Electromagnetic Biology and Medicine, June 2013; 32(2): 253–266
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ISSN 1536-8378 print/ISSN 1536-8386 online
DOI: 10.3109/15368378.2013.776437

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healthcare

Replication of heart rate variability provocation study with 2.4-GHz cordless phone confirms original findings

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This is a replication of a study that we previously conducted in Colorado with 25 subjects designed to test the effect of electromagnetic radiation generated by the base station of a cordless phone on heart rate variability (HRV). In this study, we analyzed the response of 69 subjects between the ages of 26 and 80 in both Canada and the USA. Subjects were exposed to radiation for 3-min intervals generated by a 2.4-GHz cordless phone base station (3–8 $\mu W/cm^2$). 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. Based on the HRV analyses of the 69 subjects, 7% were classified as being "moderately to very" sensitive, 29% were "little to moderately" sensitive, 30% were "not to little" sensitive and 6% were "unknown". These results are not psychosomatic and are not due to electromagnetic interference. Twenty-five percent of the subjects' self-proclaimed sensitivity corresponded to that based on the HRV analysis, while 32% overestimated their sensitivity and 42% did not know whether or not they were electrically sensitive. Of the 39 participants who claimed to experience some electrical hypersensitivity, 36% claimed they also reacted to a cordless phone and experienced heart symptoms and, of these, 64% were classified as having some degree of electrohypersensitivity (EHS) based on their HRV response. Novel findings include documentation of a delayed response to radiation. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of EHS when they are exposed to electromagnetic emitting devices. The protocol used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it may under diagnose those who have adrenal exhaustion as their ability to mount a response to a stressor is diminished.

Keywords: heart rate variability, mobile phone, tachycardia, arrhythmia, microwave radiation, radio frequency radiation, electrohypersensitivity, autonomic nervous system

Introduction

Individuals who complain of electrical hypersensitivity experience a myriad of symptoms that may include heart palpitation, arrhythmia, tachycardia, pain or pressure in the chest that may or may not be accompanied by anxiety, dizziness, nausea and headaches (Austrian Medical Association, 2012; Bevington, 2010; McCarty et al., 2011; Eltiti et al., 2007; Johansson, 2006). Since we have technology to measure the activity of

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the heart and the autonomic nervous system (ANS), monitoring the effect of electromagnetic radiation (EMR) on the heart is relatively straightforward.

In 2010, we published a proof-of-concept study (Havas et al., 2010) that asked a basic questions, "Does the electromagnetic radiation (2.4 GHz) from a cordless phone affect the heart?" A cordless phone base station[1] was selected for this provocation 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). Andrzejak et al. (2008) tested the effect of mobile phones on HRV in healthy volunteers and they observed a change in the autonomic balance with an increase in the parasympathetic nervous system (PNS) and a decrease in the sympathetic nervous system (SNS), but they could not rule out the effect of talking on the phone.

In our proof-of-concept study, 10 out of 25 subjects (40%) in Colorado responded to the EMR generated by the cordless phone. In these subjects, response and recovery were immediate. The common responses documented were an increase in HR (tachycardia), upregulation of the SNS and downregulation of the PNS similar to a *fight-or-flight* stress response. The severe and moderate responders had a much higher low frequency/high frequency (LF/HF)[2] ratio (SNS/PNS) than those who either did not respond or had a mild reaction to the EMR exposure from the cordless phone.

We repeated this study with an additional 75 subjects from Canada and the USA and provide the HRV results here. The analysis of the wellness questionnaire is provided elsewhere (Havas & Marrongelle, 2012).

Primer on HRV and the ANS based on Nerve Express

The Nerve Express technology, developed by Alexander Riftine, provides a quantitative assessment of the ANS based on HRV. The theoretical basis and clinical use are available (Riftine, 2002) and only a brief description will be provided here to make the content easier to understand, since some graphics are specific to Nerve Express.

Orthostatic testing

Rhythmograph: Orthostatic testing is done to determine the response of the ANS to mild stress experienced when a person moves from a supine (lying down) to an upright (standing) position. This test is based on the time intervals between the R–R beats of the heart over a period of 448 beats (frequency interval) and is demonstrated as a rhymograph. Figure 1 provides examples for four different conditions.

A healthy and physically fit person (Figure 1a) has high HRV – as shown by the regular undulations; a sharp decrease (elevated HR) and rapid recovery in the R–R interval during the transition phase (beats 192–256). The HR is generally low and increases marginally with exertion.

An unhealthy person with poor physical fitness (Figure 1b) has a flat rhythmograph (low variability); a shallow dip during transition to standing; and an elevated HR with and without exertion.

Atrial fibrillation (Figure 1c), the most common cardiac arrhythmia, is shown by the multiple spikes or extra systoles, which are extra contractions of the heart

[1] The base for a cordless phone is referred to as the *base station*. With multiple handsets, the primary base is the base station and the rest are satellite stations.

[2] 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 an indicative of SNS dominance.

