frequency of symptoms associated with electrosmog exposure (n=75).

Of the devices that contribute to adverse symptoms, cordless phones are third after tube fluorescent lights and cell phones (Fig. 7). The cordless phone we used operates at 2.4 GHz the same as Wi-Fi, which was 5^{th} on the list. Four of the top five objects emit microwave radiation.

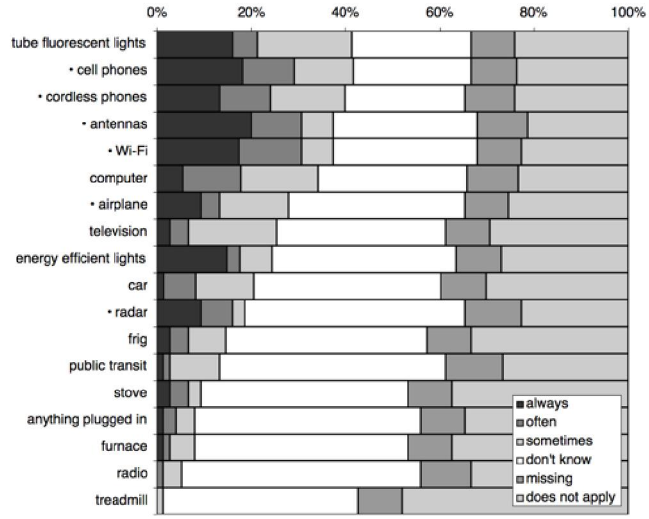


Figure 7. Objects that contribute to adverse health symptoms. Those marked with an dot generate microwave radaition (n=75).

E. Orthostatic HRV

Orthostatic testing is highly recommended to assess the state of the autonomic nervous system (ANS) for each test subject. Healthy subjects should be able to mount a response when confronted with a stressor. Those who are severely fatigued or demonstrate dysautonomia may have difficulty responding to an additional stressor or may respond in an unusual way. More information about the importance of an orthostatic HRV test prior to monitoring is provided elsewhere.

Some of the subjects in the current study demonstrated moderate to severe dysautonomia (9 subjects), moderate to severe fatigue (18 subjects), poor fitness scores (20 subjects), and atrial fibrillation (2 subjects) indicative of either chronic or acute health issues. Those with atrial fibrillation were not included in the HRV analysis. HRV equipment malfunctioned during testing of one subject so those data cannot be used.

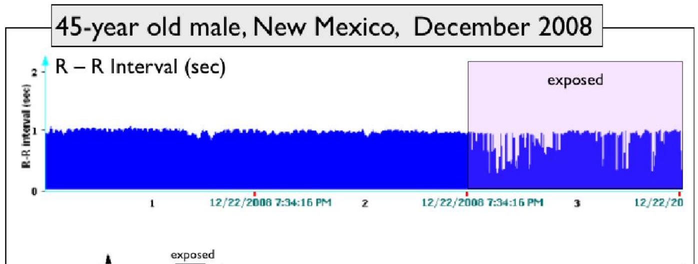
F. Provocation HRV

As in the previous study, a few subjects mounted a strong reaction with altered heart rate, HRV, and sympathetic and parasympathetic responses when exposed to radiation from a 2.4 GHz cordless phone base station. One example of a strong reaction is provided.

Subject is a 45-year old male in New Mexico with moderate fatigue but normal limits on orthostatic test. During exposure, total power increased significantly, and there was an up regulation of the sympathetic and parasympathetic nervous system (Fig. 8). Subject demonstrated a strong but appropriate alarm reaction to stress.

Our monitoring was designed to detect immediate reactions to provocation. Those individuals with a delayed reaction are likely to be missed by our testing protocol. To demonstrate this one subject told us that he normally had a delayed reaction to microwave exposure. Indeed his results showed no change in HRV, HR, SNS or PNS responses during exposure. We did another orthostatic test 2 hours after the original 3-minute exposure. His results were unusual (Fig. 9). Subject is a 52-year old male (Ontario) with fatigued autonomic nervous system and mild dysautonomia during the first orthostatic test. On reexamination, subject demonstrated severe dysautonomia coupled with tachycardia (124 bpm while lying down) and extra systoles, as well as extreme exhaustion of autonomic nervous system based on objective observations and symptoms reported by subject. This is an example of a delayed and severe EHS.

