The Interaction of Specific Frequency Bands in the Geomagnetic Field Diurnal Spectrum, With Specific Frequency Bands in the Human Heart Rate Variability Diurnal Spectrum.

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Research Article

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Abstract

BACKGROUND.

For over 50 years, experiments have been demonstrating an interaction between the dynamics of the human heart and the dynamics of the earth's magnetic field. In these experiments, specific frequency components in the variability of the geomagnetic field (GMF), involving micropulsations, are shown to significantly interact with specific frequency components in human heart rate variability (HRV). A significant difference was found in the HRV ratio of VLF/HF, on days of low geomagnetic variability (L gmf) compared with days of high geomagnetic field variability (H gmf) *(P = 0.0001, n = 24, effect size 1.014).*

METHODS.

Experiments were conducted prospectively, over a period of 3 years, on one 70 year old, healthy female subject, using a 24 hour holter electrocardiogram (ECG) machine, and the results were analysed for the HRV frequency spectral components. The local geomagnetic field was simultaneously monitored over 24 hour periods, using a 3-axis fluxgate magnetometer, and the frequency spectra were analysed for the various spectral power components. Statistical analysis was performed using XLSTAT software.

RESULTS.

It was shown that there was a correspondence in the power spectra of the high (HF) and very low (VLF) frequency components in HRV and GMF variability. It was shown that there was a significant difference in the ratio of the VLF and HF frequency band power of the HRV between the ECGs recorded during days of lower geomagnetic variability, and days of higher geomagnetic variability.

CONCLUSION.

These findings support the hypothesis of a homeostatic response of the human heart to the earth's magnetic field. This may have implications for prognosis and management of heart disease, during times of significant environmental change.

Background

It has long been suspected that the large scale geomagnetic disturbances, characterised as geomagnetic storms, which are capable of knocking out electric power stations and the grid supply, manifesting as variances in the GMF micropulsations of hundreds of nanotesla, may also be responsible for increase in heart attacks around the time of the disturbances, *(1a,1b,1c,1d,1e,1f)*.

Coronary heart disease is the third largest cause of death, after Covid and Alzheimers/dementia, in the UK population at present, and sudden catastrophic heart attack (myocardial infarction) can happen without warning in susceptible individuals *(2).* Research has shown how chaotic systems like the human heart, can be affected by subtle changes in neurological function, mediated by cellular changes in enzyme activity, *(3, 4).* Much of cellular enzyme activity is electromagnetic in nature, non-linear, and highly susceptible to small environmental changes *(4a,4b,4c)*. It seemed important to investigate the possibility of environmental factors contributing, possibly as a last straw, to such unanticipated fatalities .

Where two non-linear systems interact, the human heart, and the earth's magnetic field, some correspondence may be hypothesised. It seems inevitable that the human heart has evolved in synchronising its homeostatic activities with the variability in the geomagnetic field which permeates it. The ability of adjustment in a finely balanced system like the heart, depends on the healthy responsiveness of all the components involved in its balancing act. It has been shown that when enzyme systems are malfunctioning, or sluggish in their activity, they fail to respond optimally to external signals. Heart disease often involves malfunctioning enzyme activity in blood vessel cells, called baroreceptors, sensitive and responsible for changes in arterial blood pressure, *(4).* This insensitivity can manifest as neurological malfunction in the timing of the complex rhythmic function of heart pumping and valve activation. Any additional stress on this system, leading to damping or blocking, or lowering of responsiveness, may be a final factor in catastrophic malfunction of the heart. It is considered that the inability of a diseased heart to successfully adjust to the changes in the micropulsation amplitude variation and rhythmicity in the geomagnetic field, may be an important parameter to investigate, for optimising the prognosis in patients with heart disease, *(5).*

The geomagnetic field is monitored worldwide by a number of geological sampling stations. In the UK there are two main stations situated in Eskdalemuir in Scotland, in Northern UK, and at Hartland Point in Devon, Southern UK. These UK stations are managed by the British Geological Survey, and provide data accessible to the public on their website *(6).* They also provide statistical data to researchers. The diurnal hourly geomagnetic field components of the total field are available for public perusal. The graphical display of the diurnal micropulsations are also available as a time series, displayed in their various periodicities. The micropulsations in the geomagnetic field are categorized in various frequency bands according to a universally accepted scale, ranging from frequencies lower than 2 milliHerz (mHz), to frequencies higher than 5 Hz, *(6,7).* These translate respectively, in the time domain, to periods longer than 600 seconds, to periods shorter than 0.2 seconds. These micropulsations are very low amplitude in relation to the total geomagnetic field, 10,000 times smaller, or one tenthousandth of the total field. They are usually in the range of 3–150 nanoTesla, while the total field is measured in the range from 22, 000–64,000 nT worldwide. Local field measurements in the locality of these experiments are in the region of 48,000 nT, and the average standard deviation of the diurnal field ranges from 2 nT – 16 nT as recorded in these experiments. The annual gmf varies over an 11 year period, determined by cyclic activity in the sun, manifesting in solar flares. The period of these experiments coincided with the lower part of the low 11 year cycle 24, (2016–2019) with fewer perturbations in the field. These trains of micropulsations vary in amplitude and in shape and periodicity, and are perceived to carry information. It is understood that the high frequency micropulsations (0.02 Hz -5 Hz) correlate with ionospheric disturbances, including lightening flashes in the cavity between the earth and upper atmospheres which occur with a frequency of up to 50 Hz, *(8)*. However, less is understood about the very low frequency micropulsations. These may correspond to electromagnetic field changes within the earth itself, and may be shown to relate to various piezoelectrical activity in the rocks of the mantle and in the core, *(9);* in the continental plate movements, and in the polar ice, and in the shear and stress forces of the viscous mantle and convection current changes within the earth, due to the cooling of the earth *(10,11).* This can lead to highly localized changes in the micropulsation profiling, and amplitudes. For this reason, it is essential to monitor the geomagnetic field locally, to understand any specific effect on local biology.

Heart rate variability has been internationally categorized in a number of parameters, including linear time series measurements of the ECG periodic signal, and the non-linear harmonic components of the frequency spectral analysis using fast fourier transform (fft) mathematical algorithm *(12).* The spectral characteristics of the ECG involve 4 standard power measurements bands, two of which are found to be important in this research, namely the very low frequency (VLF) band, (3–40 mHz, or 25-333.3 second periodicity) and high frequency (HF) band, (0.15–0.4 Hz, or 2.5–6.6 second periodicity). Both these bands have been implicated in autonomic nervous system control of the heart, involving sympathetic and parasympathetic system control interaction and responsiveness, *(13).*

The experiments that follow, represent an attempt to investigate any possible interaction between harmonic parameters of heart rate variability (HRV) and harmonic parameters of local geomagnetic field variability (gmf sd).

Methods

The GMF was measured continuously, with mean measurements recorded at the sampling rate of 0.1 Hz, or 1 sample every 10 seconds, over 24 and 48 hour epochs, using a Bartington 3-axis fluxgate magnetometer, (Mag690). The specifications are as follows: XYZ coordinate system, with a positive polarity, non-inverting output when pointing North. Full scale measurement ranges from +or – 1 uT to 1000 uT. Bandwidth at -3dB, > 1kHz. Measurement noise floor >10 to < 20 p Trms/sq rt Hz at 1 Hz. Scaling from 10 mV/uT to 100 mV/uT. Offset error + or – 100 nT, offset temperature coefficient + or – 1 nT/ degree C. scaling temperature coefficient from + or – 100 ppm/degree C to 200 ppm/degree C. calibration error + or – 1%. Frequency response: maximal flat response (+ or – 5% from DC to 100 Hz) Hysteresis: < 2nT for exposure to up to 2 X full scale. Excitation Breakthrough: < 10 mV pk-pk at 16 kHz. Operating range from – 40 degrees C to + 70 degrees C.

