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# Effect of Novel Nanoscale Energy Patches on Spectral and Nonlinear Dynamic Features of Heart Rate Variability Signals in Healthy Individuals during Rest and Exercise

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*Abstract* – **LifeWave energy patches are novel nanoscale semiconducting biomolecular antennas, that when placed in the oscillating bioelectromagnetic field of the body, resonate at frequencies in unison with certain biomolecules in the cells and signal specific metabolic pathways to accelerate fat metabolism. As a consequence of accelerated fat burning more cellular energy becomes readily available to support all bodily energy-consuming functions.**

**Heart rate variability refers to the beat-to-beat variation in heart rate (HR) and is modulated largely by the autonomic nervous system via changes in the balance between parasympathetic and sympathetic influences. Since short-term variations in HR reflect sympathetic nervous activity, they provide useful non-invasive markers for assessing autonomic control under various physiologic states and conditions.**

**To evaluate the effect of LifeWave energy patches on HRV signals, pilot data from healthy volunteers were collected under three different conditions during rest and exercise using a BIOPAC system. The HRV signal was derived from pre-processed ECG signals using an Enhanced Hilbert Transform (EHT) algorithm with built-in missing beat detection capability for reliable QRS detection.**

**Autoregressive (AR) modeling of the HRV signal power spectrum was achieved and different parameters from power spectrum as well as approximate entropy were calculated for comparison. Poincaré plots were then used as a visualization tool to highlight the variations in HRV signals before and after exercise under normal conditions and under the influence of placebo and energy patches.**

**In this paper, for the first time, we present the spectral features and approximate entropy of the HRV signals in healthy individuals during rest, exercise, with placebo, and with energy patches. The results demonstrate that LifeWave energy patches have significant and clearly distinguishable effects on these important HRV signal features. These exciting results warrant comprehensive investigations to study the effects of these energy patches under different physical and health conditions in a large number of subjects in different age groups.**

*Keywords* - **LifeWave energy patches; nanoscale molecular antennas; bioelectromagnetic field; heart rate variability signal processing; athletic training aids; acupuncture points.**

## I. Introduction

LifeWave energy patches [1] are a new patent pending technology that incorporates organic nanoscale biomolecular antennas into a wearable apparatus that consists of a white patch and a tan patch. The patches contain a proprietary formula of biomolecular stereoisomers, which when dissolved in water exhibit liquid crystal properties. The white patches contain L-stereoisomers and the tan patches contain D-stereoisomers [2]. The patches are constructed so that an aqueous solution is injected into a reservoir containing a small disc of fabric, which is sealed between two pieces of water impermeable medical grade polyethylene. The fabric serves as a template that allows the organic molecules to crystallize out of solution forming a matrix antenna composed of nanoscale sized crystals. The end result of this manufacturing process is the creation of semiconducting biomolecular antennas. Because the materials are sealed in a nonporous material the patches are nontransdermal (*no material enters the body*). The nontransdermal nature of the patches has been confirmed by independent laboratory testing [3].

The resonant frequency of a material is defined as the natural vibratory rate or frequency of each substance be it an element, a molecule or a spring. Energy transfer can occur between materials when their resonant frequencies (oscillations) are matched. In addition, when biomolecules in a cell are exposed to an externally applied or internally created electromagnetic field that matches their resonant frequency, the field can be said to be coupled to the biomolecule and the biomolecule will subsequently absorb energy from the electric component of the field.

The vibratory interaction of the organic semiconducting molecular crystals in the patches with the oscillating bioelectromagnetic field of the body generates weak electric signals, which in turn frequency modulate the bioelectromagnetic field of the body. Frequency modulation of the body's bioelectromagnetic field encodes a set of information signals in the same way that electromagnetic carrier waves are modulated by radio stations to communicate audio information [2].

The specific information signals that are encoded by frequency modulation into the body's bioelectromagnetic field by the "energy patches" have the same resonant frequencies as certain cellular structures involved in activating a metabolic cascade that results in increasing beta oxidation of long chain fatty acids. The end result is that these "energy patches" increase energy production in the body through a resonant interaction.

The white patches have been found to be most effective when they are placed on the skin over acupuncture points that are electrically positive. The tan patches are most effective when they are placed on the skin over acupuncture points that are electrically negative.

