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A Review of Heart Rate Variability and its Applications

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Abstract

The heart is a key component of the human body, acting as a pump that transfers oxygenated and deoxygenated blood around the body. Like all other organs, it is susceptible to diseases and age. Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval. Its variation may contain indicators of current disease, or warnings about impending cardiac diseases. The indicators may be present at all times or may occur at random-during certain intervals of the day. It is strenuous and time consuming to study and pinpoint abnormalities in voluminous data collected over several hours. Computer based analytical tools for in-depth study of data over daylong intervals can be very useful in diagnostics. In this paper we have discussed the various applications of HRV and different linear, frequency domain, wavelet domain, nonlinear techniques used for the analysis of the HRV.

Keywords: Heart rate variability, nonlinear techniques, frequency domain , data over daylong intervals

1. Introduction

The origin of ECG is a special node which acts as a pacemaker for the heart. It is called the SA or Sinoatrial node, and assists in the acquisition of ECG when one attaches electrodes to specific points on the body, usually the right leg. The form and structure of the ECG as seen on a printed chart indicates whether an individual has a healthy heart or not. The first is the wave boundary and determination of the primary fiducial points, as shown by the onset and offset of the QRS complex as well as P and T waveforms. The baseline for the QRS-T is determined in an interval before the QRS onset. It is important to note that baseline wander,

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atrial fibrillation and a high or irregular heart rate can cause errors in ECG assessments.

Tests after tests show that the most suitable alternative for the development and assessment of ECG is the three channels CSE database, although it can only be used for assessments of one channel accuracy[1]. In order to accurately determine the ECG of an individual, several aspects are put into consideration. One of them is the HRV or Heart Rate Variability, which refers to the variation between the normal heart rate and a given mean value.

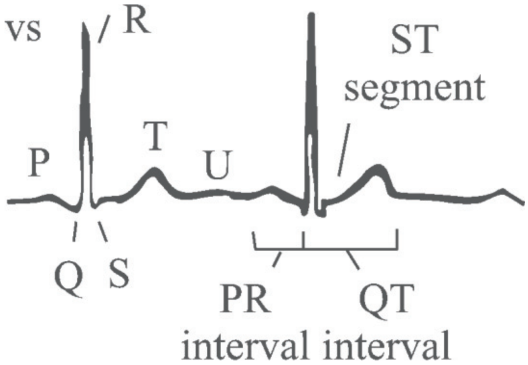

Figure 1. Heart wave signals

The heart rate may vary but may result from diabetes complications, feotal distress in a pregnant mother, and congestive heart failure. One thing worth noting is that HRV is useful in predicting myocardial infarction. A reduced HRV is symptomatic of this condition which if left untreated is usually fatal.

2. Methods

2.1. HRV Analysis Methods

The first thing to note is that HRV methods for analysis of heart rhythms, do not generally involve opening up the body and physically examining the heart. Usually, doctors employ three different methods namely, the Non Linear, time domain, and frequency domain methods. Even with these methods, one ought to consider various factors such as the individual in question's health status, respiration, gender and age. Other parameters that generally influenced HRV tests were abnormalities in the Sympathetic nervous System (SNS) and Parasympathetic nervous system (PNS). There are three states of HRV signals are compared: anger, relaxation, and appreciation. Once again, the tachograms are displayed, along with power spectra analyses, derived from the tachogram patterns. Short term power spectra analyses produce peaks or clusters of data points mostly within three main regions[2]:

- High Frequency (HF) from 0.15 Hz to 0.40 Hz reflects the activity of the parasympathetic system and the vagus nerve.
- Low Frequency (LF) from 0.04 Hz to 0.15 Hz reflects sympathetic activity.
- Very Low Frequency (VLF) from 0.003 Hz to 0.04 Hz reflects a host of factors, including not only the sympathetic nervous system, but also input from chemoreceptors, thermoreceptors, the renin-angiotensin system and others.

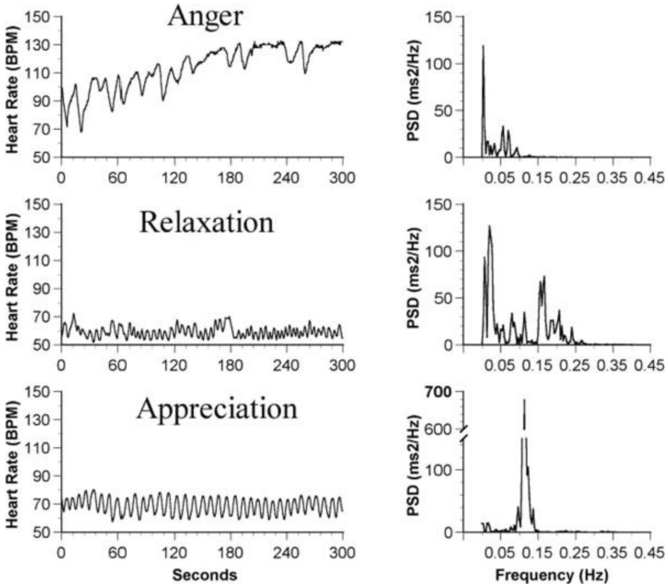

Figure 2. Anger, relaxation, and appreciation signals

According to most research journals, the most frequently used technique for HRV is the linear technique, specifically Spectral Analysis. In this method, spectral power in a high frequency band is employed to reflect respiratory sinus arrhythmias while at the same time, a low frequency reflects baro-receptors control. Very low frequency power on the other hand shows the vascular and thermo-regulatory functions of the heart[3].