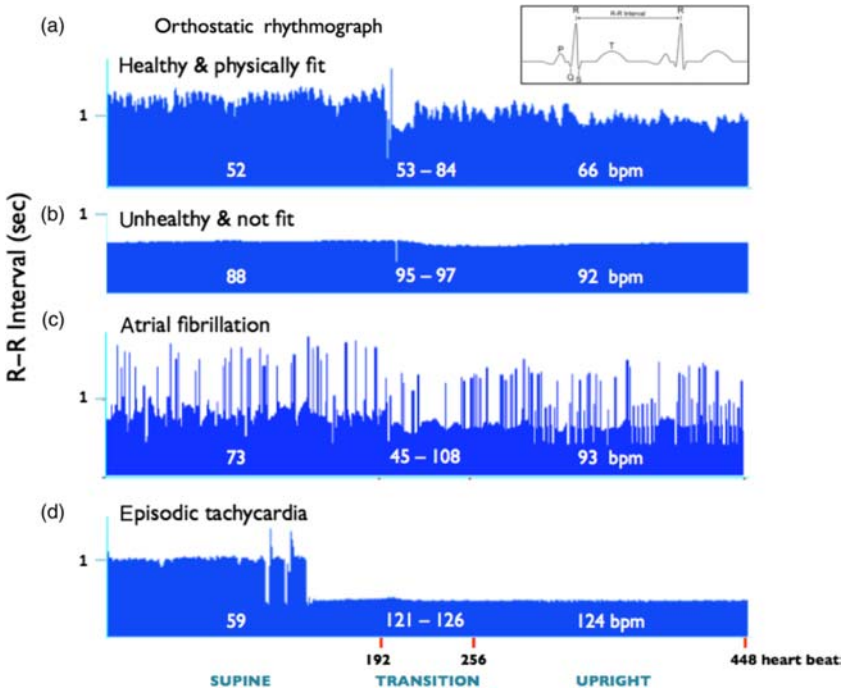


Figure 1. Examples of the Nerve Express orthostatic rhythmograph for different conditions.

that interrupt the normal regular rhythm of the heart. They occur when there is electrical discharge from somewhere in the heart other than the sino-atrial node.

Episodic tachycardia (Figure 1d) is represented by the sudden decrease in the R–R Interval, which indicates a faster HR. In this case, the HR increased from 59 to more than 120 beats per minute while the person was lying down and remained elevated for the duration of the test period.

SNS versus PNS: Changes in the SNS (fight-or-flight) and the PNS (rest-and-digest) as one moves from a supine to an upright position are shown in Figure 2. How the body regulates the SNS/PNS can provide valuable information on the relative health

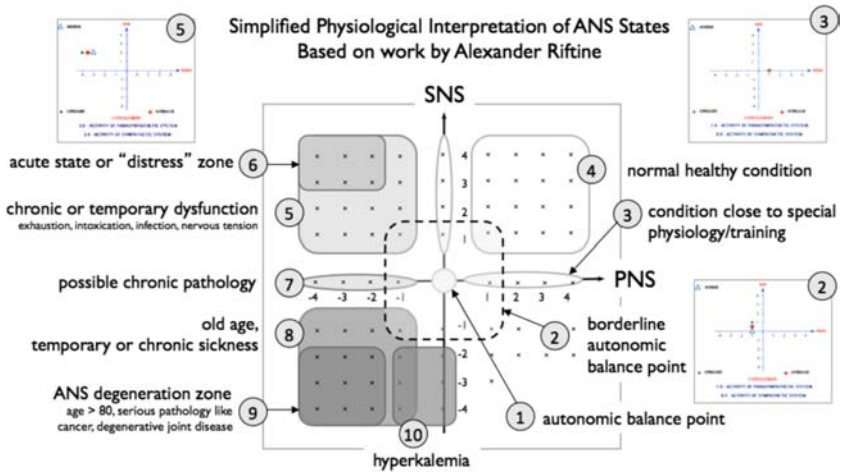


Figure 2. Interpretation of the ANS response for the orthostatic test based on Riftine (2002).

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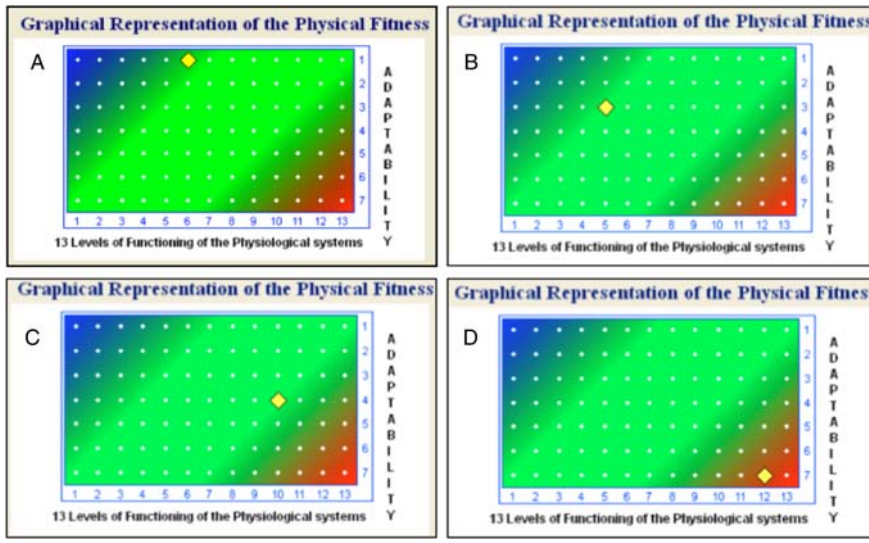


Figure 3. Physical fitness based on the orthostatic test. Fitness decreases as one approaches the lower right corner of the graph. A fitness score at and above 10 (horizontal axis) indicates fatigue. The relative fitness of the four examples decreases from A (6–1) to D (12–7).

of the ANS and based on the direction and magnitude of the response can indicate chronic or temporary dysfunction, pathology and degeneration.