The resolution of this system allowed for the gmf micropulsations in the HF range (PC3, 0-45 seconds, 22 – 100 mHz) and in the VLF range (PC5, 150 – 600 seconds, 2-7 mHz) to be visualised, and measured, using the Z, vertical component of the field.

The magnetometer was operated by software control provided by the Bartington company, using a mains frequency data logger attached to a dedicated mains operated computer. The magnetometer sensor was connected by a long shielded cable to the data logger, and aligned to the local gmf North pole, and placed securely in a draft-free indoor location in a local house in Eastbourne, East Sussex, UK, where the experiments were conducted. This was a small laboratory environment, at ambient temperature, with the magnetometer apparatus being the only electrical and magnetic apparatus in operation. The distant external local traffic comprised vehicles, usually small cars, leaving and exiting from a small local carpark during the day. This created artifacts in the data, due to the electromagnetic field of the engine dynamos. These artifacts were easy to recognise, as they involved sudden large linear changes, and they had to be removed from the data streams before analysis.   The Z coordinate was used in all measurements, for statistical analysis.

The following ***figures*** (located in the supplemental files section) show the time series for ***a)*** 22 hr geomagnetic field readings during diurnal High mean standard deviation of 12.74 nT. ***b)*** 80 minutes ***c)*** 10 minutes ***d)*** 120 seconds. This demonstrates the micropulsation resolution achieved with this magnetometer. It can be seen that the amplitude of the field and the micropulsations is lower during the night.

Diurnal hourly measurements of the gmf including the hourly and total mean diurnal standard deviations in the geomagnetic field from the Hartland Point observatory were received daily by e-mail, from the British Geological Survey, as a generous contribution to this research project. This observatory, at Hartland Point, on Southern coast of Britain was the closest to the local experimental environment, which was in Eastbourne, on the Southern coast of Britain. These measurements were used to determine a general local degree of total variability (coefficients of variation) in the general local diurnal gmf, for the purpose of dividing the ECG data into two experimental sets, of low gmf and high gmf, involving respective standard deviation (sd) of <6nT and >9nT respectively, for comparison.

The two different variables of L gmf and H gmf showed significant difference (P=0.0001) at the alpha level of 0.05. The means of the standard deviations (sds) of the two variables was 4.748 nT and 11.692 nT respectively.

The subject was a 70 year old, healthy woman, retired and leading a normal routine of housekeeping, family care work, walking, reading, studying and writing. 24 hour ECG measurements were made using a 3 channel, 6 lead, Contec Holter ambulatory digital ECG recorder. This was a low cost machine, made in China, with accurate digital signal monitoring and sophisticated inbuilt analytical software program, providing downloadable full analysis of 24 hour heart rate variability, in all the recognised internationally agreed important time series and frequency spectral parameters, with hourly mean measurements. It was easy to use, lightweight, and facilitated normal diurnal activities, as well as comfortable nocturnal sleeping. Specifications are as follows: recording time 24 hr; battery operation; interface USB 2; scale voltage 1mV; sensitivity 10mm/mV; noise level< 30uV; CMRR>60dB; resolution 50uVp-p.

It was marketed as clinically certified, to be comparable with regular clinical NHS EEG apparatus. A comparison of the downloaded ECG data was made with a conventional 12 lead ECG performed by a consultant cardiologist, to check and confirm the ECG provided by the Contec apparatus, during a brief episode of apparent abnormal ventricular signalling, following the death of the subject's mother. The consultant confirmed this anomaly which had appeared over several months on the Contec ECG. The consultant suggested that this anomaly was sometimes evidenced in subjects following bereavement, and often corrected itself. Indeed, the anomaly disappeared from the Contec ECG recordings after another two months. Apart from that short-term deviation from normal, the ECG of the subject was normal and showed healthy heart activity for someone of her age (70 – 73 yrs) ***(see the following Contec Electrocardiograms, figures e and f**).*

Silver chloride, pre-gelled, disposable electrodes were used in the placement of the 6 electrodes, as shown in the following diagram **(see figure g,** below**).** The data was uploaded into a computer program provided, by USB lead, onto a computer. Each experiment was 24 hours duration.

The following, **figure h,** shows a comparison of the 24 hour time series measurements of HRV variability and GMF variability, with the scales adjusted accordingly**.**

Results

The following analyses, tables and plots are produced using the XLSTAT statistical analysis software. The alpha significance level was set at 0.05. L vlf/hf is the abbreviation for the HRV ratio of vlf/hf in the ECG spectrum during diurnal low geomagnetic field sd (L gmf) (<7 nT sd). H vlf/hf is the abbreviation for the ECG HRV vlf/hf ratio during diurnal high gmf sd (H gmf) (>9 nT)

Table 1, below, displays the summary statistics for the ratio of the VLF and HF bands (VLF/HF) in the ECG HRV spectra, during diurnal high geomagnetic standard deviation (H gmf) and during diurnal low geomagnetic standard deviation (L gmf). Normality tests showed the data to be non-parametric.

Summary statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
L vlf/hf	24	0	24	8.940	23.800	14.729	3.436
H vlf/hf	24	0	24	8.860	20.400	11.491	2.947

Table 1. *showing summary statistics for VLF/HF ratio in HRV spectra during Hgmf (H)and Lgmf (L)*

Analysis, using the Mann-Whitney two-tailed test, showed a significant difference *(P<0.0001, n=24, effect size 1.014),* between the two conditions of H gmf and L gmf, for the ECG HRV ratio of VLF/HF. The graphical display of the results is shown in ***figure 1***, below

The following analyses, show the effects of high and low GMF variability on the individual VLF and HF components of the ECG. ***Table and figures 2 and 3,*** below, show the HF and VLF bands of the ECG frequency spectra, comparing the power density means of each band during H gmf *(> 9nT, n=23)* and L gmf *(< 7nT, n=20)*

Table 2, below, shows summary statistics for the VLF band of the HRV during high gmf (H) and low gmf (L)

Summary statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
VLF L	20	0	20	985.400	1589.100	1238.190	160.669
VLF H	23	0	23	1050.100	1772.000	1355.630	184.557

Table 2 *showing summary statistics for the VLF band of the HRV during high gmf (H) and low gmf (L)*

The data showed a normal distribution, therefore the parametric two-tailed T-test for two independent samples was used. The analysis showed a significant increase in the VLF spectral band *(P=0.033, n=23 effect size 0.68)*, during days of H gmf compared with days of L gmf. The box plot below gives a graphical display of the results ***(see figure 2).***

Table 3, below shows the summary statistics for the high frequency (HF) band of HRV during H gmf (H) and L gmf (L)

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
HF H	23	0	23	47.400	181.700	112.183	36.524
HF L	21	0	21	49.200	166.200	83.933	28.207

Table 3 *showing summary statistics for the HF band of HRV during Hgmf (H) and Lgmf (L)*

The data for this analysis showed a normal distribution, therefore the parametric two-tailed T-test for two independent samples was used. The analysis showed a significant increase in the HF spectral band of HRV, in diurnal H gmf compared with diurnal L gmf, *(P=0.007, n=23, effect size 0.87).* The box plot below gives a graphical display of the results ***(see figure 3).***

The following tables and plots show data analysis for the individual GMF spectral components, (mean diurnal power densities) during days of high and low GMF variability.