Under resting conditions the heart rate is under the influence of parasympathetic nervous system. During or after exercise the vagal and the sympathetic activity constantly interact [4]. In this paper, we derived the spectral and nonlinear dynamic features of the HRV signal and used Poincaré plots to visualize the effects of the patches on variations of HR under different conditions with Placebo and Energy and without these patches. ECG signals during different physical states were recorded from young male and female healthy volunteers and the variations in HR at rest and after exercise under the effect of Placebo and Energy patches were determined.

## II. Materials and methods

### A. Subjects and Protocol

Ten young healthy male and female volunteers participated in data collection. Two sets of patches (*Placebo* and *Energy*) were provided to the participants as set-1 and set-2, respectively. *Placebo* patches: patches with inactive natural nutritional substances or preparation (normal saline solution) used as a control in an experiment or test to determine the effectiveness of an active patch. *Energy* patches: patches that allow natural biomolecules to interact with the bioelectromomagnetic field generated by the human body to improve energy level by burning body fat (which is more energetic than sugar) without ingesting anything. No organic material enters the body [3].

Data were recorded from volunteers in six different conditions: 1) at rest; 2) after 5 min exercise (walking up and down stairs); 3) at rest wearing the *Placebo* patches; 4) after 5 min exercise wearing the *Placebo* patches; 5) at rest wearing the *Energy* patches; 6) after 5 min exercise wearing the *Energy* patches.

### B. Data Acquisition and Signal Processing

ECG signals from each volunteer were recorded for 5 minutes during each condition using a Biopac system. The system consisted of integrated software and hardware components. The hardware included the MP30 Acquisition Unit, connection cables, wall transformer, transducers, electrode cables, disposable Ag/AgCl electrodes and other accessories. The MP30 unit amplified the ECG signals, filtered out unwanted electrical noise or interfering signals, and converted these signals to a set of numbers that the computer could read and transfer to the computer via a cable. The software acquired the electric signals coming from the hardware unit and displayed them as a waveform on the computer screen [5]. Three ECG electrodes were used to measure the ECG signals. ECG data were recorded under 6 different conditions using a sampling rate of 360 Hz. Accurate determination of the QRS complex and more specifically, reliable detection of the R wave peak plays a central role in computer-based ECG signal analysis. An Enhanced Hilbert Transform algorithm with automatic R-peak correction capability developed in our research lab was used to detect the QRS complexes. Occurrence of R waves in the QRS complexes were manually verified for error-free detection [6].

### C. Spectral and Nonlinear Analysis

Spectral analysis provides the basic information on how HRV signal power is distributed as a function of frequency. Methods for calculation of HRV power spectra may be generally classified as non-parametric and parametric. The parametric method provides smoother spectral components which can be distinguished independently, easy post–processing of the spectrum with an automatic calculation of low and high frequency components and also easy identification of the central frequency of each component. It also provides an accurate estimation of the power spectrum with small number of samples when the signal is assumed to maintain stationarity [4].

Fluctuations in the heart rate, occurring at the spectral frequency band of 0.15- 0.4 Hz, known as high frequency (HF) band, reflects parasympathetic (vagal) activity, while fluctuations in the spectral band 0.05-0.15 Hz, known as low frequency (LF) band is linked to the sympathetic modulation, but includes some parasympathetic influence (sympatho-vagal influences). The spectral band 0.003-0.05 Hz, known as very low frequency (VLF) is possibly related to the long-term regulatory mechanisms (for example, the renin-angiotensin system, the thermoregulatory peripheral blood flow adjustment). It is now established that the level of physical activity is clearly indicated in the HRV power spectrum. For example, when a healthy subject stands up there is an increase of HRV in the LF spectral band, which is considered to be an estimate of the sympathetic influence on the heart. Consequently, the LF/HF ratio is considered to mirror sympathovagal balance or to reflect sympathetic modulations.

The three main spectral components are distinguished in a spectrum calculated from short-term recordings of 2 to 5 minutes: very low frequency (VLF), low frequency (LF), and high frequency (HF) components. "The distribution of the power and the central frequency of LF and HF are not fixed but may vary in relation to changes in autonomic modulations of the heart period" [4]. Determination of VLF, LF and HF power components was made in normalized units (n.u.) which represent the relative values of each power component in proportion to the total power minus the VLF component. The representation of LF and HF in n.u. emphasizes the controlled and balanced behavior of the two branches of the ANS [4].

It has been shown that LF and HF can increase under different conditions. An increased normalized LF is observed during $90^o$ tilt, standing, mental stress and moderate exercise in healthy subjects [4]. Conversely, an increase in normalized HF is induced by controlled respiration, cold stimulation of the face and rotational stimuli (See references 24 - 79 in [4]).

