The effect of regional exposure to 50 Hz magnetic fields on human heart rate variability

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Abstract

This experiment was designed to replicate earlier findings in this laboratory that magnetic field exposure causes significant decreases in the Low Frequency (LF) component of human heart rate variability (HRV) and to also investigate the mechanism/s responsible for this field induced change. Thirty subjects were exposed to a 28 µT continuous circularly polarised 50 Hz magnetic field. Regional exposure was used in an attempt to identify whether the mechanism responsible for any effects was located at the level of the brain stem or at the site of the pacemaker, in the actual heart itself. Subjects received both whole body exposure (both head and heart exposed) as well as only heart exposed (head shielded). A mu-metal shield was used to screen the head from the magnetic field exposure. Periods of sham exposure and field exposure were compared for each exposure condition (shielded vs non-shielded). Results failed to replicate earlier findings of a significant decrease in the LF component of HRV. This result highlights the difficulty in replicating small but significant findings in research involving human volunteers even in carefully controlled laboratory conditions.

Key words - magnetic field, human, heart rate variability, spectral analysis

1. Introduction

The question of whether electric and magnetic fields associated with electric power delivery and appliance use can affect physiological processes, has long been a matter for both scientific and societal debate. A great deal of research has been conducted in an attempt to answer this question but as to date no definitive conclusion has been reached as to the health effects of EMF exposure. Research studies have suggested that EMF exposure may be linked to a variety of biological conditions ranging from cancer, childhood leukemia, psychological conditions and cardiovascular disease. One of these effects which appears to be more reproducible than others is that of EMF exposure on the cardiovascular system.

A number of studies have reported that exposure to occupational levels of 50/60 Hz magnetic fields can cause slowing of human heart rate [1-4]. While alterations in the mean HR suggest that some interaction is occurring between field exposure and the heart, it provides no information as to any oscillations around this mean. The heart does not beat at a constant rate and displays significant beat-to-beat variability even in resting conditions. The fluctuations around this mean value are referred to as heart rate variability (HRV). Techniques exist which facilitate investigation of the frequency content of HR. Akselrod et al [5] were the first to introduce the use of power spectral analysis as a tool for quantitatively evaluating beat-to-beat cardiovascular control.

In a normal resting individual two main spectral components are evident within the HRV spectrum calculated from short-term recordings of between 2-5 minutes; the low frequency band (LF), and the high frequency band (HF). These bands represent the level of control of the two branches of the autonomic nervous system (ANS) on HR. The LF band is generally considered as a marker of sympathetic modulation and is usually centered around 0.1 Hz. The HF band reflects parasympathetic modulation or vagal control. This band also corresponds to the HR variations related to respiration and is usually centered around 0.2-0.4 Hz.

The parasympathetic influence on HR is mediated via release of acetylcholine by the vagus nerve and it serves to slow the HR. The sympathetic influence on HR is mediated by release of epinephrine and norepinephrine and serves to accelerate the HR. The two branches of the ANS are in constant interaction. The relative power distribution in the LF and HF components of HRV can be used to interpret the relative contributions of these branches on the HR at any given time, under any given condition.

Only a small number of studies have investigated the effects of EMF exposure on the natural variability of the human heart. Sastre et al [6] reported a significant decrease in the LF content of the HRV spectrum with
nocturnal exposure to an intermittent circularly polarised 200 mG magnetic field. No significant changes were observed for a continuous field of the same strength. Sait et al \[7\] found a significant decrease in the LF band of HRV with acute exposure to a continuous circularly polarised magnetic field of the same strength.

Reduction in the LF spectral power similar to that found in EMF studies has been reported in number of cardiac conditions. Depressed HRV has been recognised as a predictor of risk after acute myocardial infarction (MI) \[8\] and as an early warning sign of diabetic neuropathy \[9\].

Spectral analysis of HRV is a quick, easy and non-invasive method for investigating the ANS system influence on HR control in a enormous variety of circumstances. EMF exposure is yet another area where this analysis can be utilised to determine any alteration on the neural control of the heart and what this may mean for the general health of the public.

2. Methods

Subjects

Thirty subjects (17 male) participated in this study with ages ranging between 18-58 years. Unpaid volunteers were recruited from staff and students within the university. All subjects were healthy and did not suffer from any known illnesses or cardiovascular conditions and were not taking any medications. All subjects were non-smokers. Most subjects had a tertiary level of education. Written informed consent was obtained from each subject before participating in the study. Subjects were asked to refrain from drinking any caffeinated or alcoholic beverages for at least 12 hours prior to recording. Experimental procedures were approved by the university ethics committee.

Exposure System

Subjects were exposed to a continuous 28 µT circularly polarised 50 Hz magnetic field. The exposure system consisted of Merritt type \[10\] modified Helmholtz coils forming a 2 m cube employing two orthogonal sets of coils, the current in one set 90° phase-delayed in respect to the other to produce a circularly polarised field. Circularly polarised fields have been used by others \[11,12\] and resemble the magnetic field patterns produced from power lines and electrical appliances. Each set of coils consisted of four windings in series which were split so that current could either flow in the same sense through each half of the winding (field-aiding) or in the opposite direction (field-canceling). This removed any possibility of auditory or thermal clues to the subject to whether the field was actually on or off.