The comparison between mean diurnal power densities of the HF bands in the frequency spectrum of the diurnal GMF during days of low GMF (<8nT sd) and high GMF (>8 nT sd) is shown below ***(see table 4).*** The high frequency band (HF) in the gmf showed a non-normal distribution in both the low diurnal sds and the high diurnal sds, so the Mann-Whitney non-parametric two-tailed test was used for comparison. This showed a non- significant difference between the two conditions *(P =0.091, n=17, at the 0.05 alpha level).* The plot below gives a graphical display of the results ***(see figure 4)***

Statistical analysis, using Fisher's Two-tailed F-test, showed a significant difference between the variances in the HF band between the two conditions (P=0.0001)(n=17) ***.***

Table 4 below shows the summary statistics for the mean HF band of the diurnal GMF spectral analysis, during days of H gmf and days of L gmf.

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
H gmf HF	17	0	17	0.038	3.480	0.393	0.810
L gmf HF	17	0	17	0.033	0.357	0.124	0.085

Table 4 *summary statistics for the mean HF band of the diurnal GMF spectral analysis, during days of H gm and days of L gmf.*

The comparison between mean diurnal power densities of the VLF bands in the frequency spectrum of the diurnal GMF during days of low GMF (<8nT sd) and high GMF (>8 nT sd) is shown below ***(see table 5).*** The VLF frequency band in the GMF showed a non-normal distribution in both the low diurnal GMF and the high diurnal GMF, therefore, the non-parametric Mann-Whitney two tailed test was used for comparison. This showed a non-significant difference *(P= 0.375, n=17 at the 0.05 alpha level).* ***(see figure 5).*** However, statistical analysis, using Fisher's Two-tailed F-test, showed a significant difference between the variances in the VLF band between the two conditions (P=0.0001, n=17)

Summary statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Hgmf VLF	17	0	17	0.923	9.880	4.872	2.936
Lgmf VLF	17	0	17	0.282	42.800	6.676	10.872

Table 5 *showing summary statistics for mean diurnal power density of VLF bands in the frequency spectrum of the diurnal GMF during days of low GMF (<8nT sd) and high GMF (>8 nT sd)*

Statistical analyses, using Fisher’s Two-tailed F-test, showed a significant difference between the variances in the VLF band of the gmf during low gmf (< 8nT) and high gmf (< 8nT) *(P= 0.0001, n=17),* at the alpha level of 0.05. There is higher variance in the Low gmf VLF band mean diurnal readings. There is higher variance in the High gmf HF band mean diurnal readings *(P=0.0001, n=17).* What this difference actually signifies, may involve many chance environmental factors. This difference is noted further in the discussion.

GMF ratio of VLF/HF, comparing days of Lgmf with days of Hgmf, showed no significant difference in this parameter *(P=0.683, n=17),* and no significant difference in variance *(P=0.261, n=17).* This is noted further in the discussion which follows.

Discussion

The results in these experiments show that the ratio of HRV frequency band mean power, VLF/HF, in the diurnal ECG HRV is significantly lower in days of high GMF variability (> 9 nT sd) from the the same ratio during days of low GMF variability (< 7nT sd)*, (P= 0.0001, n=24, effect size 1.014)* ***(see figure 1).***

The VLF and HF spectral bands of the ECG HRV, individually, show a significant difference in mean power *(P=0.007 and 0.033, n=17, effect size 0.68 and 0.87, respectively)* during the conditions of high and low GMF variability, ***(see figures 2 and 3)****.* The HF and VLF bands are both significantly higher during H gmf.

Considering, now, the spectral analysis of the GMF In these experiments, it is shown that both the HF and VLF bands of the GMF show a non-significant difference in mean spectral density ***(see figures 4 and 5),*** albeit a significant difference in variance of the bands *(P=0.0001 and 0.0001, respectively)*, during high and low GMF variability.

The HF band range in the ECG is close to the HF band range in the GMF; and the VLF band range in the ECG overlaps the VLF band in the GMF. ***(see table 6 below)***

Table 6

Hf ecg = 0.4 - 0.15 Hz , 2.5 sec- 6.6 sec; **VLf ecg** = 0.04 -0.003 Hz, 25 sec – 333 sec;

Hf gmf (PC3) = 0.1 - 0.022 Hz , 10 sec – 45 sec **VLf gmf** (PC5) = 0.007 – 0.002 Hz, 150 sec – 600 sec

The following plot (***figure 7)*** shows the relative oscillations of the low diurnal mean standard deviation of the GMF (Lgmf) in one 10 hour period, and various frequency parameters of ECG heart rate variability. The scales have been adjusted for the purpose of visualisation,

It can be seen from ***table 6 and figure 7***, that GMF variability and ECG heart rate variability (HRV) share similar frequency band characteristics, and time series characteristics.

The results shown in these experiments, demonstrate in greater detail, some of the specific frequency characteristics, and suggest how they interact. The gmf HF band power density is higher in days of high geomagnetic variability, the variance is significantly higher and the standard deviation is higher. The gmf VLF band is higher in days of high geomagnetic field variability, the variance is significantly lower, and the standard deviation is lower.

It is shown that the ECG HRV is significantly affected in the ratios of these two similar frequency characteristics of HF and VLF, during 24 hour periods of different high and low variability in the geomagnetic field.

It is shown that the power in the HF band of the ECG is significantly higher in the days of High gmf variability, than in the days of low gmf variability. The power in the HF band of the gmf is also found to be higher (but not significantly) in days of high gmf variability, than in days of low gmf variability.

The ratio of VLF/HF frequency band power in the diurnal ECG HRV is significantly different (P= 0.0001) (n=24) in days of high gmf variability (> 9 nT) from the ratio of VLF/HF frequency band power in the diurnal ECG HRV in days of low gmf variability (< 7nT). The ratio is shown to be higher during low geomagnetic field variability.

What does this mean?

This is a small scale experiment, conducted on just one 70—73 year old female, over a period of 3 years, involving a total of 48 diurnal periods, during relatively low level annual geomagnetic variability. This means that the two conditions of Hgmf (High geomagnetic field diurnal mean standard deviations) and Lgmf (low geomagnetic field hourly mean diurnal standard deviations), although significantly different *(P<0.0001, n=24, effect size 2.79),* were not extreme conditions, such as witnessed during episodes of geomagnetic storms, when the differences are much greater.

The statistical significance of the analysis for HRV ratio of VLF/HF is high, *(p= 0.0001, at the alpha significance level of 0.05)*, but is related to a small sample size, n=24, The effect size, however, is independent of sample size, and gives a truer measure of the statistical power for this analysis, and this is shown to be high *(1.014).*

But what does it mean that 24 days' measurements of heart rate variability during Lgmf, differed very significantly from 24 days of Hgmf? Could this be due to differences in season?

Analysis of the dispersion of the months in which the diurnal samples from the two groups appeared was as follows:

the number of diurnal samples during different seasons for Low gmf and High gmf

	November – February	March – May	June - October
Low gmf	14	4	6
High gmf	1	10	13

The greatest difference between the sample groups for seasonality, rested in 58% of the Lgmf group being in the winter months, compared with only 4% of the Hgmf group. There was a difference in sampling between Lgmf and Hgmf groups for the spring and summer months; 95% of the Hgmf group compared with 41% of the Lgmf group were sampled in these months. Over half of the Lgmf sampling took place during periods of lower light levels and lower temperatures compared with the Hgmf group.

Could the difference in the ECG HRV frequency ratio, VLF/HF, have been affected by the seasonal light and temperature changes during winter months? The HRV VLF/HF ratio was higher during Lgmf. However the HRV HF and VLF bands were both lower during Lgmf.

The HF frequency band in HRV is considered by cardiologists, to relate to parasympathetic control of the heart, the respiratory band, *(12),* and baroreceptor reflex activation, *(4).* It increases at night, and decreases during the day. The VLF band is considered to be the 'slow recovery' component of autonomic nervous system control, and has been shown to have an unexplained association with cardiovascular disease prognosis.