Just as a stressor or physical activity can increase the ratio of SNS to PNS, eating a large meal immediately before HRV testing can also alter this ratio, but in the opposite direction making a person feel tired or sleepy. This postprandial somnolence (sleepiness following a meal) has two components:

(1) Parasympathetic upregulation, in response to food in the stomach and small intestine, combined with sympathetic downregulation shifting the body into a "rest-and-digest" state.
(2) Hormonal and neurochemical changes associated with glucose metabolism and insulin secretion. For this reason, it is important to standardize when, how much and the type of food consumed prior to testing or, if this is not possible, to record time since last meal was consumed.

Fitness and adaptability: The physical fitness score (Figure 3) is a combination of the short-term state of the physiological system (1–13, horizontal axis), which can change quickly and is a reflection of how well rested the person is; and the long-term adaptability of the system (1–7, vertical axis), which changes more slowly. Top athletes rank in the blue zone (top left corner) and those who are chronically ill in the red zone (bottom right). Healthy individuals fall within the green zone (middle area) and their relative fitness is a function of how close they are to the two extremes.

Real-time monitoring

During real-time monitoring, stages can be set for data analysis which are based on a pre-determined number of heart beats (frequency interval). In this study, we set the stage length (or refresh rate) to 192 R–R intervals (approximately 3 min duration depending on HR). Data provided include HR, HF, LF1, LF2, SNS and PNS in a table. The latter two are also provided graphically and the R–R interval is presented as a rhymograph (Figure 4).

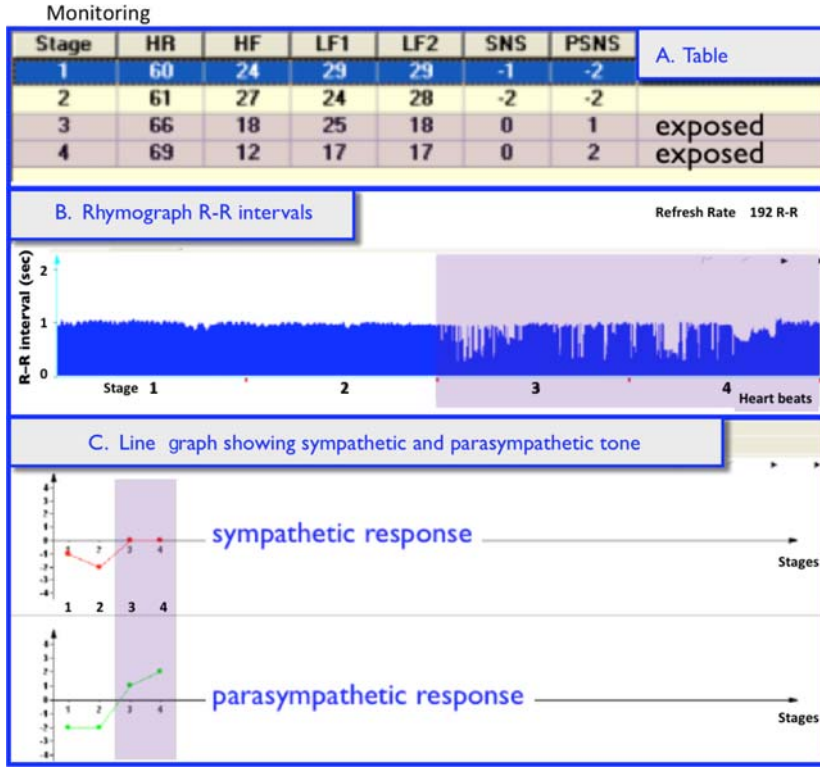


Figure 4. Real-time monitoring of exposure showing HR, HF, low frequency (LF1 and LF2), SNS, PNS and the time interval for the heart beats (R–R interval). The example provided shows exposure during stages 3 and 4.

Definition of terms and acronyms:

- HR – heart rate (beats per minute).
- HF – high-frequency variations (0.15 and 0.5 Hz) are highly correlated with the activity of the PNS.
- LF – low-frequency variations (0.04 to 0.15 Hz) are used to assess activity of the SNS although these are not as precise as for HF; the LF bandwidth is further divided into LF1 (reflecting adrenergic and cholinergic response) and LF2 (reflecting changes in baroreceptors, also known as the Mayer waves below 0.1 Hz or 10-s waves).
- SNS – regulates the "fight-or-flight" response resulting in an increase in HR in preparation for activity.
- PNS – regulates the "rest-and-digest" response and counterbalances the SNS by bringing the heart back to a resting state once the "stressor" is no longer present or the activity is reduced.

Material and methods

This was a double-blind, sham-controlled study. The same recruiting method and the same testing protocol for measuring the electromagnetic environment and for monitoring HRV were followed as in the previous study and are provided elsewhere (Havas et al., 2010). Only situations specific to this study and related to the

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Table 1. Measurement of the electromagnetic environment at each testing location.