Regional Exposure

Regional exposure was achieved by shielding the head region from exposure through use of a magnetic field shield. This meant that whole body exposure (head and heart) could be compared to only heart exposure (head shielded). The shield used in this experiment was made from mu-metal, a nickel-iron alloy (77% Ni, 15% Fe, plus Cu and Mo) which has extremely high magnetic field permeability at low field strengths and as such can be used as a very effective magnetic screen. The shield was suspended from the coil’s frame so that the subject was seated in the field region with their head placed within the mu-metal shield (Figure 1). The field level within the shielded chamber while shielded was the same as that of the sham exposures.

Figure 1. Subject seated in exposure coils with mu-metal shielding the head region.

Controlled Respiration

The respiratory component of the HRV signal was entrained by requiring subjects to breathe regularly in time to a LED metronome set at 0.2 Hz (12 breaths per minute). This breathing rate is well outside the upper entrainment limit of the blood pressure control mechanism so as no frequency pulling could occur. Subjects were asked to inspire as the lights moved up
and to expire as the lights moved down. In this way the shape of the respiration curve was maintained with inspiration and expiration each taking approximately half of the respiration cycle. Although the duration of each breath was controlled for the subject, they were allowed to maintain their normal depth of inspiration throughout recording thus preserving essentially their normal blood gases and ventilatory mechanics.

Data Acquisition/Analysis

A commercially available electrocardiogram (ECG) was used to record each subject’s heart beat (Nihon Kohden cardiofax, ECG-6551). These measurements were facilitated by the use of a PowerLab data acquisition system which sampled the data at a rate of 400 Hz and permitted viewing of the data while recording. Each recording session was 7.5 minutes long and comprised of three 2.5 minute segments of two sham and one field exposure or just three shams. The order in which subjects received exposure was in a counterbalanced and randomised design. Data segments of 2-2.5 minutes are informative as they include at least 5-15 times the period of heart rate fluctuation being estimated while still maintaining the required level of signal stationarity for spectral analysis. An in-house threshold peak detection program was used to identify the location of each R-wave of the cardiac cycle off line. Heart rate was measured as the reciprocal of the interval between successive R-waves (R-R interval). Group averaging of the instantaneous R-R interval was performed after interpolating individual records at 2 Hz to provide uniformly sampled data. Fast Fourier Transformation (FFT) was performed on 128 seconds of data (256 points when re-sampled) for all sham and field periods.

Statistical Analysis

Analysis of Variance for repeated measures was used to determine any significant differences between field conditions. A p value of less than 0.05 was considered significant.

3. Results

Figure 2 shows the power spectrum obtained for all of the experimental conditions used in this study. An ANOVA for repeated measures failed to establish any significant interaction between the sham and field condition, with or without the shield for the LF region of HRV. Significant interactions were found for the HF region of the spectrum, but were found to be related to the subject’s ability to maintain a constant respiratory rate of 0.2 Hz. The first of the three 2.5 minutes in each data collection period was greater in power than the succeeding two periods.

Taking this into consideration the HF region of the spectrum is not discussed in this paper and only absolute (not normalised values) of the LF region are reported (see Table 1). A more detailed analysis and discussion of the full results will be presented in a future paper. The HF values did not effect the LF absolute values as the entrainment frequency was well outside this region.

Table 1. Mean spectral power (msec²/Hz) in the Low Frequency (0.02-0.15 Hz) region of the HRV spectrum.
to precisely reproduce less sensitive than those tested initially. The inability that the subjects used in this experimental group were sensitivities to magnetic field exposure [7]. It may be the past that different subjects have shown different very
However, it may also be possible that the effect is just nonstationarity in the data.
additional sham periods to detect any effects of particularly so given that this experiment had
results. The first and most obvious is that the previous reasons why this experiment failed to find significant
A variety of possible explanations can be suggested as
The lack of replication of significant findings is consistent with studies conducted by other researchers in this field [1,14]. This lack of consistency in results highlights the difficulty of researching small effects in a biological model as complex as the cardiovascular system.
4. Discussion and Conclusions
The current study failed to replicate earlier findings in this laboratory of a significant decrease in the LF region of the HRV spectrum with exposure to a 28 µT, 50 Hz circularly polarised magnetic field. Regional field exposure was used in an attempt to determine the site at which any field induced alterations to ANS control were occurring. Whole body exposure (head and heart) versus only heart exposure (head shielded) were used to determine whether the site of interaction was at the level of the brain stem or at the cardiac pacemaker in the heart itself. Subjects controlled their respiration rate at 0.2 Hz as in the previous experiment.

on the biological system makes it very difficult to reproduce data unless the effect itself is very robust.
Further experimental work is needed before a conclusion can be made as to whether there really is any interaction occurring between magnetic fields and the cardiovascular system.
5. References

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