Heart Rate Variability Analysis In Occupational Stress Using BIOPAC Systems

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Abstract: *Heart Rate Variability (HRV) refers to the variations in the time intervals between successive heartbeats, specifically the intervals between the R peaks in an ECG (electrocardiogram) reading. HRV is a useful measure of autonomic nervous system (ANS) activity, reflecting the balance between the sympathetic (fight or flight) and parasympathetic (rest and digest) branches. Higher HRV generally indicates a healthier cardiovascular system and better adaptability to stress and environmental changes. Conversely, lower HRV can be associated with stress, fatigue, or certain pathological conditions. Changes in HRV can be caused due to occupational stress also which is the aim of this paper. 10 ECG readings of staff and 10 ECG readings of students in academic institutions were recorded using BIOPAC MP150 system and the frequency domain methods was used to analyse the low frequency values. The Box and Whisker plots were used to present the difference of LF, HF and LF/HF Ratio between the staff and students. Further, paired t test was used to prove that heart rate variability is lower in staff ($p<0.05$) as compared to students.*

Keywords: *Heart rate variability, Occupational stress, Frequency domain, Autonomic nervous system, Signal processing.*

1. Introduction:

Heart Rate Variability (HRV) is a measure of the variation in time between the consecutive heartbeats and this interval always varies from person to person. These are recorded by using electro cardiology. The time interval between consecutive R waves that correspond to the contraction of the ventricles is called the RR interval (RRI). HRV is a time series of RRIs that fluctuate beat by beat in healthy humans because of time-to-time changes in activities of sympathetic and parasympathetic nerves innervating to the sinus node [1]. These fluctuations are controlled by the autonomic nervous system that consists of sympathetic and parasympathetic nervous system. So any fluctuations indicate the autonomic functioning imbalance if any, in case of stress or various diseases like diabetes, cancer or cardiovascular

dysfunction. Lower HRV are associated with body being under stress which has dominance of sympathetic system and decreased parasympathetic activities. Higher HRV indicates adaptation of Autonomic nervous system which signifies a healthier balance between the stress and relaxation. So, therefore by analysing HRV, we can gain better understanding of the body's physiological responses to various stress factors [2].

Occupational stress is one of the highest causes of stress in the present world like high job demand, tight deadlines, long working hours, lack of control, or interpersonal conflicts. Some of the most highly stressed jobs are healthcare professionals, police officers, academic personnel, corporate managers, legal professionals and so on. Under occupational stress sympathetic nervous system often becomes dominant that results in higher heart rate and reduced HRV and vice-versa the parasympathetic activity becomes reduced which further results in low HRV [3]. This low HRV leads to deterioration in mental health, physical health and the cognitive function.

HRV is usually studied extensively related to stress responses, mental health disorder, cardiovascular health, sports and physical performance, sleep quality, aging and many more. The recent advances in HRV has lead to the development of wearable technology for monitoring the HRV like smartwatches and fitness tracker which is non-invasive and have continuous monitoring [4].

Although there are developments in the medicinal field, cardiovascular diseases are the major cause of death and too in young age which is caused by stress [5]. HRV is a non-invasive method to track this stress and how it affects the health and overall well-being. In this study, we are analysing the heart rate variability of academic stress on academic personnels. Several analysis methods of HRV are known like time domain, frequency domain and non linear methods. In this study the LF power (Low Frequency) and HF power (High Frequency) is used along with the LF/HF power ratio which estimates the sympathovagal balance [6]. The low frequency (LF, 0.04-0.15 Hz) power of HRV shows both sympathetic and parasympathetic activity, high frequency (HF, >0.15 Hz) power of HRV shows the parasympathetic input and LF/HF ratio is considered as the sympathovagal balance.

2. Objectives:

I. Comparing heart rate variation among academic staff and students.

II. To determine the relation between the heart rate variability and occupational stress.

3. Materials and methods:

3.1 Subjects:

Ten academic personnel working in college as lab assistant or research scholar were included in the study, age groups of them vary from 27-45 years old, along with ten students with the age group of 22-27. All their ECG recordings were collected at four different stages and performed in the laboratory. The subjects were assured of full safety, privacy, confidentiality about their personal information.