Location	Date of testing	No. of subjects tested	Background levels		
			Magnetic field (mG)	Dirty electricity (GS units)	Radio frequency ($\mu W/cm^2$)
San Francisco, CA	23–24 Oct 2008	21	0.5	30	<0.004
Simcoe, ON	15 Nov 2008	7	0.4	60	<0.004
Taylor, WI	24 Nov 2008	10	0.2	48	<0.004
Tucson, AZ	20 Dec 2008	9	0.8	60	0.05
Santa Fe, NM	21 Dec 2008	11	0.6	42	<0.004
New York, NY	26 Feb–1 Mar 2009	17	1.5	90–110	0.01

functioning of the ANS are provided here. The wellness questionnaire data are published elsewhere (Havas & Marrongelle, 2012).

In this study, we tested 75 subjects in six locations during the period 23 October 2008 to 1 March 2009. Testing was done in either a private home or doctor's office in five U.S. cities (San Francisco, CA; Tucson, AZ; Santa Fe, NM; Taylor, WI and New York, NY) 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. Graham Stetzer (GS) filters were installed where needed to improve power quality (reduce dirty electricity). All other exposures were naturally low. The background values for each environment are provided in Table 1.

Results and discussion

Electromagnetic exposure in test environment

Environments were selected for low background levels of anthropogenic electromagnetic exposure (Table 1). Extremely LF magnetic fields (ELF MF) ranged from 0.2 mG (Taylor, WI) to 1.5 mG (New York, NY). Power quality was between 30 GS[3] units (San Francisco, CA) and 109 GS units (New York, NY). Radio frequency radiation was undetected (less than 0.004 $\mu W/cm^2$) in all but two environments where levels were low (0.01–0.05 $\mu W/cm^2$ in Tucson and New York, respectively).

The radiation generated by the cordless phone was between 3 and 8 $\mu W/cm^2$ at the closest body part (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 approximately 3 min and were randomized. Neither the subject nor the doctor (JM) analyzing the HRV data knew when subjects were exposed. Radiation from the cordless phone base station was 100–1000 times higher than background levels in the test environments and was considerably lower than the guidelines recommended by International Commission for Non-Ionizing Radiation Protection (ICNIRP) for 2.4-GHz radiation of 1000 $\mu W/cm^2$. Maximum exposure to radiation from the cordless phone was at 0.8% of ICNIRP guidelines. The guidelines are the same in Canada and the USA, although in Canada public exposure is averaged over a 6-min period and in the USA over a 30-min period. Neither country has long-term exposure guidelines. Note also that these guidelines are based on a thermal effect of increasing body temperature. They do not consider more subtle effects such as changes in cardiac function.

[3] GS refers to the Graham Stetzer unit of measuring the energy associated with HF transients between 4 and 150 kHz on electrical wiring.

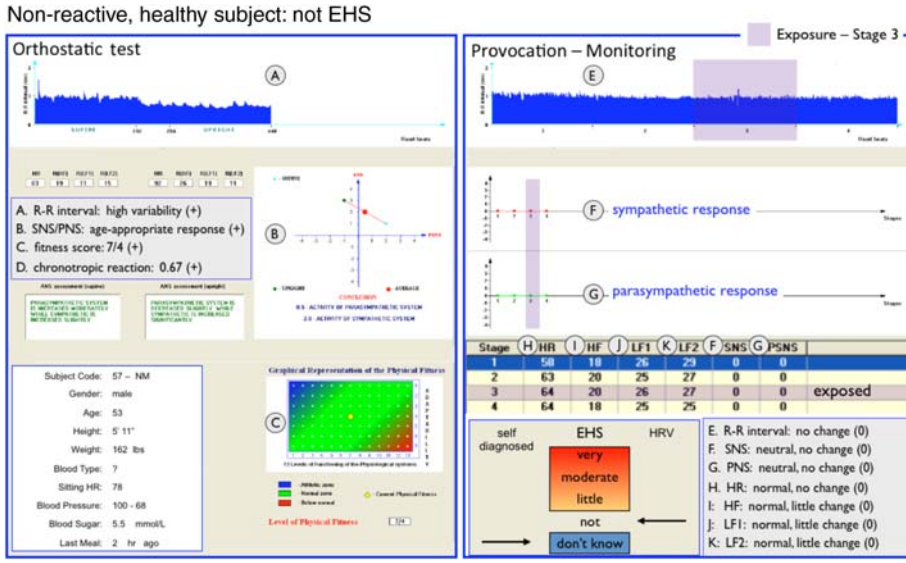


Figure 5. HRV parameters for a healthy subject who is not responding to any exposure. This subject was classified as not electrically sensitive based on short-term exposure to the radiation generated by a cordless phone base station.

Test subjects

Participants ranged in age from 26 to 80 with 82% between the ages of 40 and 70; most were female (73%). Additional information is provided elsewhere (Havas & Marrongelle, 2012). The data for six participants were not included in the final HRV analysis: one had atrial fibrillation that prevented accurate analysis (Figure 1c); another experience episodic tachycardia that was not related to exposure (Figure 1d); and either missing data or compromised testing protocol eliminated the remaining four. The HRV analysis is based on a total of 69 participants.

Assessment of electrohypersensitivity status

Determining whether or not a subject is "responding" to provocation is fairly straightforward in those subjects who mount a significant response during or immediately after exposure to the radiation through changes in the rhymograph, HR and/or the relative ratio of sympathetic to parasympathetic tone. It is also obvious in those who are "nonresponders" (no significant change in any parameter tested).

Determining whether a responder or a nonresponder has electrohypersensitivity (EHS), however, is not straightforward. In this study, the intensity of the response and the number of parameters that were altered during or after exposure contributed to the EHS classification with more intense reactions labeled "very sensitive".