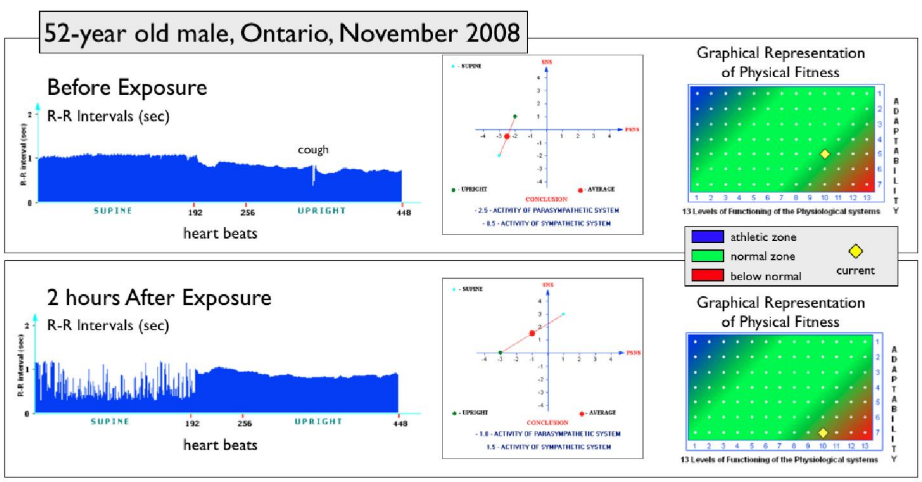
Several subjects did not experience altered ANS function but did experience headaches and other symptoms, which, our testing was not designed to monitor. One subject, with a brain tumor that had been operated but not successfully, indicated that he experienced seizures following exposure. We encouraged him not to participate in the study but he insisted. He told us how to take care of him if he did seizure. About 2 minutes after exposure stopped subject had a seizure that lasted 3 to 5 minutes. He remained weak for several hours after exposure. Such individuals need to be cautious about their exposure and often have difficulty in urban environments because of pervasive radio frequency exposure generated by cell towers, Wi-Fi, and smart meters. Being close to someone using a cell phone can trigger a reaction.



Stage	Exposed	Heart Rate (bpm)	Total Power	HF (PNS)	LF1 (SNS)	LF2 (SNS)
1	NO	60	4,868	24	29	29
2	NO	66	6,953	27	24	28
3	YES	69	24,017	18	25	18

SNS – sympathetic nervous system; PNS – parasympathetic nervous system;
TP – total power (0.04 to 0.50 Hz); HF – high frequency (0.15 to 0.50 Hz);
LF1 – low frequency (0.07-0.15 Hz); LF2 – low frequency (0.04-0.071 Hz)

Figure 8. Response of a 45-year old male to pulsed microwave radiation generated by a cordless phone. Note the altered R-R intervals; the up regulation of both the sympathetic (SNS) and parasympathetic (PNS) nervous system; the increase in total power and the changes in HF and LF2 during exposure.



Exposure	Ortho Test: Supine HR	TP	HF	LF1	LF2	Ortho Test: Standing HR	TP	HF	LF1	LF2	Chronotropic Reaction	Compensation Response	Ortho Test Ratio
Before	57	249	162	24	62	81	1073	26	200	846	0.74	0.83	1.42
After	124	2706	734	1182	790	71	100	32	38	30	1.00	0.99	0.45

HR – heart rate; TP – total power; HF – high frequency (PNS); LF1 & LF2 – low frequency (SNS)
Chronotropic reaction: heart rate (supine) vs. maximum heart rate
Compensation response: minimum heart rate vs. maximum heart rate
Ortho Test Ratio: heart rate supine vs. heart rate upright

Figure 9. Delayed response of a 52-year old male to pulsed microwave radiation generated by a cordless phone. These resuls were noted 2 hours following a 3 minute exposure to 8 µW/cm^2. Both orthostatic tests were conducted in a clean electromagnetic environment with no exposure to radio frequency radiation.

Subjects have varied reactions to radio frequency exposure at levels that are well within federal guidelines in both Canada and the United States (currently 1000 µW/cm^2 for microwave frequencies at 2.4 GHz). For some the reaction is immediate, for others it is delayed, and for some it is prolonged well beyond exposure. The protocol we used in this study is likely to underestimate sensitivity or reactivity to radio frequency radiation. This protocol can be modified to take into account delayed responders.

4. Conclusion

Our results show that some individuals are highly sensitive to electromagnetic frequencies generated by a cordless phone base station at 2.4 GHz. In this double-blind, sham-controlled study, we document an increased heart rate, altered HRV, and changes in the sympathetic and parasympathetic control of the autonomic nervous system similar to our previous study. The results are not due to electromagnetic interference (EMI) since exposure of the sensors to much higher levels of microwave radiation than we used in the original testing of subjects (100 µW/cm2 rather than 2 µW/cm2) did not elicit a reaction in a non-reactor. Our results demonstrate that pulsed microwave radiation affects the autonomic nervous system and may put some individuals with pre-existing heart conditions at risk when exposed to electromagnetic frequencies to which they are sensitive.

Acknowledgment

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