Lower ECG HRV HF power is found to correlate with stress, panic, anxiety and worry *(4).* In these experiments, the HRV HF band is seen to be higher during Hgmf, than in Lgmf. The GMF HF band is also seen to be higher in the GMF spectra during Hgmf, than in Lgmf, (using the difference of <8 nT > 8 nT) (n=17). None of the samples of the Hgmf group are winter samples. But 12 of the Lgmf group are winter samples. Low light is known to have a seasonal (SAD) affect association, low mood change and depression *(15).* The forced wakefulness during the dark hours, associated with winter working day, may increase distress in the autonomic nervous system. Added to this, is the effect of low HF band power in the GMF, if indeed this has any effect independently.

The ECG VLF band is considered to be related to the sympathetic autonomic response, *(16).* Low ECG VLF power is associated with arrhythmic death, high inflammation, and lower levels of testosterone. It is suggested that there is a connection with efferent sensory nerve stimulus in the heart. In these experiments, The VLF band in the ECG HRV is significantly lower during Lgmf than in Hgmf. The gmf VLF band power is marginally (insignificantly) lower during Lgmf than during Hgmf, and there is significantly higher variance of the diurnal VLF gmf band during Lgmf.

Very high variability in the GMF has been associated with damping of the baroreceptor responsiveness in animals, *(4)*. This, in itself, may lead to abnormal conditions in HRV, associated with heart malfunction *(16a)*, especially if the heart function is already compromised, as in ischaemic heart disease. The combination of the seasonal factors and changes in the GMF spectrum as witnessed in these experiments, could all serve to effect the ECG HRV changes seen in these experiments.

So, is it possible, in these experiments, to control for this seasonal confounding effect? Local measurements of the barometric pressure, outside temperature, light level, were not routinely recorded. They could be factored in retrospectively. However, it may be considered sufficient to mention them as a possible confounder in any effects noted *(16b,16c).*

In the ECG VLF/HF analysis, the sample size was selected, out of a total of 62 samples, by using the specific differential between high GMF (>9nT) and low GMF (<7nT). This led to a selection of 48 samples in total for analysis. The ratio of VLF/HF was significantly higher during Lgmf, using 24 out of 48 samples, 14 of which were in winter months, and 10 of which were in spring and summer months. So, 14/24, or 58% of the results may have had some confounding correlation with the winter effects of low light and colder conditions on autonomic regulation.

However, the increase in ratio during low GMF, is interesting, as both VLF and HF bands in the ECG are lower during low GMF. This suggests a difference in the balance of the two harmonic components in the ECG during Low GMF from that during High GMF.

VLF band in ECG, has been shown, by Usui and Nishida, *(13)* to correlate with slow recovery from stress, by decreasing. HF decreases after a stress test, but recovers more quickly, *(13).* If VLF/HF is lower during Hgmf, it must be that VLF is lower in its comparison with HF, than during Lgmf. It is considered that higher levels of variability in GMF act as a stressor, by damping the natural responsiveness of baroreceptor cells in the heart arterial walls, *(17,18,19).* This depression of cellular enzymic activity, during Hgmf, noted in other experiments *(20a, 20b)*, may have an overall effect on HRV. HF in HRV correlates with this in the VLF/HF parameter.

The ratio of VLF/HF is lower by a factor of 0.78 during H gmf than during L gmf ***(see table 1****).* During Hgmf the HRV HF component of the VLF/HF ratio, is shown to be higher in power by a factor of 1.33 than in Lgmf, ***(see table 3)*** and the VLF component is shown to be higher in power by a factor of 1.09 than in Lgmf ***(see table 2)***. This power ratio difference is 0.81 (1.09/1.33). This means that there is a greater increase in the HF band of HRV in relation to the VLF band during Hgmf than during Lgmf.

This mean power ratio difference of the HRV ratio VLF/HF during days of Hgmf compared with Lgmf is 0.78 (11.49/14.72)

What does this mean? Can this have any significance for HRV and heart functionality? Are these harmonics meaningful? Could they be artifacts of the analysis?

There were two experiments during an intermediate GMF variability level, which were not used in the two groups, because the GMF sd was in the borderline variability level < 8nT > 7nT). These particular two experiments were during a short period when the ECG showed an abnormality, an inversion of the T wave part of the signal, which correlates with ventricular repolarization defect. This was during a stressful time of bereavement, before and shortly after the subject's mother's death. The abnormal ECG returned to normal within 3 months. However, the HRV spectra of both samples, showed characteristics in the VLF/HF ratio, that showed a power differential that was different from the mean Lgmf ECG HRV power spectra. The ECG VLF/HF ratio of these two abnormal ECGs gave a mean (n=2) value of 7.9. This was very different from the mean (N=24) Lgmf bulk ECG VLF/HF ratio, of 14.7.

The abnormal stress-related ECG parameter of VLF/HF differs from the normal ECGs by a factor of 0.53. The HRV VLF/HF parameter during H gmf differs from that during L gmf by a factor of 0.78.

It is not really possible to infer much from this fortuitous comparison, as two individual samples do not make statistical power analysis practical when compared with 24 samples. And one subject may be quite unique physiologically, and outside the normal range of physiological parameters in HRV. But it suggests a possible difference in the power ratios of VLF to HF that could be indicative of temporary abnormal cardiac function. In this respect the HF band of HRV is significantly increased during H gmf, and even more so during a severe stress situation of bereavement. One might infer from this that a combination of a severe stress situation with a geomagnetic storm, might lead to an increase in power in the HF band of HRV in relation to the VLF band.

One could deduce from this that in a normal healthy heart, HF in the ECG HRV is proportionally higher than VLF during High local geomagnetic variability compared with that during Low local geomagnetic variability. Moreover, during a high stress situation, such as bereavement, HRV HF may be proportionally much higher in relation to HRV VLF than during a comparable period of normal stress and normal geomagnetic variability.

The 1996 guidelines from the American heart Association and the European Society of Cardiology, *(12)*, state, " components of the HRV provide measurements of the degree of autonomic modulations rather than of the level of autonomic tone, and averages of modulations, do not represent an averaged level of tone." It is considered that vagal activity is the major contributor to the HF component, via efferent parasympathetic activation of the vagus nerve in autonomic control. It is considered that there is great stability of HRV measures in the 24 hour holter monitoring, in both normal subjects and in the post infarction and ventricular arrhythmia populations. Therefore the long-term monitoring of a single subject, should be able to pick up any variation, indicative of changes in the modulating influence of the autonomic nervous system control of heart function. Changes in the HF band of ECG HRV, and the ratio of VLF/HF, could be one such important indicator.

In a 2017 paper, Usui and Nishida *(13)* show that both the HF and VLF bands of HRV spectrum significantly decrease during a stress task, compared to that during resting. After the stress task, HF values immediately returned to baseline, which was not significantly different from resting time values. After task the VLF band had significantly decreased compared with the baseline, and resting values, and remained so for several hours.

So it seems, according to the cited research *(13)*, that during a short stress episode, VLF band of HRV spectrum significantly decreases compared with normal values, in relation to HF band. In the experiments reported here, during the Hgmf conditions, the ratio of VLF/HF in HRV spectrum, is shown to be significantly decreased compared with that during Lgmf conditions. The HF band is shown to be significantly increased in this ratio, by a factor of 1.33, compared with the VLF band, which is hardly increased at all, by a factor of 1.09. This appears to follow a similar trend to that shown in the short term stress task *(13),* where the HF band responds proportionally differently to stress than the VLF band, which remains proportionally lower for much longer. It also mirrors the effects shown by Sastre et al, in 1998 , *(13a),* in which nocturnal HRV HF frequency band of sleeping volunteers, was significantly increased during application of a pulsed sinusoidal magnetic field (geomagnetic field strength), and periodic frequency of 0.15Hz, (gmf HF band).