For example, 44 (64%) of the subjects tested experienced fatigue and adrenal exhaustion based on the fitness results and the chronotropic reaction (orthostatic test). Someone with adrenal exhaustion has limited ability to mount a response to a stressor and, consequently, he or she could be mistaken for someone who is not electrically sensitive.

Examples of two nonresponders are provided in Figures 5 and 6. Subject in Figure 5 was healthy and fit and did not respond immediately to the exposure and, consequently, he was classified as not sensitive. Subject in Figure 6 had dysautonomia and adrenal exhaustion and probably had limited energy to mount a response. For this reason, it was not possible to determine his EHS status. Because of this distinction, the orthostatic test is essential to assess the baseline response for

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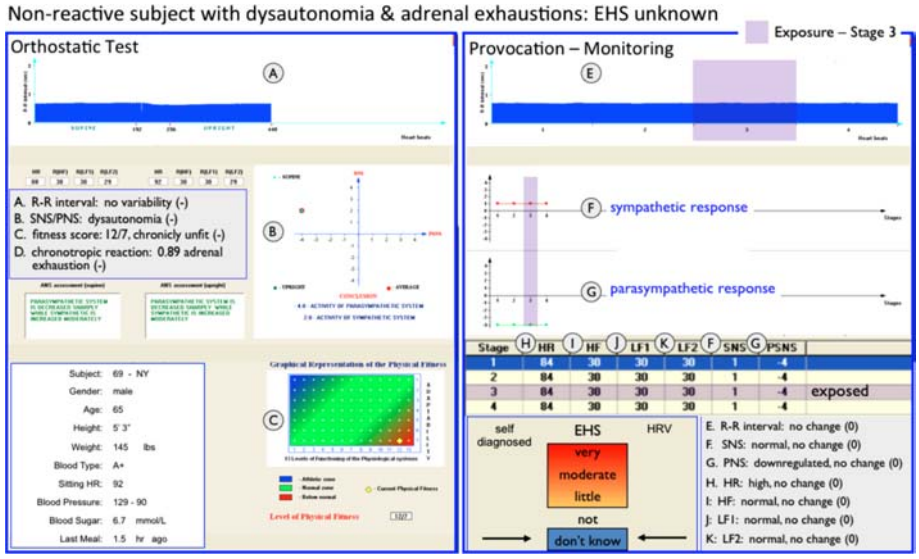


Figure 6. HRV parameters for a subject with dysautonomia and adrenal exhaustion who is not responding to any exposure. This subject's electrical hypersensitivity was classified as unknown due to adrenal exhaustion.

each subject and to compare their monitoring results to the degree of stress experienced when standing up.

Examples of reactive subjects are provided in Figures 7–9. Subject in Figure 7 had sufficient energy to mount a response as can be seen in the rhymograph (irregularity), the sympathetic and parasympathetic increase and changes in HF, LF1 and LF2. This subject was classified as moderately sensitive. Subject in Figure 8 had exhausted adrenals and was able to mount a significant response during the first exposure but not during subsequent exposures. He was classified as "very" sensitive. Subject with moderate fatigue (Figure 9) was able to mount a response during both

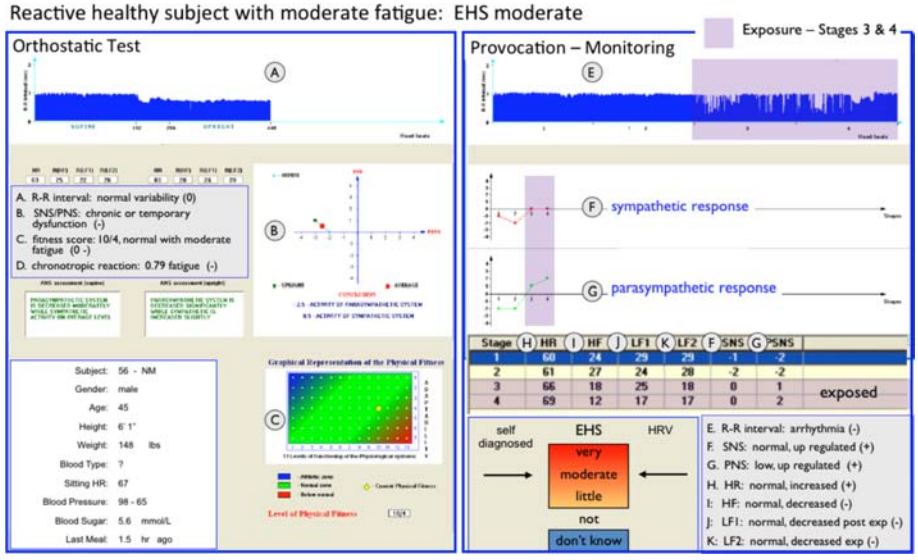


Figure 7. HRV parameters for a healthy subject with moderate fatigue who is reacting to the radiation generated by a cordless phone base station. This subject was classified as moderately sensitive.