We calculated the power spectrum of HRV signals using the autoregressive (AR) spectral estimation method as detailed in [4]. We used p = 20 for the AR model order [6]. This method provides more easily interpretable physiological results for short-term signal analysis. We also obtained the spectral components: low frequency (LF), high frequency (HF), and their ratio (LF/HF).

Nonlinear dynamics phenomena are involved in the genesis of the HRV signal. It has been speculated that analysis of HRV based on nonlinear dynamics methods might supply valuable information for the physiological interpretation of the HRV signal [4]. Poincaré plots are valuable visualization tools for HRV signal analysis due to their ability to display nonlinear aspects of the interval sequence [7]. In a Poincaré plot, the value of each interval is plotted against its successive interval. We implemented a MATLAB code to fit an ellipse to the Poincaré plot with the axes calculated from the auto-covariance function [7] of the RR intervals.

Approximate Entropy (ApEn) is a "regularity statistic" that quantifies the unpredictability of fluctuations in a time series [8]. We implemented a MATLAB code to calculate ApEn. The input to the function ApEn (m, r, N) is the length 'N', of a time series data $S_n$, pattern length 'm' which is set to 2. Criterion of similarity 'r' was set to 0.2*SD (standard deviation of $S_n$). Approximate Entropy was calculated as a robust quantitative descriptor of the degree of regularity of HRV signals. A high ApEn reflects a time series with less predictable repetitive patterns or more variability.

## III. Results

ECG data from young subjects under six different conditions were collected using a Biopac Student Lab system. Enhanced Hilbert Transform with missing peak correction was used to locate the R peaks and derive the HRV signal. Frequency domain analysis was performed and spectral parameters were calculated. Poincaré plots were plotted for simple visual inspection and easy to follow differentiation between different conditions with and without patches. Approximate entropy was calculated to show the degree of predictability of repetitive patterns in the HRV signals. Table 1 shows these parameters calculated from the HRV signal collected from a young healthy male volunteer. Table 2 shows the same parameters for a young healthy female volunteer. These features show considerable differences for different physical conditions. Figures 1 and 2 show the recorded ECG signals, derived HRV signals, AR spectrum and Poincaré plots for HRV signals under six different conditions in the male subject. Tables 1 and 2 show a summary of these parameters for 2 representative subjects.

## V. Discussion & Conclusions

The results show some interesting changes in the spectral and nonlinear dynamics parameters of the HRV signals when wearing the *Energy* patches compared to these values when wearing the *Placebo* patches. They showed that during rest, there was a slight decrease in LF (<1% in the male and <3.5 in the female) as well as in the ApEn (<3.5% in the male and < 1% in the female). There was a large increase in HF (30% in the male and 108% in the female). The LF/HF for the resting condition showed a large reduction (24% in the male and 54% in the female). The results also demonstrated that after 5 min exercise, while wearing the *Energy* patches, there was a slight decrease in LF (<3.5% in the male and <1% in the female) as well as in the ApEn (7% in the male and almost 0% in the female). There was a large increase in HF (62% in the male and 31 % in the female). The LF/HF showed a large reduction (63% in the male and 24% in the female).

TABLE I
SPECTRAL AND NONLINEAR DYNAMIC FEATURES OF HRV SIGNALS IN A MALE SUBJECT

| Condition | LF norm | HF norm | LF/HF norm | ApEn |
|---|---|---|---|---|
| Rest | 97.70 | 2.28 | 42.75 | 0.98 |
| Rest with Placebo Patches | 97.62 | 2.31 | 42.23 | 1.14 |
| Rest with Energy Patches | 96.95 | 3.01 | 32.29 | 1.10 |
| | | | | |
| Exercise | 97.42 | 2.56 | 38.03 | 1.05 |
| Exercise with Placebo Patches | 97.97 | 2.03 | 48.36 | 0.98 |
| Exercise with Energy Patches | 94.72 | 5.23 | 18.10 | 0.91 |

TABLE II
SPECTRAL AND NONLINEAR DYANMIC FEATURES OF HRV SIGNALS IN A FEMALE SUBJECT

| Condition | LF norm | HF norm | LF/HF norm | ApEn |
|---|---|---|---|---|
| Rest | 99.15 | 0.83 | 119.25 | 1.01 |
| Rest with Placebo Patches | 97.33 | 2.58 | 37.61 | 1.11 |
| Rest with Energy Patches | 94.20 | 5.37 | 17.54 | 1.10 |
| | | | | |
| Exercise | 90.58 | 9.41 | 9.62 | 0.87 |
| Exercise with Placebo Patches | 96.40 | 3.54 | 27.27 | 1.10 |
| Exercise with Energy Patches | 95.32 | 4.62 | 20.63 | 1.10 |

Based on these preliminary observations it could be concluded that both during both rest and after 5 min of exercise, the *Energy* patches enhanced the relaxation level as they reduced the LF/HF. This is a very desirable effect as a reduced sympatho-vagal balance during rest has an enhancing relaxation effect and during exercise has an enhancing activity effect. These exciting preliminary results warrant comprehensive investigations to study the effects of these *Energy* patches under different physical and health conditions in a large number of subjects within different age groups.

