Experiment HH-12: Pulse and Heart Rate Variability (HRV)

Background

Until the mid-1990's, it was difficult to quantify the cardiac risk factor known as stress. Statistics indicate that people who are unable to cope with stressful events run a seven times higher risk of suffering from coronary heart disease than others. These persons demonstrate aggression, impatience, dissatisfaction, and irritability during stressful events, Analysis of the variability in pulse wave intervals, also known as heart rate variability (HRV), can indicate any imbalances between sympathetic and vagal influences on the heart. Comparisons of sympathetic and vagal activity can be used as a measure of stress.

HRV can be studied by different methods: mathematical modeling of heart rate regulatory systems; non-linear methods for determining indices for regulatory functions; time domain methods to determine the deviation of successive N-N (normal pulse-pulse) intervals; or spectral domain methods to determine the power spectral density of definitive frequency components of the ECG.

HRV Spectral Analysis

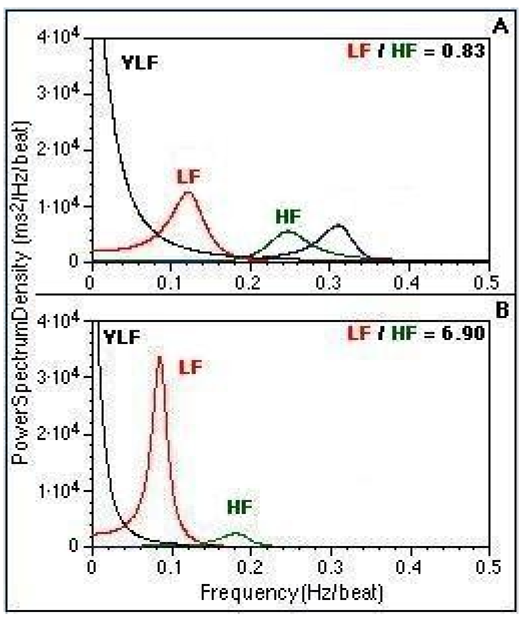

Figure HH-6-B1: Spectral analysis of healthy (A) and stressed (B) subjects, adapted from report of 2nd HRV Congress.

In this experiment, a power spectral analysis (PSA) of the heart rate variability (HRV) of a subject will be determined from the subject's pulse waves. The analysis involves the mathematical transformation of the ECG record to yield its power spectrum and the analysis of the spectrum to determine the density of defined frequency ranges in the spectrum. The first step in the analysis is to express successive pulse-pulse intervals as a function of the time or the heartbeat number in the record. The second step is to convert the product of the first step, which is a tachogram, to a HRV power spectrum by using a Fast

Fourier, Lomb, or other type of mathematical transformation. The final step in the analysis is to determine the power spectral density (PSD) of certain frequency ranges in the HRV power spectrum. The magnitudes of the PSD in certain frequency ranges indicate the relative amount of activity in certain parts of the autonomic nervous system and the level of stress in the subject. The HRV power spectrum can be broken into four components based on frequency range:

- ULP is the power density number for the ultra low frequency range (<0.003Hz), and its prognosis of sudden cardiac death taken from 24 hour ECG recordings is highly accurate.
- VLP is the power density number for the very low frequency range (0.003-0.04Hz), and it is thought to be connected to thermoregulation, the renin-angiotensin system, and changes in physical activity.
- LP is the power density number for the low frequency range (0.04-0.15Hz) that is generated mainly by sympathetic activity. It is hypothesized that baroreceptor (pressure) modulation is a major component of LP power.
- HP is the power of the high frequency range (0.15-0.40Hz) and is derived from vagal activity which is modulated by respiration.

Since LP represents mainly sympathetic activity and HP represents vagal activity, their ratio (HRV ratio) is a good indicator of sympathetic-vagal balance. This ratio is used to assess the balance of the autonomic nervous system in various diseases, some are characterized below.

Stress

Stress is accompanied by an increase in the power spectrum density (PSD) of LP and a decrease in PSD of HP. The power spectral density of a healthy individual at rest can be seen as A on Figure 1 HRV ratio of this subject is 0.83, which indicates vagal activity has a greater influence on heart rate than the sympathetic system. In young subjects at rest, the HRV ratio is as high as 1.5, which is consistent with increased sympathetic activity.

The power spectral density of a subject in a stressful situation can be seen as B on Figure 1. The HRV ratio of this subject is 6.90, which indicates that sympathetic activity has a greater influence on heart rate than the vagus nerve.

Hypertension

Persons with high blood pressure (systolic >139mmHg, or diastolic >89mmHg) are at double the risk of a heart attack, at six times the risk of heart disease, and at four times the risk of cerebral hemorrhage (stroke). Hypertensive subjects (diastolic >89mmHg) have a significantly higher LP value than subjects that are normotensive (diastolic O80mmHg) or prehypertensive (diastolic 80-89mmHg). Concurrently, hypertensive subjects have a significantly lower HP value than the normotensive or prehypertensive groups. The HRV analysis of hypertensive subjects placed on a six month regime of physical training demonstrates that LP decreases and HP increases with small reductions in arterial pressure and heart rate.

Diabetes

Diabetic men have a fifty percent greater risk of arteriosclerosis than non-diabetics; diabetic women have a three times greater risk! Diabetics have a two to three times greater risk of coronary heart disease. Neuropathy is a frequent complication of diabetes mellitus. Because it can be a functional autonomic denervation, patients develop a fast, fixed heart rate. This causes diabetics to have lower R-R variance with a smaller R-R interval. Their power spectrums look normal at rest, but show a diminished increase in LP and a diminished decrease in HP when the subjects are tilted or standing.

Smoking

Smokers have a high risk of lung and laryngeal cancer, but an even higher risk of dying from a myocardial infarction (heart attack). Smokers have a seventy percent increased risk of fatal coronary heart disease, and a two to four-fold higher risk of nonfatal coronary heart disease and sudden death. Smoking acts synergistically with hypertension to markedly increase the risk of coronary heart disease. In women, the use of oral contraceptives is also synergistic with smoking to increase the risk of heart attack, stroke, and brain hemorrhage. Smokers usually have LP values that are higher and HP values that are lower, so that HRV ratios for smokers at rest are usually greater than 1.5.

In this experiment, the subject’s pulse is recorded for at least a ten-minute period during each exercise. During the recording, an analysis of the pulse recording is performed by computed functions, and the results are displayed on four additional channels on the Main window:

- On the Heart Rate channel, the times between the peaks of the pulse waves are measured; the inverse of these times, which is the incremental heart rates, are calculated; and the incremental heart rate of each heart beat is plotted as a function of the recording time. The heart rate is displayed to demonstrate any variations in heart activity during the experiment.
- On the HRV LP channel, the power spectral density (PSD) of the low frequency range of the heart rate variability (HRV) spectrum is plotted against the time of the recording. This is the part of the HRV spectrum caused primarily by the activity of the sympathetic nervous system.
- On the HRV HP channel, the power spectral density (PSD) of the high frequency range of the heart rate variability (HRV) spectrum is plotted against the time of the recording. This is the part of the HRV spectrum caused primarily by the activity of the parasympathetic nervous system.
- On the HRV Ratio channel, the ratio of the low frequency PSD to the high frequency PSD is plotted against the time of the recording. This quotient is a measure of the subject’s vagal-sympathetic balance.
- The values for these parameters will be determined from subjects who are at rest, recovering from exercise, or taking a quiz or a test.