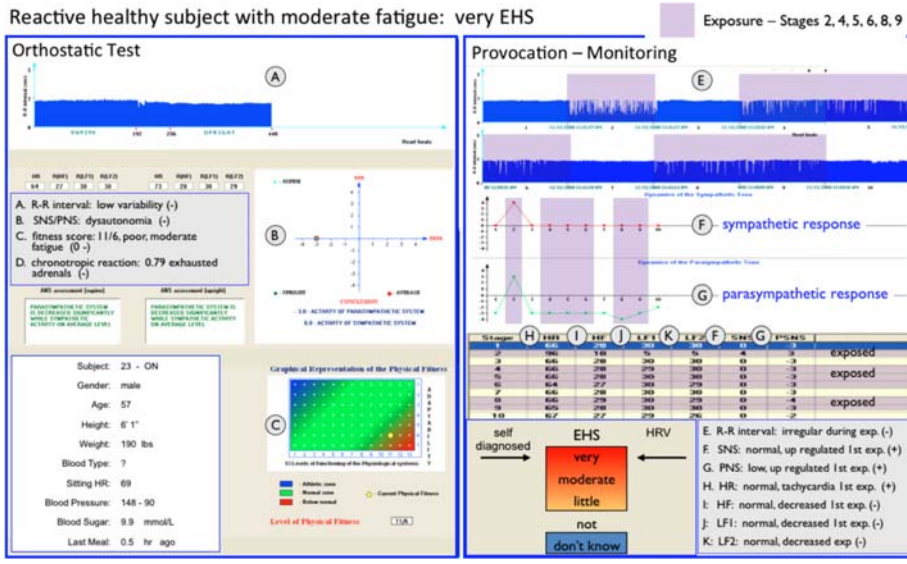


Figure 8. HRV parameters for a healthy subject with adrenal exhaustion who is reacting to the radiation generated by a cordless phone base station. This subject was classified as very sensitive due to tachycardia and sharp upregulation of both the SNS and PNS that is indicative of an alarm reaction. Subject responded primarily to first exposure perhaps due to adrenal exhaustion.

sets of exposures. An upregulation of the SNS combined with a downregulation of the PNS is a typical alarm – "fight-or-flight" – reaction.

One of the test subjects mentioned that he normally responds to electromagnetic exposure with a delay of 10 min or more, so we extended the monitoring time postexposure by approximately 30 min (Figure 10). Subject 28 began to respond postexposure at stage 7 and the fluctuations in the rhymograph and in SNS and PNS become increasingly common over time. Based on the delayed response, this subject

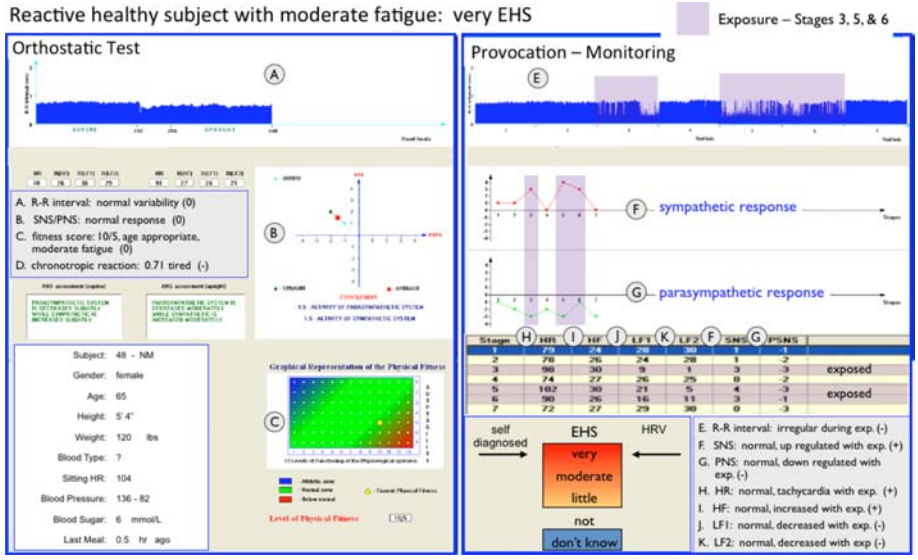


Figure 9. HRV parameters for a healthy subject with moderate fatigue who is reacting to the radiation generated by a cordless phone base station. This subject was classified as very sensitive due to tachycardia and sharp upregulation of both the SNS and PNS that are indicative of an alarm reaction. Subject reacted during all exposures.

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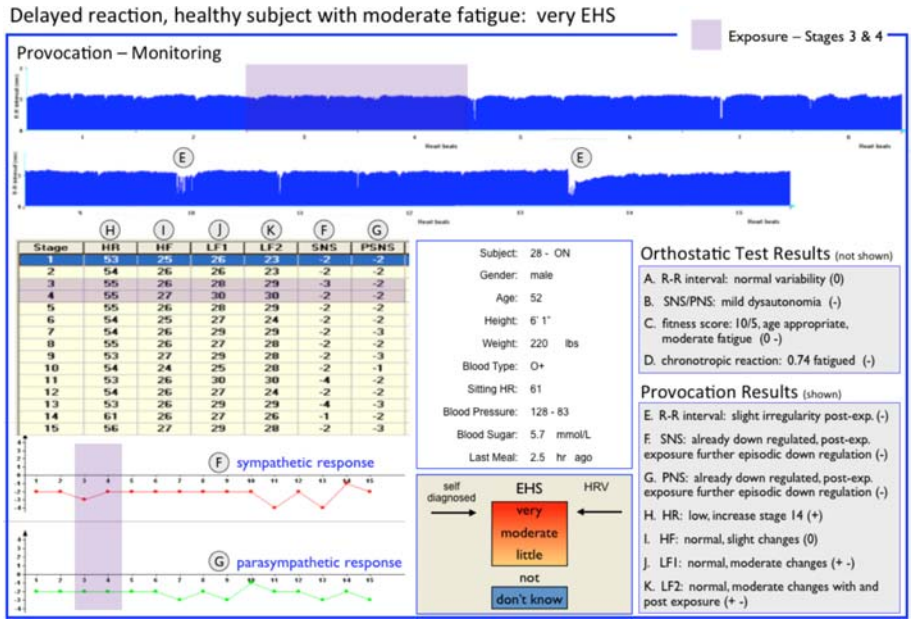