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**Rest** | **Rest S1 (Placebo Patches)** | **Rest S2 (Energy Patches)**

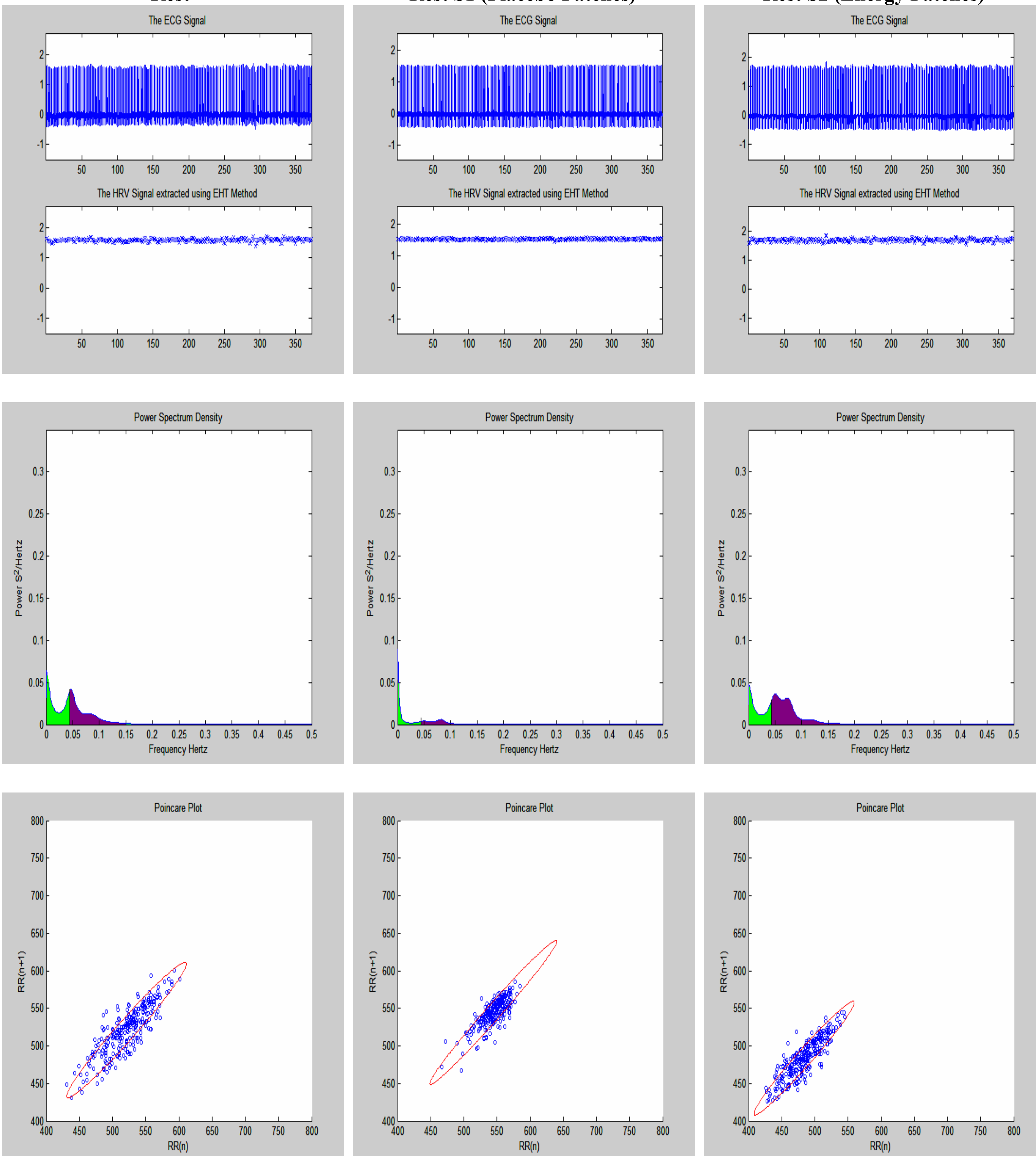


Figure 1. Resting: Male Subject
ECG & HRV signals (Upper traces)
AR spectra of HRV (Middle traces)
Poincare Plots (Lower traces)
Spectral features and ApEn (Tables)