2.2. HRV Analysis of Diseases

Heart rate variation techniques and indexes have proved crucial in treating not just cardiovascular system diseases, but unrelated conditions such as stroke, Alzheimer, renal failure, leukemia, epilepsy, chronic migraines, and obstructive sleep apnea. Most doctors tend to agree that all biological systems, even the healthy ones tend to show haphazard dynamics while biological systems suffering from disease show reduced levels of dynamics. Since all organs depend on the flow of blood from the heart, any cardiovascular abnormalities will affect all other organs and affect the heart rate activity. That said, autonomic dysfunction is a key characteristic of heart and diseases such as sepsis, brain trauma, multiple organ failure, and myocardial infarction. Other conditions that show high HRV indices include Congestive Heart Block (CHB), Left Branch Bundle Block (LBBB), Sick Sinus Syndrome (SSS) and Premature Ventricular Contraction (PVC).
As said before, Heart Rate Variability is affected by Sympathetic and Parasympathetic system disorders, but those of the peripheral nervous and the central nervous systems also play a major role[3].

2.3. HRV Analysis of ANS Dysfunction

Any change that occurs to the thyroid has a direct effect on an individual's heart and peripheral vascular system due to changes in ANS. A Power spectral analysis of HR for hypothyroid displays certain key features in patients with hypothyroidism. They include autonomic dysfunction with a higher level of vagal tone, change in the metabolism of some of the amines in the brain, and reduced parasympathetic activity with increased t3 and t4. Therefore, any change in the thyroid hormone causes a change in the heart rate activity.

Simply put, a thyroid that is not working well by either under producing or overproducing hormones bears negative effects on the heart. The physical manifestation of a poorly functioning thyroid is a rise in the blood pressure and hyper tension of the arteries. A non-linear analysis method to check for heart rate variability showed a value for CD of slightly over 5 for an individual with hypothyroidism. This is in comparison to the 6.42 figure needed for a healthy individual. A reduced CD reading is regarded by physicians as a sign of reduced tolerance to cardiovascular (heart) stress. The relationship between the thyroid hormones is best seen with regard to the sympatho-vagal balance, which shows an ECG reading of 5 minutes [4].

2.4. HRV Analysis of Depression

For a long time, researchers have known that ANS deregulation causes death from heart disease and HRV analysis, which provides information about the ANS in various ailments. HRV methods possess the ability to show the amount of dysfunction in ANS, brought about by psychiatric disorders such as depression and schizophrenia. To some people, depression is not a psychiatric disorder; however, when it reaches chronic levels, it is harmful to the cardiovascular system. Results from several studies show that ANS dysfunction is one of the markers for depression. In the case of depression, HRV measures cardiac autonomic innervations of the brain, which will eventually result to coronary artery disease and myocardial infarction. Some scientists postulate that a reduction in parasympathetic nerves allows the unopposed stimulation, which could lead to an irregular heartbeat and even death. Scientists also note that in chronic sympathetic stimulation, major depression occurs side by side with severe neuropathy. In the case of subjects with major depression, heart rate variation methods using frequency domain provide more accurate results. They include non-linear correlation methods, frequency domain methods, and time domain methods. Regardless of the test used, a very severe depressive illness will always show a change in the heart rate activity [5].

3. Heart Rate Variability and its Applications

3.1. Non-Linear Methods and Applications for Arrhythmia Analysis

Traditional methods and indices lack the ability to unearth the fine changes in the heart rate activity because it is not stationary. That means in plain terms that fluids constantly move from one body organ to the next, through arteries and veins. This is of course can only happen if the individual is alive. A nonlinear deterministic method seems like being more appropriate in explaining more complicated phenomena, indicating that evidently; erratic behavior is capable being created even through a simple deterministic system that has nonlinear structure[6].

$$\begin{aligned} y_n^{calc} &= a_0 + a_1 y_{n-1} + a_2 y_{n-2} + \ldots + a_\kappa y_{n-\kappa} + a_{\kappa+1} y_{n-1}^2 + a_{\kappa+2} y_{n-1} y_{n-2} + \ldots + a_M y_{n-\kappa}^d \\ &= \sum_{m=0}^{M-1} a_m z_m(n) \end{aligned} \tag{1}$$

The cardiovascular system is very complex to be of a linear nature, so the only way one can understand the HRV is by using predominantly nonlinear methodologies. For HRV analysis of Arrhythmia, a medical practitioner must adopt a concept based on rapid fluctuations that may show changes in sympathetic and vagal activity [7].

