NEW PARADIGM FOR PERSONALISED FITNESS

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ABSTRACT - *This paper is designed for the use of cardiac health control, psychology, medicine or in any training session to analyze the HRV by using many advance techniques like Time domain and frequency domain analysis, Spectral analysis including fast Fourier transform, autoregressive method and Non-linear analysis. Analysis of HRV is very popular to characterize the autonomic balance and mortality in cardiac patients. Poincare plot plays very important role in nonlinear analysis of HRV. Extended Poincare plots to measure HRV are very popular nowadays. New techniques trigonometric regressive spectral (TRS) and wavelet transform have been developed for the future research area to analyses the heart rate variability in more efficient way. We can use the approach of amplitude domain analysis or future research.*

Keywords: Heart rate variability, Spectral analysis, Fourier transforms, Autoregressive models, Time and frequency domain, Poincare plots, Nonlinear Analysis, Autonomic nervous system.

1. ADVANCE ANALYSIS OF HRV

INTRODUCTION

Heart Rate Variability is the physical sensation of variation in time between each heartbeat. The variation in beat to beat interval is controlled by the nervous system. HRV is widely used in many clinical conditions like diabeties, heart failure, hypertension and coronary artery disease to monitor the treatment results in very efficient way. Time domain and frequency domain techniques are very traditional to determine the heart rate variability in different disease so new methods and techniques are developed like Nonlinear and spectral analysis. In this paper we are discussed the advance techniques, tool and method for analyzing the heart rate Variability. These methods are: spectral analysis based on fast Fourier transform and autoregressive spectral analysis, Time and frequency domain analysis, nonlinear analysis. Poincare plots play a very important role to evaluate the performance of heart rate variability in Non linear analysis.

2. MATERIALS AND METHODS

2A. SPECTRAL ANALYSIS OF HRV

Spectral Analysis of heart rate variability is a non-coercive and valuable tool for identifying cardiac autonomic activity. Attributes of frequency domain are mainly used in spectral analysis like High frequency power (HF) activity range between 0.15 to 0.40 HZ which represents sympathetic activities, Low frequency power (LF) activity range between 0.04 to 0.15 HZ which represents modulation of heart rate and LF/HF ratio indicates low frequency to high frequency ratio which is used in nervous system activities to measure the balance between sympathetic and vagal activities in an appropriate and efficient manner.

2B. SPECTRAL ANALYSIS METHODS

Spectral analysis of HRV is analyzed by two proper methods like fast Fourier transform and autoregressive models by using many advance software, tools and techniques. Fast Fourier algorithm (FTF) is very efficient algorithm having low computational cost and autoregressive (AR) gives an assessment in the short form of periodically waveform. On the basis of comparison of both tools we can calculate the difference of both methods. Fast Fourier transform has many restrictions in length of data and need limitations to implements its application while on the other hand autoregressive method has faster and shorter result than fast Fourier transform. Matlab software is commonly used to measure the results of autoregressive methods. When short frames of data are used then FTF gives a poor spectrum resolution while short frame are used in autoregressive method then it produces a very high-resolution spectrum. kubios software are used to investigate the results of autoregressive approach and measure the value of PSD.

There have been several autoregressive models in ECG signal processing. Burg's algorithm, the least square approach and Yule-Walker method are commonly used [1, 3]. Each method has its advantages and disadvantages. Records than Yule-Walker method, and Burg's algorithm has no implied windowing which distorts spectrum in Yule- Walker method [3, 4]. The least square approach has improvements in the issues of spectral line splitting and the bias in the positioning of spectral peaks, but is less stable than Burg's algorithm [1, 2, and 4].