This may support a hypothesis that high GMF variability, or GMF storms, may act as a physiological stressor, by altering autonomic nervous system responses in the vagal system of the heart, (*5,13b,13c*). In these experiments, the GMF variability was small, even in the H gmf condition, compared with the degree of variability noted in geomagnetic disturbance during peak sunspot activity in some epochs. However, even with the relatively small, albeit significant differential between L gmf sds and H gmf sds in these experiments (1.95 : 1) (n= 35 and 24, respectively,) significant effects are shown in physiologically indicative parameters of the ECG HRV.

The difference in the coefficients of variation of Hgmf / Lgmf, = 1.26 (P=0.0001)

The variability ratio of Hgmf/Lgmf is 1.26 (P=0.0001).

The variability ratio of HRV VLF (Hgmf/Lgmf) to HRV HF (Hgmf/Lgmf) is 1.22 (P=0.0001)

It seems that there is some coherence between the harmonics of the geomagnetic field variability and the harmonics of the heart variability. The HF band in the GMF has similar frequency and time series range (10s-45s) as the VLF band in the ECG (25s – 333s). The HF band in the GMF has less power at night, when the VLF band of the ECG has higher power. The HF band in the GMF varies slightly in its peak frequency, according to the season and the time of day (7), and conditions in the solar, ionospheric and geospheric activity, which may include the technologically produced electromagnetic environment *(13a)* as well as the earth's inner and outer structural components. Perhaps, one might hypothesise, that in a relatively healthy heart, the heart adapts optimally with a resonant response to the changing parameters in the GMF. However, if that natural adaptation becomes maladjusted for any reason, possible disturbance in autonomic control of the heart vagal system control may manifest as subtle changes in HRV, and ultimately, over the long term, in health.

Homeostasis is the constant, subtle adaptations of the human bioelectrical energy fields to the signals coming from the environment. Too much light causes contraction of the iris; too much heat causes sweating; hypothermia causes shivering; contact with another organism causes either delight or anxiety or fear: emotions which register in heart rate variability changes, as well as changes in the brain wave frequency bands, *(22).* Such responses are evidenced in the earliest evolutionary life forms, such as single cell slime mould amoebae, *(23a,23b).* It has been shown that regular rhythmic cell shape changes, in two frequency bands of 0 - 5mHz and 8–40 mHz in Dictyostelium discoideum amoebae, are evidenced, mediated by cell membrane enzyme kinetics, and calcium fluxes, and that their frequency characteristics are modified by environmentally produced magnetic fields (23a). These frequency bands overlap with the frequency bands of the GMF HF and VLF bands, and of the VLF band in HRV. The same enzymes that regulate rhythmic activity in heart physiology are those that regulate rhythmic activity in Dictyostelium discoideum amoebae (*20a, 20b)*. It makes sense that the rhythmic electrochemical activities of the cellular environment should be constantly adjusting to adapt to these electrochemical rhythmic activities of other cellular organisms, and of the larger electrochemical systems in the external environment. These larger electrochemical systems include the earth itself, in the rocks of its crust, and the rocks and fluids of its mantle and in its cooling core. It also includes the ionospheric cavity between the earth and upper atmosphere, with its rolling thunderstorms and lightening flashes, and perturbations caused by solar flares. Humans are commensals, both individually, containing communities *(24),* and operating as individuals within a larger community, and the larger community operating within a universal commensalic whole. That is the basis of the holistic outlook to health and wellbeing.

Because the frequency response and spectrum amplitudes of the geomagnetic field have been shown to correlate with actual HRV biological parameter changes, it is highly probable that the HRV spectral changes are real and not artifacts of an algorithm.

It seems from research, that heart rate harmonics are meaningful, and synchronise in a meaningful way with harmonics of the GMF. Harmonics and subharmonics are meaningful in terms of complex nonlinear signalling systems *(4a,22a,24a).* Human biology, geophysical phenomena, astrophysical phenomena, all exhibit complex signalling, involving complex waveforms, that can be analysed or deconstructed into component harmonic frequencies. There is information in these signal waveforms, and in their harmonics. This is how the commensality of the universe evolves, in cooperative harmony, maintaining form and content; each part holding and reading information from the whole; a holographic evolution of chaotic systems.

But what causes the harmonics of the geomagnetic field, with its complex micropulsations? And with what systems is the geomagnetic field synchronising to cause these specific perturbations?

The highest frequency bands of the GMF, PC1-PC2 (periodicity 0.2seconds – 10 seconds; 0.1Hz – 5 Hz), corresponds, in their subharmonic, to lightening flashes and thunderstorms circulating around the whole global cavity between earth and upper atmosphere at a rate of 33 flashes a second, or 33 Hz, *(8).* The PC3 High frequency band of the GMF (periodicity 10 seconds – 45 seconds; 0.022 Hz – 0.001 Hz) corresponds most closely to the seismic tremors felt by humans each year over the surface of the earth, at a rate of 1 every 33 seconds, or 0.03 Hz. For these tremors to affect the geomagnetic field, which is 4 orders of magnitude greater in amplitude, they must be connected with electromagnetic perturbations in the earth itself, as the interior of the earth is the generator of the main geomagnetic field. The main geomagnetic field varies diurnally and seasonally in relation to the earth's changing trajectory, and these are very low frequency changes *(7,11).* The higher frequency perturbations are less consistent, and possibly more chaotic. What are the electrogenic processes within the earth, that can cause such small scale, relatively high frequency changes in the micropulsations of the GMF?

There are processes within the earth that involve piezoelectric and pyroelectric activity in the rocks and the molten mantle around the core, and the viscous layers beneath the crust. It has been noted recently that many of the rocks in the earth have piezoelectric and pyroelectric properties, *(9).* Amongst the most common are quartz and ice, which includes the large ice deposits in the polar regions *(25,26,27*). Regional rock strata vary, and so do the pressure and temperature changes in the rocks, caused by convection currents in the molten viscous mantle, heating and cooling, and the expansion and contraction that accompanies this, the grinding of the continental plates, and concomitant shear and stress tensions, *(10).* Radioactivity in rocks contribute to all of these effects. These forces are difficult to measure, but may be witnessed in the seismic graphology, which records electric field changes in the earth. They may also manifest in the micropulsations in the geomagnetic field, monitored by magnetometers.

Schumann resonance of the earth is designated as a 7.83 Hz electromagnetic wave, travelling around the circumference of the earth in the 60 mile ionospheric cavity between the crust and the upper atmosphere. It resonates with itself as it completes every 2 or 3 circuits, *(28).* This ultra low frequency wave varies around 8Hz, and has subharmonics, which vary according to diurnal, seasonal, solar and water aerosols in the atmosphere, and other terrestrial phenomena which may include the geomagnetic field. It is possible that some resonance exists between the geomagnetic field, the Schumann resonance and the human heart, and this would be in the subharmonic region of the Schumann spectrum *(28a)*

It is of interest to note that the Schumann frequency lies within the alpha band of the human electroencepholagraph (EEG) brain wave spectrum. The EEG alpha band lies between 8 – 12 Hz, and is correlated with a relaxed and unfocussed state of mind, or 'neutral gear' for the brain activity, according to neurofeedback research, *(29a, 29b).* This relaxed state might correlate with the vagal tone in heart rate variability *(22a).*

There are, indeed, real dynamic mechanisms within the earth that can manifest in the variability of micropulsations in the PC3 HF band of the geomagnetic field, which in turn corresponds in its rhythmicity, to the VLF band in the human ECG, which in turn, can synchronise with these subtle changes, in a finely tuned balancing act, known as homeostasis, fundamental to all successful life forms on the earth.