They contain indicators of current HRV behavior or evidence of future medical conditions. For instance, the DFA method or Adopted Detrended Fluctuation Analysis can quantitatively and qualitatively study abnormalities of the heart rhythm[8.]

3.2. Interpretation of the ECG Signals and Graphs

The ECG graph is a printout designed to show the electrical activity in the form of waves occurring in the heart muscle. To plot this wave, it is important that one understands a number of technical terms like the QT interval, which is between depolarization of the ventricles and the end of the depolarization. The QRS complex and the T wave represent depolarization and re-polarization respectively.

The QT interval assessment method consists of QRS complex detection and T wave offset. The key to interpreting QT interval assessment is the initial detection of characteristic points. It is vital that QRS complex markers be made available. The assessment begins by splitting the main signal into single heartbeats and detecting the individual points separately. The individual doing the assessment must detect and identify the onset peaks and offset of the P wave. Then the onsets and offsets from different channels must be combined leading to a single onset and offset for P, QRS and T per beat[9].

In single wave detection, the QRS onset detection exists as well. The QRS onset detection requires the filtering of a signal using a 60 Hz low pass filter, which modulates the signal within a short time window. Detection of the exact point desired to show heart rate variation is done by systematically decreasing the threshold value. A calculation to show the possible onset point and the mean range is determined, such that the point with the lowest ratio in between the mean values is chosen as the exact onset point.

Coarse T offset detection comes from QT- DB. The standard QT-DB is actually composed of a very broad range of ECG's from patients with a multitude of ailments. It is important when calculating the Exact T offset detection in a heart variation rate. One must compare the value of the margin by calculating the following parameters: the gradient of the descending wave with respect to that of the ascending wave, the stability of the signal outside of the wave, and the distance between the preceding and subsequent extremum. Other things to calculate and consider are the amplitude of the wave and the high bypass cut off frequency[10].

4. Conclusions

Analysis of change in RR interval demonstrated that training induces a resting bradycardia accompanied by increased cardiac vagal modulation in healthy individuals. By this mechanism, exercise training may be able to exert an antiarrhythmic effect. The small number of studies using the latter methodology means caution should be employed before any generalizations being made regarding the superiority of one technique over the other. In conclusion, the results of the current review suggest that HRV analysis using ECG recording could be effective in automatically detecting real-life condition, such as a university examination. Further research on a large sample size and on different stressful conditions will help to further elucidate the findings of this study and effectiveness of HRV analyses for differentiation between low and high condition.

References

[1] Acharya, Kumar. Classification of cardiac abnormalities using heart rate signals. New York, Med. Bio. Eng Comp: 42 (3): 288-9, 2004. Print.

[2] Hales S. Statistical Essays: Containing Haemastaticks. London, UK: Innys, Manby and Woodward; 1733.

[3] Yi Gang and Malik, Marek. Heart rate variability Analysis in general medicine". New York, Indian pacing and Electrophysiology Journal 3(1) 34-40, 2003. Print.

[4] Chua, Kuang, Vinod Chandran and Rajendra, Acharya. Cardiac health diagnosis using Higher order spectra and support vector machine. Boston: Open Med Information Journal, 2009. Print.

[5] Schroeder & Vallverdu, Patrick. Linear and Non Linear heart Rate variability Risk stratification in Heart failure patients. Computers in cardiology. New York, 35: pp 957-959, 2008. Print.

[6] Gustav, Krastic. Non linear analysis of Heart rate variability in Patients with Coronary Heart Disease. Chicago. Computers in cardiology (29). 673-675, 2003. Print.

[7] Denton TA, Diamond GA, Helfant RH, Khan S, Karagueuzian H. Fascinating rhythm: a primer on chaos theory and its application to cardiology. Am Heart J. 1990;120:1419–1440.

[8] Kheder, Kachouri, and Messouad, Mouhamed. Application of a non linear dynamic method in the analysis of the HRV (Heart Rate variability towards clinical application: New York, Tiresome diagnosis. IEEE procedding pp 177-182, 2006. Print.

[9] Peng, Havlin, and Goldberger, Stanely. Quantification of scaling exponents and crossover phenomena in non stationary heartbeat time series: New York, 5: 82-87, 1995. Print.

[10] Steinnand, Phyllis. Non Linear heart rate Variability and Risk stratification cardiovascular Disease. New Dehli, Indian Pacing and Electrophysiology Journal, 2005, 5(3): pp 210 -220. 2002. Print.