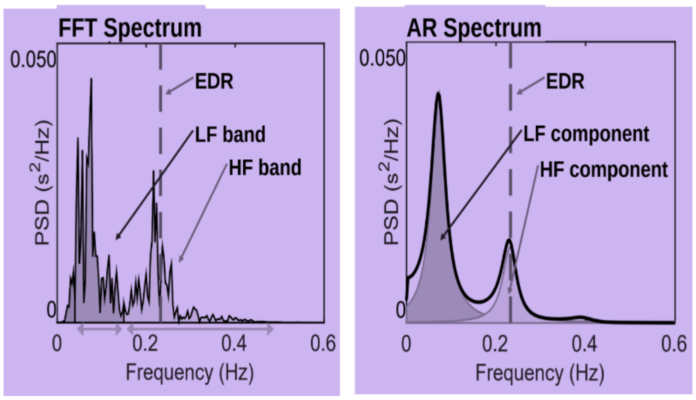


Fig-1: kuibos HRV

3. TIME AND FREQUENCY DOMAIN ANALYSIS

Time domain parameters are associated mostly with the overall variability of the R-R intervals over the time of recording. They are Mean-R-R, Standard deviation of all NN intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD), number of adjacent NN intervals differing more than 50 msec (NN50 count), percentage of differences between adjacent NN intervals differing more than 50 msec (pNN50 %), RR triangular index, standard deviation (STD) of the mean heart rate per minute [6].

By using various methods, we can measure the HRV of each heartbeat. HRV measurement usually based on the sequence of RR interval and ignore the fluctuation in PR intervals. Useful and effective measurement of HRV is known as SDNN (Standard deviation of Normal to Normal Interval). By using SDNN, RR interval start and end with a PAC (Premature arterial contractions) and PVC (Premature Ventricle Contraction) SDDN measured in milliseconds over 24 hours. Variables of the SDNN created by dividing the 24-hour observing period into 5-minute segments are the SDNN index and the SDANN index measured in milliseconds. The SDNN index is the mean of 5minute standard deviations of NN (normal to normal) intervals during the 24-hour period while the SDANN index is the standard deviation of 5-minute NN interval means. Frequency domain is a very complex method that elaborates how much of a signal lies between frequencies bands. Parasympathetic Nervous system activity associated with the frequency domain methods. Frequency domain measurement is presented by taking series of numbers along time axis and commute fast Fourier transform. Fast Fourier transform is an algorithm and tool that convert one type of sequence of a function into another form of representations. The complex value of FFT is computed with the power spectral density (PSD) function, denoted by P(f) and $P(f) = |X(f)|2$.PSD function has border effect on PACs and PVCs intervals at all frequency's ranges.

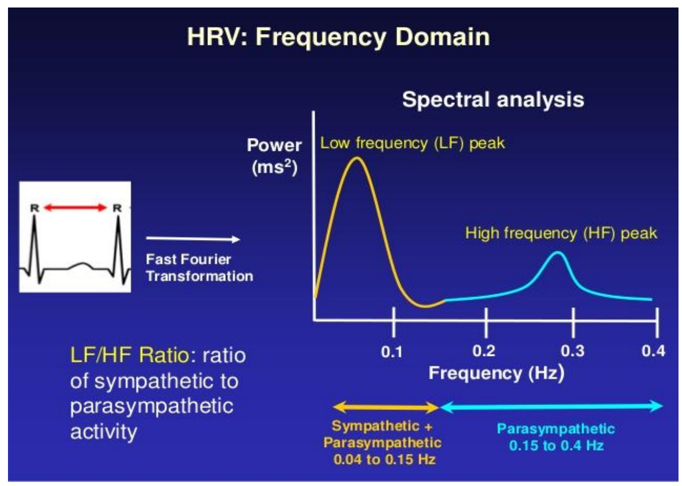


Fig-2: HRV Frequency Domain

New techniques trigonometric regressive spectral (TRS) and wavelet transform have been developed for the future research area to analyses the heart rate variability in more efficient way. Instead of traditional time domain and frequency domain analysis we can use the approach of amplitude domain analysis that how we can use amplitude domain for measuring HRV is a very elaborate and wide research area