Conclusion

These experiments support the hypothesis of a harmonic interaction of the human heart with the earth's magnetic field. Statistical analyses of 24 hour HRV spectra show a significant difference between days of low and high geomagnetic activity. This significant difference (*$P = 0.0001$, $n = 24$ effect size 1.014)* is shown to relate to the proportional difference in the VLF and HF bands in the HRV parameter of VLF/HF, during the two, significantly different, geomagnetic field conditions of low gmf (sd < 7nT) and high gmf (sd > 9 nT) *($P < 0.0001$, $n = 24$).* This balance adjustment of the HRV is shown to correspond with changes in the HF band in the geomagnetic field micropulsation spectra. It is believed that this is the first time that this particular ratio of frequency bands in the HRV spectrum has been shown to correlate with specific micropulsation frequency band spectra in the GMF. This supports the hypothesis of a homeostatic response of the human heart to the earth's magnetic field. This may have implications for prognosis and management of heart disease, during times of significant environmental change.

Abbreviations

gmf: geomagnetic field; **hrv:** heart rate variability; **ecg:** electrocardiogram; **hf:** high frequency; **vlf:** very low frequency; **VLF/HF:** ratio of very low frequency band power to high frequency band power **H gmf:** high geomagnetic field variability; **L gmf:** low geomagnetic field variability; **sd:** standard deviation.

Declarations

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Author details: the author obtained her PhD in 1994, in Pharmaceutical and Biomolecular Sciences Research Group, Brighton University, and continued research until retirement, with publications in the field of bioelectromagnetics and nonlinear dielectric spectroscopy, and worked with the Bioanalytical Sciences Research Group at UMIST, University of Manchester.

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Figures

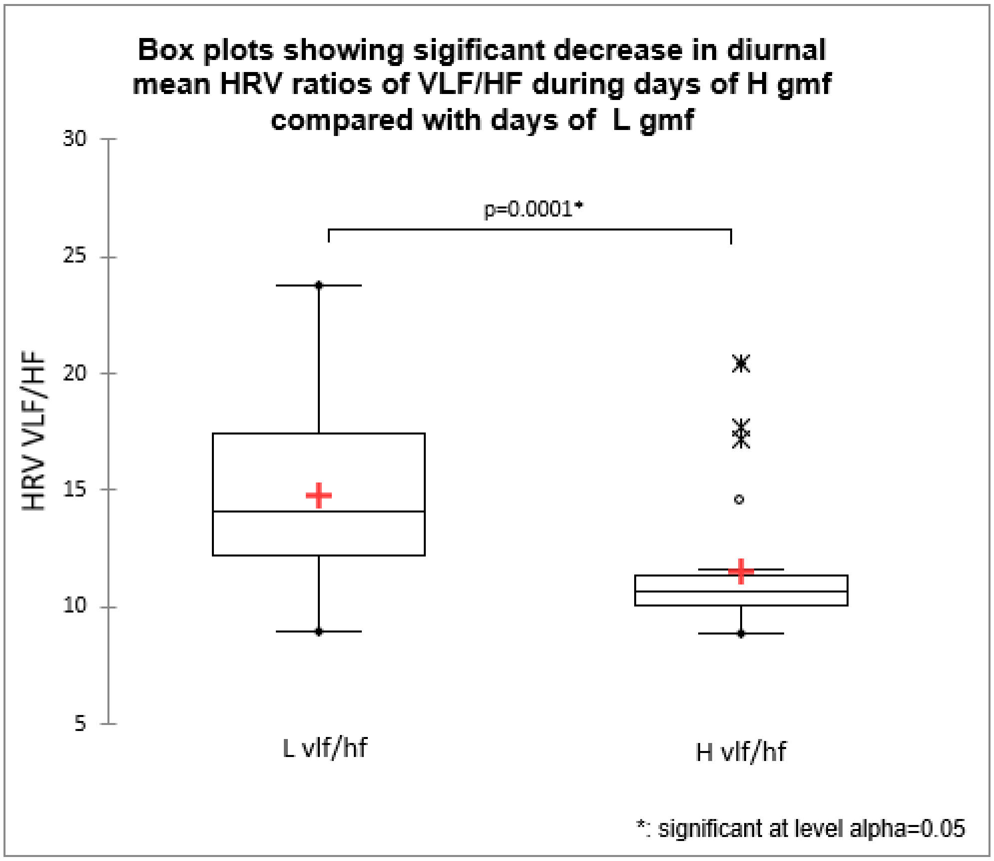

Figure 1

Figure 1 *showing a significant decrease in the HRV ratio of VLF/HF, on days of H gmf compared with days of L gmf (P=0.0001, n=24, effect size 1.014).*

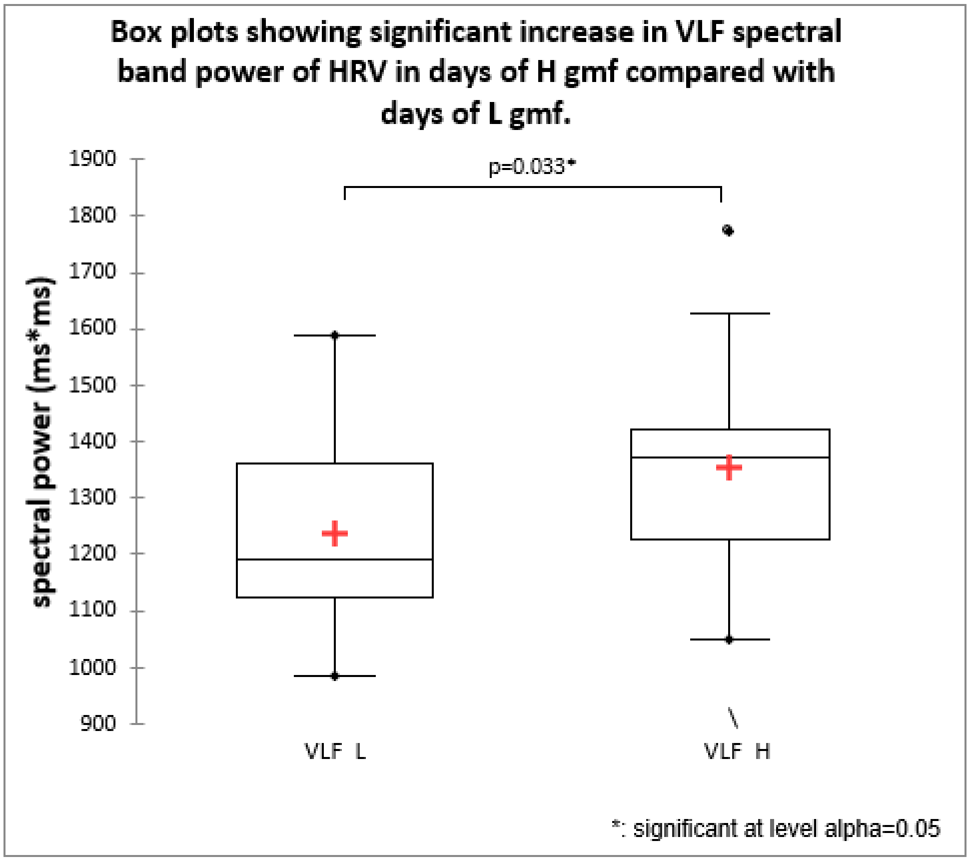

Figure 2

Figure 2 showing the significant increase in spectral power of VLF band of HRV during H gmf compared with L gmf (P=0.033, n=23, effect size 0.68)

