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Cardiac Autonomic Modulation in Psychologically Stressed Subjects as reflected by Heart Rate Variability

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ABSTRACT

Objective: To compare the frequency domain parameters of heart rate variability in stressed and non stressed subjects.

Study Design: It was a cross sectional study.

Place and Duration of Study: The study was conducted at Islamic International Medical College from June 2014 to December 2014.

Materials and Methods: Eighty subjects between 20-40 years of age were inducted in the study after fulfilling DASS questionnaire and were divided into stress and control group. Ten minutes ECG of the subject was taken using power lab and analyzed for heart rate variability following the guidelines of Task Force of European Society of Cardiology and the North American Society of Pacing Electrophysiology. Frequency domain indices of heart rate variability were compared among stressed and control group using fast fourier transform.

Results: Psychologically stressed subjects have significantly decreased high frequency in absolute unit and normalized unit ($p \leqslant 0.05$) and increased low frequency in normalized unit and absolute unit ($p \leqslant 0.05$ and .001 respectively) and low to high frequency ratio when compared with controls ($p \leqslant 0.001$). There was significant negative correlation among LF ms2 and HFms2($p < 0.001$, r = -.423), LF ms2 and HFnu ($p \leqslant 0.001$, r = -.386),HF ms2 and LFnu ($p \leqslant 0.05$, r = -.361) and HFms2 and LF/HF ($p \leqslant 0.05$, r = -.553),LF/HF and HFnu ($p \leqslant .001$ r = -.553), LFnu and HFnu ($p \leqslant 0.05$, r = -.237). There was also statistically significant positive correlation of LF/HF and LFnu ($p < .001$.r = .824).

Conclusion: Assessment of Heart rate variability is an important measure of autonomic nervous system and effect of psychological stress on autonomic nervous system can be indexed by determining heart rate variability.

Keywords: *Stress, Heart Rate Variability, Frequency Domain Methods, Low Frequency, High Frequency, Low Frequency to High Frequency Ratio.*

Introduction

"Stress is defined as a state of physiological / or psychological imbalance resulting from disparity between situational demand and individual's ability /or motivation to meet these demands".[1] Psychological stress is becoming a serious health problem worldwide and is identified as a big health hazard which reduces productivity and satisfaction.[2] Stress causes activation of sympathetic branch of autonomic nervous system which comprises of sympathetic and parasympathetic nervous system. Persistent sympathetic activation occurring in stress leads to disturbances in blood pressure, heart rate and heart rate variability.[3] High resting vagal tone is a sign of autonomic flexibility and shows that autonomic nervous system is capable of generating adequate response to external challenge by adjusting heart rate, respiration and arousal.[4] Decrease vagal tone as in stress predicts mismatch between environmental demands and cardiac reactivity making heart more prone to arrhythmias.[5] Heart rate variability (HRV) is the most important noninvasive quantitative tool to access cardiac autonomic function.[6] It is the most important predictor of mortality and morbidity in healthy and diseased population and measures the interaction of all the physiological factors that adjust the heart rate, reflecting continuous interaction between neuronal modulatory function and sinoatrial node function. Low heart rate variability is associated with different medical and psychological health problems.[3] HRV is analyzed by time and frequency domain methods.[7] For short term recording of HRV, frequency domain method is frequently used because of easy setting and are based on spectral analysis of HRV.[8] Three frequency components are usually identified in spectral band, the high frequency (HF) component of HRV, spans the 0.15-0.4 Hz and is due to heart rate variation induced by respiration and predominantly mediated by vagal outflow, lower-frequency (LF) component of HRV, defined as 0.05-0.15 Hz, is postulated to be mediated by sympathetic and

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parasympathetic system and very low frequency (VLF) <0.04 Hz which is thought to be mediated by sympathetic system but exact physiological interpretation of this is not clear. LF and HF are reported in normalized units to avoid skewness of distribution. Low to high frequency (LF/HF) ratio reflects balance between sympathetic and parasympathetic nervous sytem.[9] Decrease HRV is associated with stress.[3] Decrease vagal control on heart as shown by reduced HF component is known to be a leading cause for the development of cardiovascular disease and arrhythmias.[5]

The field of education is highly demanding and challenging and renders students as well as the educationists to deal with complex learning environment.[10] Mental stress interferes with an individual's ability to accomplish normal tasks, leading to various psychological problems and low self confidence. There is no study in Pakistan which has described the effect of stress on autonomic nervous system in terms of heart rate variability which is an important predictor of mortality and morbidity. Autonomic imbalance is a key mechanism for the development of cardiovascular diseases and diabetes mellitus. This study was conducted with an aim to access the affect of stress on the autonomic nervous system through frequency domain parameters of heart rate variability by comparing stressed and non stressed subjects.