4. NONLINEAR ANALYSIS OF HRV

Nonlinear method has been used to measure nonlinear properties of HRV. HRV is very helpful to study the autonomic nervous system and to assess overall cardiac health. Nonlinear analysis methods are to be dissimilar from the conventional HRV methods because they do not evaluate the dimensions of variability but slightly the quality, scaling and resemblance properties of the signals. We can say that they are related with the unpredictability, tractability and intricacy of the signal. Invariant and informational domain is used to measure the heart rate variability in nonlinear analysis. The concepts related to chaos theory, the fractal mathematics and the dynamic complexity of heart rate variability behavior are still far from large application in medical clinical practice, although they constitute a fruitful field for research and expansion of knowledge in both health and disease[7].There are many other nonlinear indices such as the Lyapunov Exponent (LE) and Correlation Dimension (CD), which also provide information on the characteristics of HRV, but their clinical utility has not been fully established[7].Poincare plot is used in graphical nonlinear method to identify the characteristics of HRV. ... The Poincare plot is a scatter plots in which each RR interval from time series RR = {RR1, RR2… RRn, RRn+1} were applied against the next RR interval to measure the dynamic of HRV.

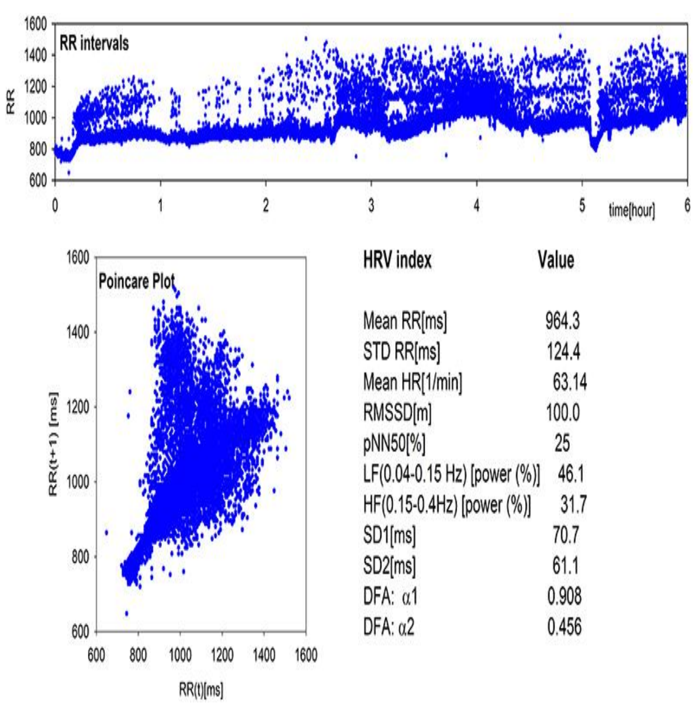
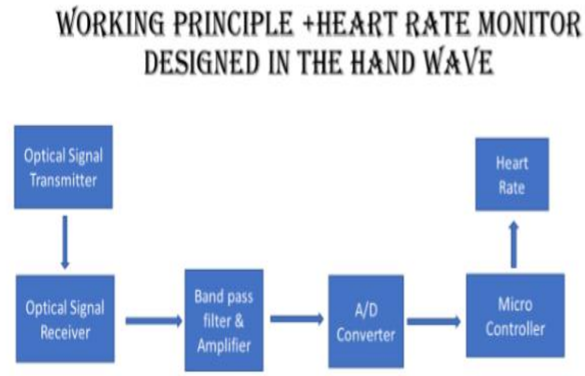


Fig-3: Visualization of Heart Rate Variability of Long-Term Heart Transplant Patient by Transition Networks: A Case Report - Scientific Figure on Research gate.

Available from: https://www.researchgate.net/figure/Elements-of-standard-and-non-linear-HRV-analysis-plot-of-RR-intervals-time-series_fig2_297656450 [accessed 21 May, 2020].



Working principle of heart rate monitor

This project intends to realize a device that can read the human pulse rate from a fingertip. The pulse rate in the unit of beats per minute (BPM) will be displayed by a 16 by 2 LCD displays. According to the National Institute of Health, the average resting heart rate for children 10 years and older, and adults (including seniors) is 60 - 100 beats per minute. Well-trained athletes is 40 - 60 beats per minute. So this device will indicate a too high pulse as well. A real-time plot of pulse signal versus time will be displayed on a laptop screen. The module is in turn connected to the Blue tooth device which then transmits the signals to the server, that contains the HRV application of Doctor Poly. The hardware consists of a pulse oximetry kind of device which is built up of an Arduino and a pulse sensor, the pulse sensor detects the blood flow and acts on the principle of photodiode and it emits an LED to detect the variation or change in the blood volume and every spike in the blood volume creates a certain analogous reading on the pulse sensor, this reading is then processed through the Arduino which is the 2nd part of the component hardware , this Arduino filters out the noise and amplifies the pulse pressure wave.