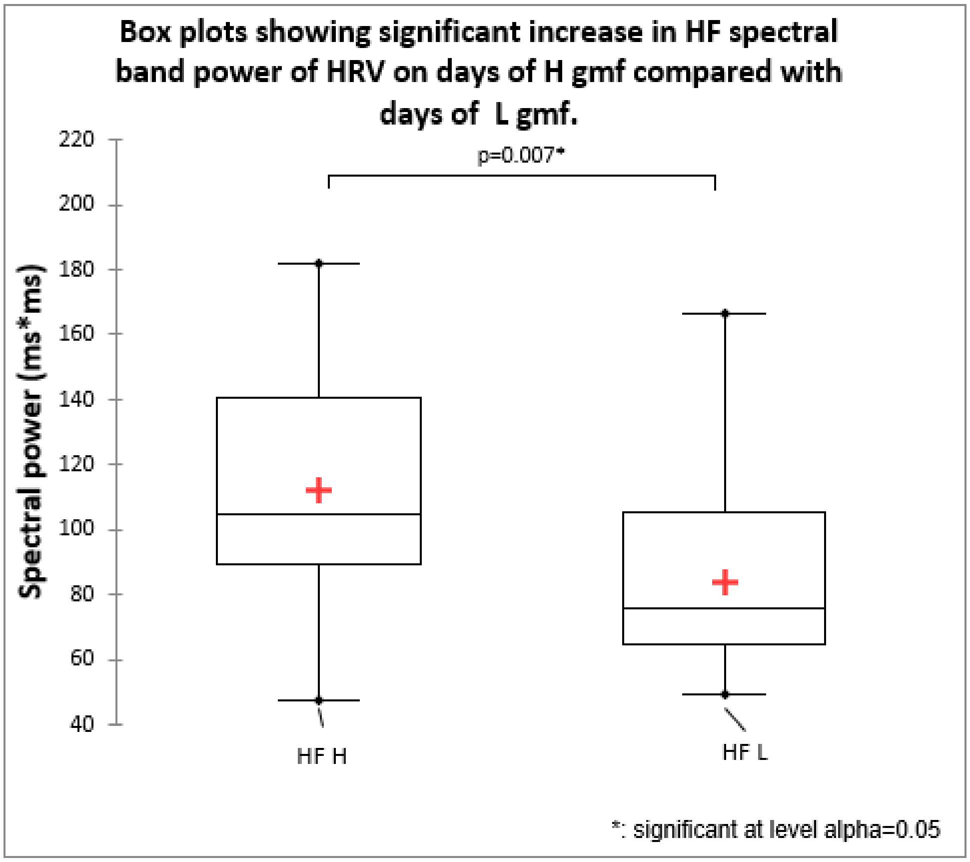

Figure 3

Figure 3 *showing significant increase in HF spectral band power of HRV in days of H gmf compared with days of L gmf (P=0.007, n=23, effect size 0.87).*

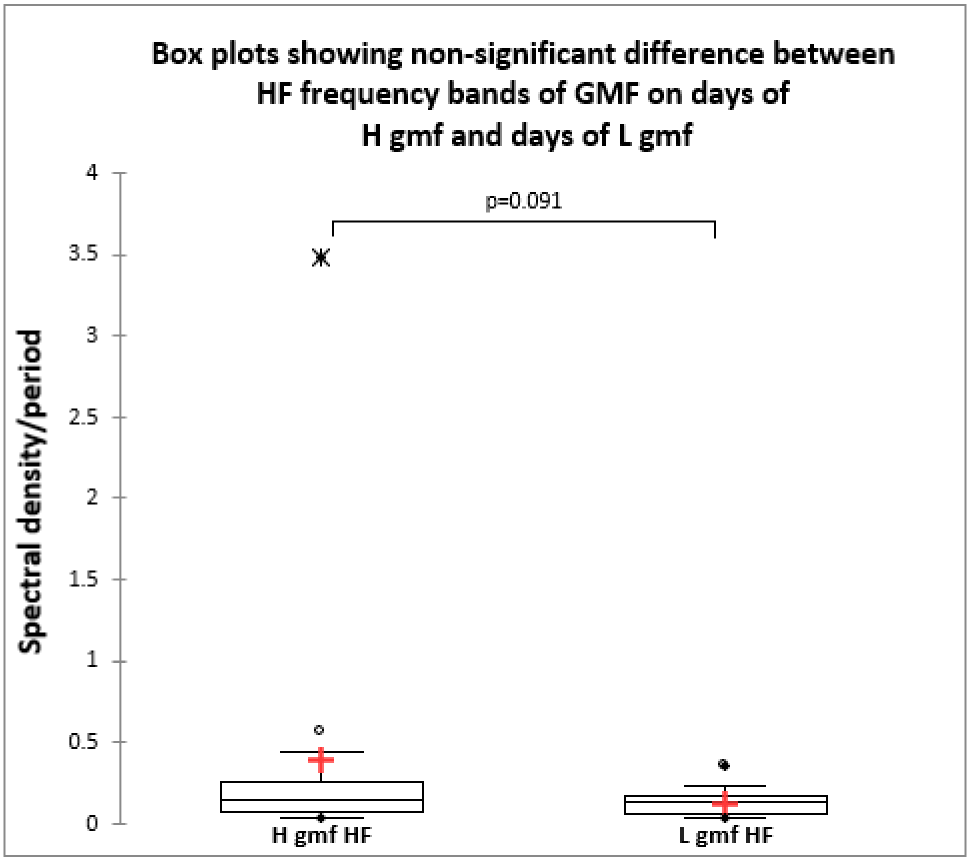

Figure 4

Figure 4 showing non-significant difference between HF frequency bands of GMF on days of Hgmf and Lgmf (P=0.091, n=17, effect size 0.6)

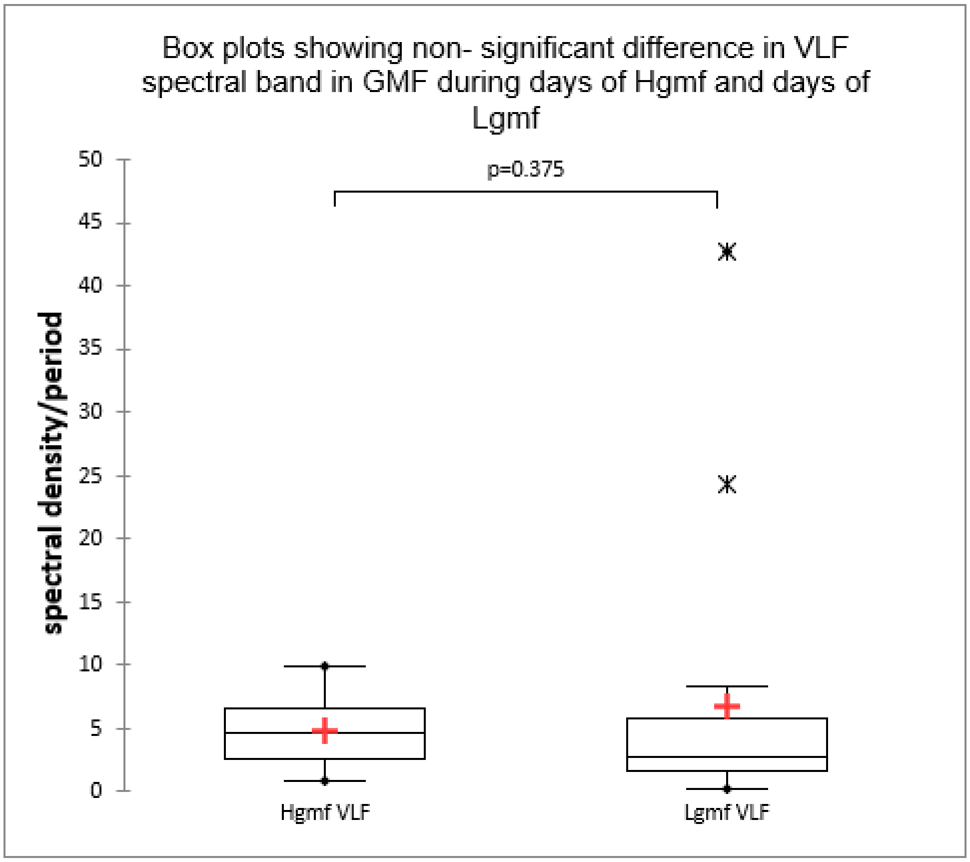

Figure 5

Figure 5 *showing non-significant difference in the GMF VLF bands on days of H gmf and L gmf (P=0.375, n=17)*