Materials and Methods

This cross sectional study was conducted in physiology lab at Islamic International Medical College, Riphah University from June 2014 to December 2014 after approval from research ethical committee Islamic international medical college. A total of eighty healthy subjects from both genders, ranging in age of 20-40 years were included in study. All the subjects were healthy and free of any disease. They were randomly grouped as stressed and control after filling DASS questionnaire proforma (Depression anxiety stress scale).[11] Those who scored between 19-25 on DASS were labeled as having moderate stress and those who scored between 0-14 were labeled as control. Subjects having any chronic disease like asthma, diabetes or hypertension were excluded from the study. After taking written informed consent, the subjects were asked to report to physiology lab in morning between 8.00 to 9.00 am. Weight of the subjects was recorded, subjects were made to relax for 5 minutes and their blood pressure was measured using sphygmomanometer. Their recording of HRV was undertaken from ten minutes ECG in sitting position using ADInstrument power lab model Yam 4/25T.

Ten minutes ECG was taken to analyze HRV, according to the standard guidelines, published by Task Force of European Society of Cardiology and the North American Society of Pacing Electrophysiology.[12] HRV was recorded in quiet environment at ambient temperature. ECG of the subjects was recorded in a sitting position by connecting MLA 250 shielded lead wires to Bio AMP cable which was plugged in power lab. Positive electrode was connected with left wrist and negative to right wrist and ground to right leg. HRV recorded by analyzing ECG. Data in power lab was analyzed using software Lab chart 7 Pro. Frequency domain was accessed using Fast Fourier transform to determine low frequency, high frequency and low to high frequency ratio.

Statistical software SPSS 21(Statistical packages for social sciences) was used for the analysis of the data. Mean ± SD of the variables was calculated. The normality of each quantitative variable was checked separately through Shapiro Wilk test. To avoid the skewness of distribution all the HRV indices were log transformed and normality checked again. Independent sample t- test was used to check difference among two groups. A p value of $\leqslant$ 0.05 was taken significant. Association among different heart rate variability indices was checked by Pearson correlation.

Results

The study included eighty subjects divided into 2 groups, stressed and control. The differences in frequency domain parameters of heart rate variability among stressed and control groups were compared. These indices were LF, HF and LF/HF ratio. Mean age of the stressed subjects was 25 ± 6 and for control was 27 ± 8 years. Descriptive statistics of stressed and controlled groups are given in the table I.

Table II shows frequency domain indices' of heart rate variability. HF in absolute unit and in normalized units was markedly decreased in stressed group in comparison to controls ($p \leq .05$). LFnu and LF/HF ratio

Table I: Descriptive statistics of stressed and control groups

Characteristics	Stressed n=40 Mean ±SD	Controls n= 40 Mean ± SD
Age (years)	26 ±6	27 ± 8
Weight (kg)	66.43 ± 15.68	64.05 ± 11.46
BMI (kg/m^2)	26.45 ± 0.823	25.46± 0.46
Systolic blood pressure (mmHg)	118 ± 6	120 ± 5
Diastolic blood pressure (mmHg)	77 ± 7	78 ± 7
Heart rate (HR)/min	83.70 ± 9.30	82.41 ± 10.423

was significantly increased in stressed subjects, compared to control (P ≤ 0.001), Low frequency in absolute units was significantly higher in stressed group when compared to controls (p ≤ .05).

Table II: Comparison of Frequency domain parameters of heart rate variability in stressed and control group

Parameters	Stressed n=40 Mean ±SD	Controls n= 40 Mean± SD	t value	p value	Normality test
LFms^2 (Reference value 1175 ms^2)	678.07 ±475.37	505.99 ± 496.16	-2.174	0.03*	.002†
HF ms^2 (Reference value 975ms^2)	297.43± 186.76	415.83 ± 224.33	2.640	.010*	.006†
LF/HF Reference value (1.5-2)	2.96± 2.49	1.277±0.83	-5.726	0.000**	.000††
LF nu Reference value :54	61.52 ± 14.29	44.8488 ± 16.75	-3.766	0.000**	.09†
HF nu Reference value 29	31.99 ± 29.85	39.72 ± 12.02	3.602	0.001*	.000††