5. FUTURE RESEARCH AREAS

New techniques trigonometric regressive spectral (TRS) and wavelet transform have been developed for the future research area to analyses the heart rate variability in more efficient way. Instead of traditional time domain and frequency domain analysis we can use the approach of amplitude domain analysis that how we can use amplitude domain for measuring HRV is a very elaborate and wide research area.

Extended Poincare plots allow deep research in the dynamic of the heart rate variability. Correlation between heart rate variability and Poincare plot is a very broad area o research.

6. RESULTS

Explore Data for non-null and extreme values

Females are assigned as 1 and Males are assigned the number 2. The Data set contains the Age Sex body weight and height of about 30 individuals from Polisetty's clinic and the BMR is calculated as per a certain code written based on Mifflin-St Jeor Equation and BMI based on a standard equation.

	Age	Sex	height	weight	BMI	BMR	VLF PEAK	LF PEAK	HF PEAK	VLF power
0	66.0	1.0	153.0	69.0	29.475843	1321.25	0.039	0.078	0.194	2.0
1	60.0	1.0	152.0	55.0	23.805402	1205.00	0.021	0.107	0.214	1.0
2	42.0	1.0	160.0	94.0	36.718750	1735.00	0.033	0.098	0.361	14.0
3	69.0	2.0	164.0	67.2	24.985128	1357.00	0.021	0.083	0.166	2.0
4	72.0	1.0	160.0	54.0	21.093750	1185.00	0.045	0.090	0.199	7.0

Fig-4: Exploration of data

HRV data was derived from the Docture Poly's prototype and spectral analysis is done after signal processing is done based on Fourier transform.

	count	mean	std	min	25%	50%	75%	max
Age	28.0	53.892857	14.275956	9.000000	45.75000	54.000000	66.000000	72.000000
Sex	28.0	1.607143	0.497347	1.000000	1.00000	2.000000	2.000000	2.000000
height	28.0	164.036786	12.513121	122.000000	157.80000	164.500000	171.200000	188.900000
weight	28.0	71.700000	17.871206	29.000000	60.00000	71.500000	81.250000	109.000000
BMI	28.0	26.523188	5.870997	16.141529	22.81572	25.389152	30.078007	38.295657
BMR	28.0	1477.765625	219.159305	1012.500000	1376.59375	1480.000000	1580.015625	2062.500000
VLF PEAK	28.0	0.032536	0.011720	0.019000	0.02500	0.029500	0.039000	0.073000
LF PEAK	28.0	0.094893	0.017844	0.069000	0.08175	0.094000	0.103500	0.132000
HF PEAK	28.0	0.228464	0.074102	0.149000	0.17500	0.198500	0.246000	0.371000
VLF power	28.0	9.785714	9.727232	1.000000	3.00000	5.500000	14.000000	40.000000
LF power	28.0	27.678571	21.267352	5.000000	13.50000	21.500000	32.500000	81.000000
HF power	28.0	45.571429	36.943830	14.000000	21.00000	33.500000	64.000000	155.000000
VLF	28.0	10.632143	8.757348	0.200000	3.17500	8.550000	16.650000	33.100000
LF	28.0	18.287500	14.514996	1.500000	6.55000	12.700000	31.725000	50.400000
HF	28.0	25.800000	21.857705	1.600000	9.55000	16.350000	37.950000	76.100000