Figure 10. Healthy subject with moderate fatigue experienced a delayed reaction to radiation generated by a cordless phone base station. This subject was classified as being very sensitive.

was classified as very sensitive. His sensitivity would have been missed had the monitoring period lasted only a few minutes. This points out one of the major weakness of a study that is so short, namely that a delayed response will be missed.

One way to improve the quality of data collection is to extend duration for the background condition, sham exposure, direct exposure and postexposure and to reduce the sampling period (refresh rate) from 192 to 48 heart beats (R–R intervals).

Electromagnetic interference

Electromagnetic interference (EMI) with test equipment has been suggested in the non-peer-reviewed literature as a possible explanation for the altered HRV parameters that we documented in our first study (Havas et al., 2010). To test this hypothesis, we repeated exposure with a blinded subject who was healthy and nonreactive and moved the radiation source from the head to the heart. This increased exposure from 2 to 100–200 $\mu W/cm^2$ at both the heart and the receiver. These levels are still below the thermal guidelines of 1000 $\mu W/cm^2$.The only change documented was a slight and temporary decrease in the PNS (Havas & Marrongelle, 2012). It is worth noting that had EMI been involved, then all of the exposures would have interfered with the technology since the identical protocol was used for all testing. Furthermore, EMI cannot explain the delayed reaction after the radiation was discontinued (Figure 10).

Provocation HRV

Of the 69 participants, 46 participants were classified (by JM) as “little to very” EHS. Of these, 18 (39%) did not know whether or not they had EHS, one (2%) believed he was not sensitive and 27 (39%) believed they were sensitive (Table 2). Indeed there was agreement with the degree of sensitivity (little to very) for 17 (25%) of the subjects. This relatively high percentage showing a convergence of assessment is not in agreement with the reviews on this subject conducted by a psychologist who

Table 2. Comparison of EHS status based on HRV analysis and self-proclamations.

EHS		EHS based on HRV Analysis						
27 (39%)		MV	LM	NL	N	?	total	agreement
EHS self proclaimed	V	4 (6%)	3 (4%)	7 (10%)	6 (9%)	1 (1%)	21 (30%)	4 (6%)
	M	0 (0%)	3 (4%)	2 (3%)	0 (0%)	1 (1%)	6 (9%)	3 (4%)
	L	0 (0%)	4 (6%)	4 (6%)	4 (6%)	0 (0%)	12 (17%)	8 (12%)
	N	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
	?	1 (1%)	9 (13%)	8 (12%)	9 (13%)	2 (3%)	29 (42%)	2 (3%)
	total	5 (7%)	20 (29%)	21 (30%)	19 (28%)	4 (6%)	69 (100%)	17 (25%)
agreement		4 (6%)	7 (10%)	4 (6%)	0%	2 (3%)	17 (25%)	

Degree of sensitivity identified as very (V), moderate (M), little (L), not (N) and don't know (?). The agreement between self-diagnosis and HRV analysis is highlighted in gray ($N = 69$).

believes that EHS is psychosomatic rather than a physical response (Rubin, Hillert, Nieto-Hernandez, van Rongen, & Oftedal, 2011; Rubin, Das Munshi, & Wessely, 2005; Rubin, Nieto-Hernandez, & Wessely, 2010).

Of the 69 participants, 39 (57%) were self-proclaimed electrosensitives; 29 (42%) stated they reacted to a cordless phone (sometimes to always) and 22 (32%) experienced some heart-related symptoms that could be detected by the HRV analysis (altered HR and/or arrythemia). Only 14 participants (20%) claimed they experienced all three simultaneously. Of these 14 subjects, 9 were classified as being "little to very" EHS based on their HRV results.

In a questionnaire study in the Netherlands, when asked "which appliances are bothering you the most?" the Digital European Cordless Telephony (DECT) phone was at the top of the list with 38% of the 189 respondents (Rubin et al., 2011). The difference between a DECT phone and the cordless phone we used in this study is the carrier frequency. DECT phones operate at 1.9 GHz and the cordless phone in this study was at 2.4 GHz. Both fall within the microwave band of the electromagnetic spectrum.

In the study mentioned above (Rubin et al., 2011), heart rhythm problems were experienced by 17% of the respondents and changed blood pressure by 10%. Chronic fatigue was one of the most frequently cited health problems with 70% of the 250 respondents complaining of this illness. Fatigue was also observed in a large percentage of subjects in the current study, and this may be a result of continuous exposure resulting in chronic stress leading to adrenal exhaustion. An alternative explanation is those who are chronically tired, for whatever reason, are more sensitive to an additional stressor on the body.

Laboratory studies with humans and rats provide similar and complementary results.