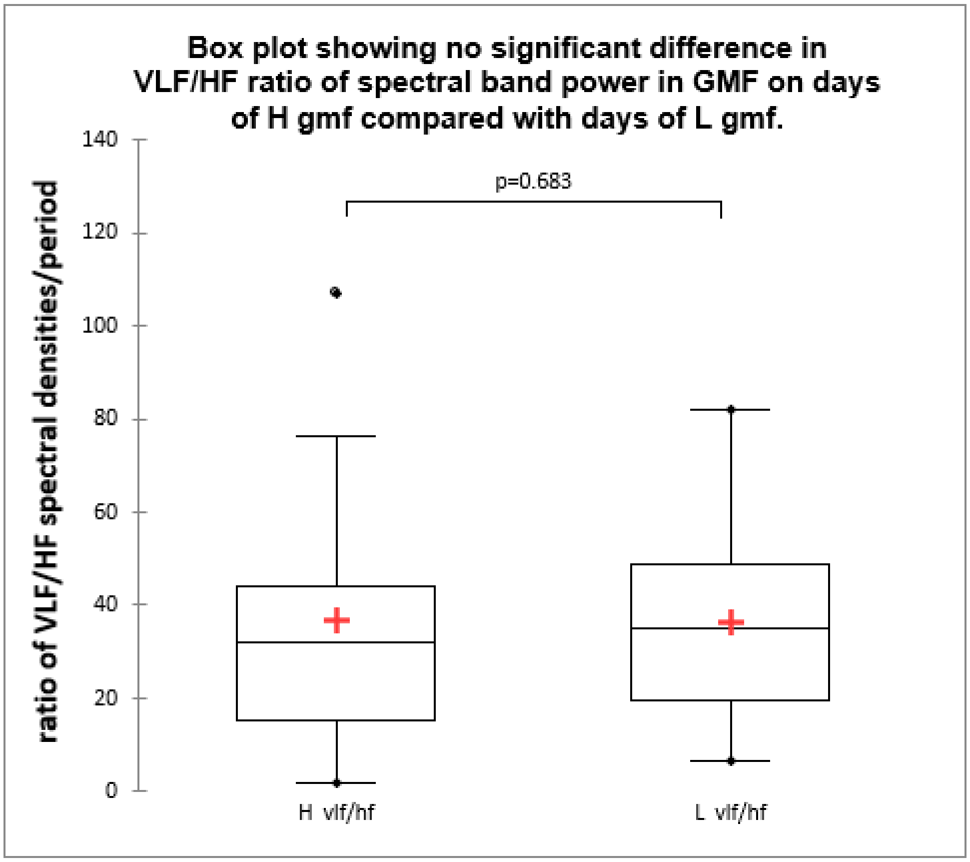

Figure 6

Figure 6 showing no significant difference in means of the GMF spectrum VLF/HF ratios during days of H gmf compared with days of L gmf.

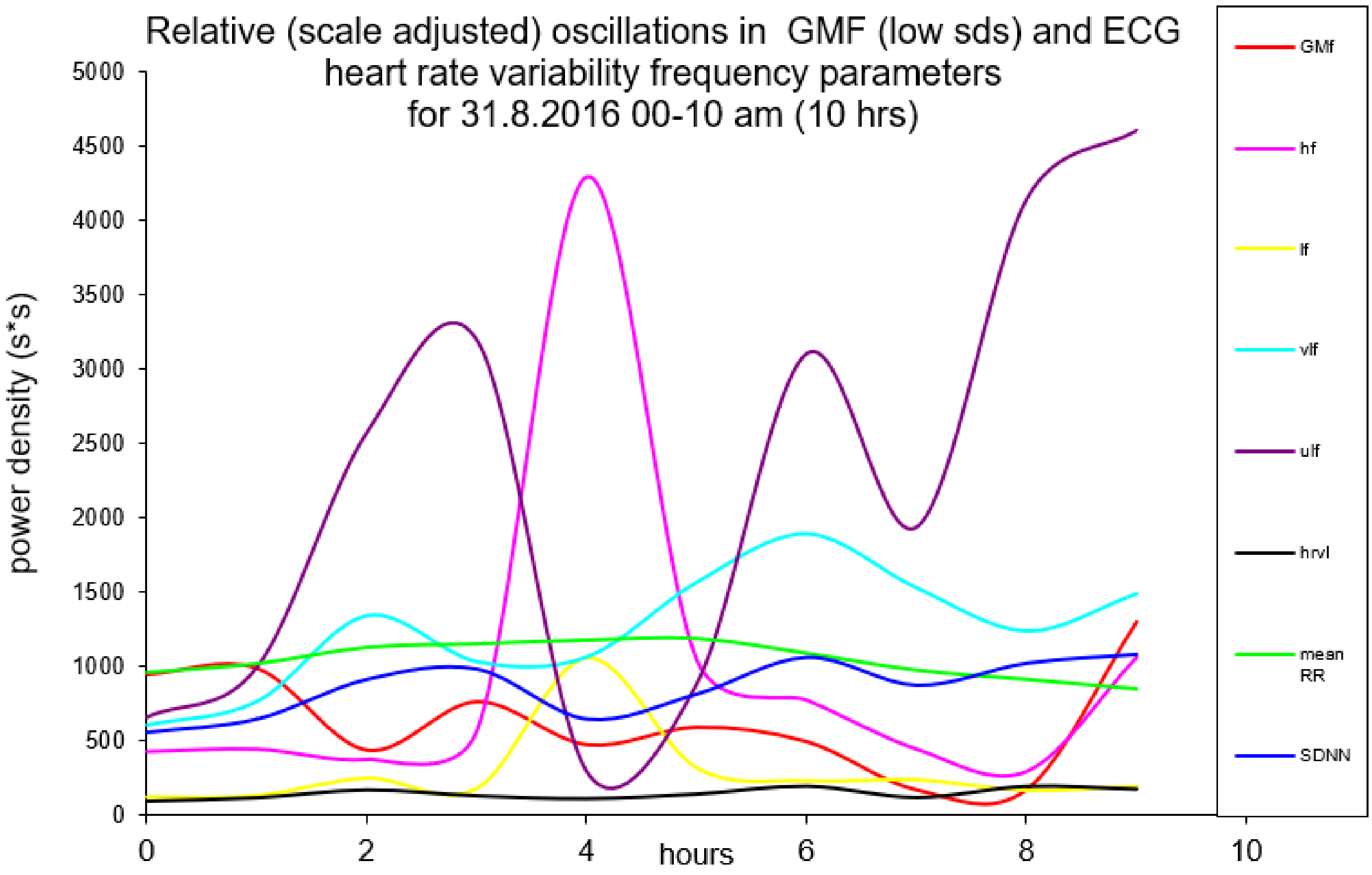

Figure 7

Figure 7 *relative oscillations of the low diurnal mean standard deviation of the GMF (Lgmf) in one 10 hour period, and various frequency parameters of ECG heart rate variability. (Scales adjusted for visualisation)*

Supplementary Files

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