Fig-5: Exploration of parameters

	Age	Sex	height	weight	BMI	BMR	VLF PEAK	LF PEAK	HF PEAK	VLF power
Age	1.000000	-0.089610	0.401342	0.203456	0.056254	-0.016572	-0.091506	0.139386	-0.242051	0.015565
Sex	-0.089610	1.000000	0.344012	-0.001250	-0.260615	0.150927	-0.127756	0.061856	-0.338563	0.020233
height	0.401342	0.344012	1.000000	0.520624	-0.011571	0.650673	-0.135373	0.362422	-0.060732	0.199228
weight	0.203456	-0.001250	0.520624	1.000000	0.836039	0.934963	0.153270	0.069373	0.126525	0.055139
BMI	0.056254	-0.260615	-0.011571	0.836039	1.000000	0.659292	0.262006	-0.133640	0.176186	-0.061768
BMR	-0.016572	0.150927	0.650673	0.934963	0.659292	1.000000	0.106478	0.140502	0.160337	0.110988
VLF PEAK	-0.091506	-0.127756	-0.135373	0.153270	0.262006	0.106478	1.000000	-0.348240	-0.267635	0.259312
LF PEAK	0.139386	0.061856	0.362422	0.069373	-0.133640	0.140502	-0.348240	1.000000	0.037685	0.081376
HF PEAK	-0.242051	-0.338563	-0.060732	0.126525	0.176186	0.160337	-0.267635	0.037685	1.000000	0.008210
VLF power	0.015565	0.020233	0.199228	0.055139	-0.061768	0.110988	0.259312	0.081376	0.008210	1.000000
LF power	0.316564	-0.103421	0.178283	0.063877	-0.038270	0.012604	-0.053963	0.122391	-0.098208	0.324421
HF power	-0.074037	-0.076022	0.211267	0.315720	0.211312	0.356956	0.069407	-0.099237	-0.005147	0.253374
VLF	0.086445	-0.036960	0.201107	0.231834	0.147766	0.232657	0.264252	-0.041645	0.166882	0.100215
LF	-0.092843	0.219906	-0.092197	-0.297111	-0.316523	-0.244939	0.049722	-0.139409	-0.110647	0.024324
HF	0.044522	-0.022486	0.146813	-0.010014	-0.102352	0.029723	-0.314562	0.359914	0.137378	0.243842

Fig-6: Exploration of correlations of BMI and BMR

From the above it can be inferred that VLF positively correlates to both BMI and BMR; LF negatively correlates with both BMI and BMR and HF correlates with BMR but negatively correlates with BMI. The percentage influence of Fourier transform frequencies on BMI and BMR are shown in the below figures.

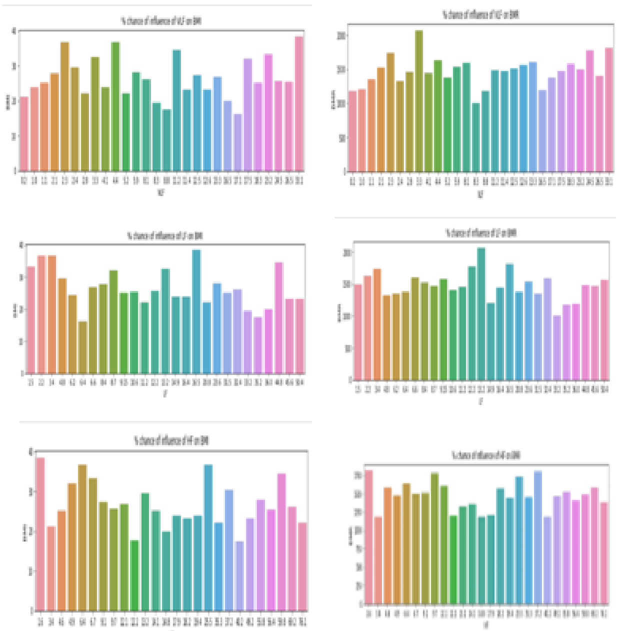


Fig-7: Calculation of BMI and BMR values

CONCLUSION

Advance analyses of HRV are very essential to measure the heart rate variability in different clinical health especially in autonomic nervous system. New tools are implemented to characterize the heart rate variability in autonomic balance and evaluate the HRV on the basis of spectral analysis relate to Fourier transform and autoregressive models, traditional time and frequency domain, Nonlinear methods with Poincare plots. Future research area is Poincare plots and amplitude domain analysis.

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