Albino rats were exposed to radiation emitted by a mobile phone for 1, 2 or 3 h daily for either 4 or 8 weeks (Mohamed, Ahmed, El-Kafoury, & Lasheen, 2011). A number of effects were documented including an increase in systolic blood pressure; a decrease in HR in the longest exposures; increased QRS duration (QRS referring to a portion of the ECG tracing of the heart) in all 8-week exposures; increase in heart weight and weight of the left ventricle; increased plasma renin activity (which plays a role in blood pressure); a decrease in plasma calcium levels; a

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decrease in plasma total anti-oxidant levels; as well as hypertrophy, fragmentation and vacuolation of the heart muscle that was directly proportional to exposure time. These results indicate damage to the heart muscle with prolonged exposure to microwave radiation emitted by a mobile phone.

A female physician who diagnosed herself with EMF hypersensitivity was exposed under controlled conditions in a double-blind provocation study to 60 Hz, 300 V/m electric fields (McCarty et al., 2011). She experienced temporal pain, headache, muscle twitching and skipped heart beats 100 s after initiation of EMF exposure ($P < 0.05$), and her responses were primarily to field transitions (on-off switching) during which time HF (radio frequency) transients are sent along electrical wires. She had no conscious perception of the field but did experience a reliable somatic reaction. The authors conclude that "EMF hypersensitivity can occur as a bona fide environmentally inducible neurological syndrome."

Why is it that some studies do not show a response to exposure? The symptoms associated with exposure are quite complex, and unlike turning on a light switch and getting light each time, the body has an internal homeostatic system that tries to maintain a healthy equilibrium. The functioning of the ANS is nonlinear and, as such, difficult to predict.

Bevington (2010) identifies some key parameters that need to be considered when conducting provocation studies.

- *Accumulation*: Cumulative exposures can produce symptoms, making symptoms from chronic exposure more difficult to recognize than from acute exposure.
- *Delay*: Symptoms can be delayed after acute exposure for a few hours or even days. This is said to become more common, the longer the patient has been sensitized.
- *Diurnal state*: Symptoms vary according to the diurnal state of the person's body. A person's own endogenous electromagnetic field often declines during the day.
- *Duration*: Individual symptoms can last for a short or long time. As a group symptoms can become worse. They can fade after 2–12 months without EMR exposure.
- *Frequencies*: The sufferer may react first to a single frequency or source but later to more (e.g. first to Wi-Fi but later to mobile phones and power cables).
- *Intensity*: As the condition progresses the level of sensitivity can increase; a person may first have pains from a phone next to the head but later from one at 3 m.
- *Variations*: Individual variations in tissue/bone density, acidity, salt content, skin conductivity, size, etc. affect absorption. This may relate to the variety of symptoms.

Subjects have varied reactions to radio frequency exposure at levels that are well within international guidelines as recommended by ICNIRP and guidelines in both Canada and the USA (currently 1000 $\mu W/cm^2$ for microwave frequencies at 2.4 GHz). Among those who respond, the reaction may be immediate, delayed and/or 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 and needs to be modified to improve the quality of the data collection for each subject. For those wanting to repeat or conduct a similar study, we would recommend the following for real-time monitoring:

1. Important to wait until the ANS (PNS and SNS) has stabilized before exposure or sham exposure begins. This can be done by monitoring HR while the person is lying down. Their resting HR and SNS, PNS response should be similar to their supine orthostatic readings.

2. Important to allow for longer exposure periods and longer periods of sham and postexposure than 3 min since there can be a delayed reaction.
3. Since subjects can react quickly to this type of provocation, reducing the assessment period (refresh rate) from 192 to 48 heart beats (R–R intervals) for the same or longer time period would enable a more accurate and detailed assessment.

The concept that microwave radiation may affect the heart is not new. In a 1969 Symposium Proceedings – under the auspices of the U.S. Department of Health, Education and Welfare – on the biological effects and health implications of microwave radiation (Cleary, 1969), scientists recognized the adverse effects on the cardiovascular system and recommend that cardiovascular abnormalities be used as screening criteria to exclude people from occupations involving radio frequency exposures. That warning has not been heeded and indeed, microwave transmitters (mobile phones, Wi-Fi routers, wireless baby monitors, wireless computer games, smart meters, etc.) are now commonly used in homes, schools, work environments as well as in hospitals and doctors clinics. If our results are real and if exposure continues to increase, we are likely to observe an increase in heart-related problems among younger people and among those whose immune system is compromised.

Conclusion

Our results show that a considerable percentage of the individuals tested were moderately sensitive to very sensitive to radiation generated by a cordless phone based on HRV, and that their reactions were not psychosomatic. In this double-blind, sham-controlled study, we document an increased HR, altered HRV and changes in the sympathetic and parasympathetic control of the ANS similar to our previous study. The results are not due to EMI, since we have examples of a delayed response after the radiation was turned off and have tested EMI with much higher exposure using the same technology with no reactions noted. Our results demonstrate that the radiation from a 2.4-GHz cordless phone affects the ANS and may put some individuals with preexisting heart conditions at risk when exposed to electromagnetic frequencies to which they are sensitive. Although documenting a response is relatively simple, determining the degree of EHS is quite complex and requires further study.

Acknowledgements

We thank Bernard Pollner, Elizabeth Kelley, Camilla Rees and Lisa Tully for helping with this research and all those who volunteered to be tested and who provided space for testing.

Declaration of interest

MH has no conflict of interest. Bioenergimed Metabolic Institute sells medical products including the Nerve Express.

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