*p value < 0.05 is significant and **p value < 0.001 is highly significant

†p value < 0.05; p ††< 0.0001 shows that particular variable is non normal (Shapiro Wilik's test)

Table III shows partial Pearson correlation controlling for heart rate, carried out between various heart rate variability indices. There was significant negative correlation among LF ms2 and HFms2(p < 0.001,r = -.423), LF ms2 and HFnu (p ⩽ 0.001,r = -.386),HF ms2 and LFnu (p ⩽ 0.05, r = -.361) and HFms2 and LF/HF (p ⩽ 0.05, r = -.553),LF/HF and HFnu (p ⩽ .001, r = -.553), LFnu and HFnu (p ⩽ 0.05, r = -.237). There was also statistically significant positive correlation of LF/HF and LFnu (p < .001, r = .824).

Table III: Partial Pearson correlation controlling for HR between various HRV indices

	LFms^2	HFms^2	HF nu	LFnu
HFms^2	.000** (-.423)			
HF nu	0.000** (-.386)	0.409 (.094)		
LFnu	0.000** (.458)	0.001* (-.361)	0.034* (-.237)	
LF/HF	0.003*	0.050*	0.004*	0.000**

* Correlation significant at p value < 0.05

** Correlation highly significant at p value < .001

r values are shown in brackets

Discussion

The current study examined the different frequency domain parameters of HRV indices in stressed and control subjects. These indices were LF, HF, LF/ HF ratio. Compared to controls, stressed subjects exhibited decrease HF, increased LF/HF ratio and LF. Mean figure of HF in controls was higher, compared to stressed, which is showing that they have good vagal control as compared to stressed.

In a model of HRV analysis, Montano et al., (2009) showed that HRV was analyzed as HF component which is regarded to be the marker of cardiac vagal control, the LF component is a measure of sympathetic outflow to heart and LF/HF ratio which reflects the balance between sympathetic and parasympathetic system controlling the heart rate.[13]

The present study validates that stress is associated with vagal withdrawal as shown by reduced HF and was confirmed through this study. Literature shows that psychological stress is linked with decrease in vagal control reflected as decrease in HF component. Hernandez- Gaytan et al., (2012) confirmed low HF in doctors complaining of psychological stress at work.[14] A study conducted by Eller et al., (2011) reported decrease in HF component of HRV in teachers and engineers also which confirm the result of our study.[15] Hintsanen et al., (2007) conducted a study showed that HF was decreased in office workers with high effort reward imbalance (ERI) along with increase in LF/HF ratio.[16] Takada et al.,(2010) conducted a study in Japanese worker suffering from psychological stress and reported that HF is considerably lower in stressed group and on receiving treatment ,their HF was increased.[17] A study conducted by Minakuchi et al., (2013) reports similar findings.[18] Kemp et al., (2012) also showed decrease in HF in depressed subjects.[19]

Findings based on sympathetic assessment were LF and LF/HF ratio. LF/HF ratio was significantly raised among stressed group as compared to control showing sympathetic over activation in stressed group. LF is regarded as a marker of sympathetic control of heart and is increased in response to stress. LF expressed normalized units showed significant difference in stressed and controls. This finding was consistent with the study conducted by Collins et al., (2005) which reported high LF/HF ratio in high strain group in working hours.[20] A study conducted by Takada et al., (2009) showed higher LF/HF ratio and reduced HF in Japanese stressed workers which again proved our hypothesis. Takada showed that depressed workers who took medication for depression had improvement in HF and LF/HF ratio.[17] This finding further supports our study. Minakuch et al., (2013) conducted a study in which he showed that in response to mental stress LF/HF ratio increases significantly.[18] However a study by Hynynen et al., (2011) reported no significant association of any HRV parameter with stress.[21] Petrowski K et al., in his study also proved that in stress LF/HF ratio increased significantly.[22] Strong positive association between LF and LF/HF ratio controlling for heart rate was seen, a finding consistent with the finding of a study conducted by Ramakers (1998).[23] He also reported significant negative correlation between high frequency and low frequency and LF/HF ratio and high frequency, the findings also reported by present study. This show that heart rate variability parameters are affected by stress and decrease in high frequency; an index of sympathetic activity is associated with increase in low frequency which is an index of sympathetic activity.

Conclusion

Stressed subjects exhibit reduced HRV as compared to non stressed subjects. HRV provides important information for evaluation of cardiac autonomic control. Reduced HRV is a predictor of cardiovascular diseases. Additional research is needed for the evaluation of HRV in frequency and time domain indices.

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