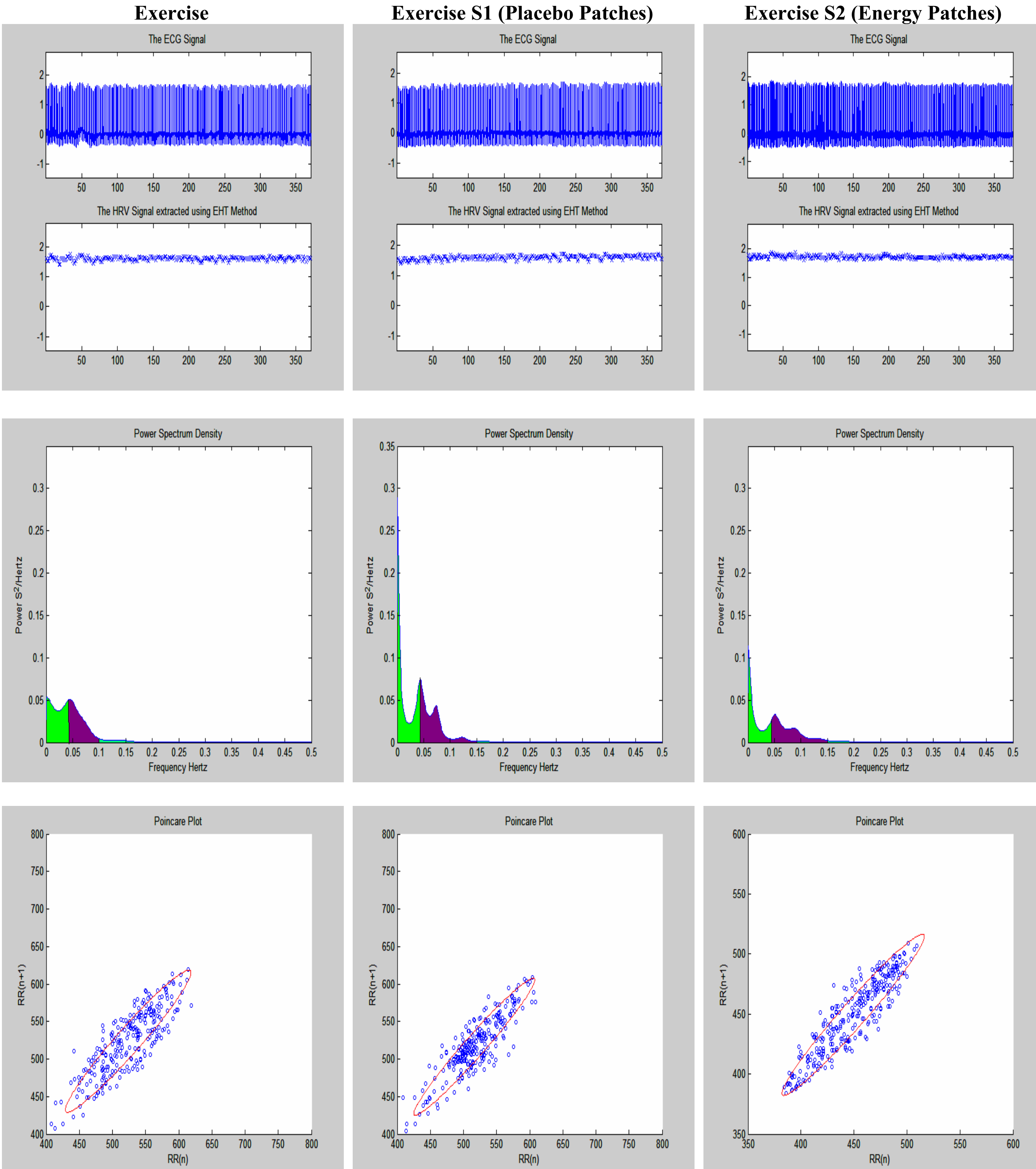


Figure 2. Exercise: Male Subject
ECG & HRV signals (Upper traces)
AR spectra of HRV (Middle traces)
Poincare Plots (Lower traces)
Spectral features and ApEn (Table)