3.2 Protocol:

The ECG readings were taken using BIOPAC MP150 system. The leads were attached to the subjects in three different places like the right arm, and both the legs beside the ankle. Readings were taken in a quiet and stable environment inside the laboratory. After the subjects were attached to the leads that were connected to the BIOPAC MP150 device which inturn was attached to a laptop to visualise and analyse the recording. The subjects were made to (i) lie down in the supine position and the heart rate was taken for 20 seconds followed by (ii) seated position for 25 seconds and then the subjects were asked to do (iii) deep inhale and exhale for 5 times on our instructions and finally the subjects were made to (iv) perform some physical activity like cardio exercises, fast walking, spot jogging to induce stress and then their ECG was recorded for 60 secs. The flow chart for the data acquisition is given in Figure 1. The BIOPAC MP150 system records at 500Hz frequency.

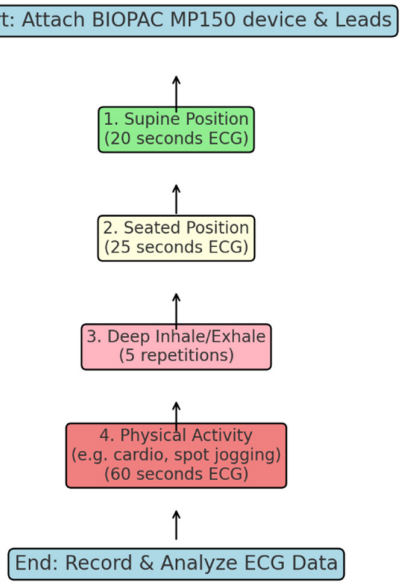

Figure 1: Flow Chart for Data Acquisition

3.3 HRV Time Series Data:

There were many difficulties faced during data acquisition like noise in the recordings with no optimal baseline called as motion artifacts and proper placement of electrodes. The data is recorded as shown in the Figure 2. The R peaks of the data was obtained using the Acknowledge software. The BIOPAC software itself was used for the frequency analysis.

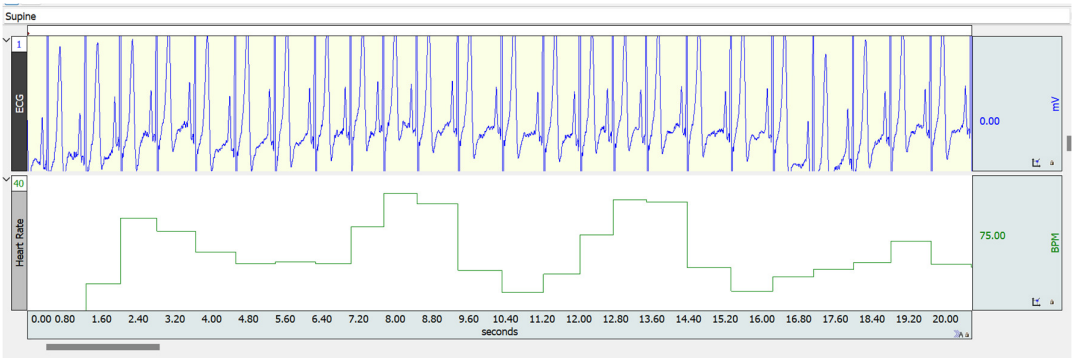

Figure 2: Time Series Data of one Subject

3.4 HRV Analysis Methods:

The time interval between the R peaks will give us the HRV. There are time and frequency domains for analysing these variations along with nonlinear methods. The time domain makes use of SDNN (standard deviation of NN interval), and root mean square of successive differences (RMSSD). In this study we use the Frequency domain method to analyse the HRV:

Frequency domain methods: [10]

Firstly, the HRV data must be analysed using "Heart Rate Variability" option in analyse tab. This is done using ARModel. It decomposes the HRV signal into its component frequencies. We get three frequency bands as a result:

1. Low Frequency (LF, 0.04-0.15 Hz) – it is said to reflect both sympathetic and parasympathetic, but some studies suggest that it is more related to sympathetic activity especially in stress states.
2. High Frequency (HF, >0.15 Hz) – it Is primarily associated with parasympathetic activity. Higher HF power means that it indicates relaxation or recovery.
3. LF/HF Ratio – this is used as a balance between the sympathetic and parasympathetic activity. A high ratio suggests that the stress is more and lower ratio means rest and recovery is more.

Therefore, a higher LF value is observed under stressful conditions that indicates that sympathetic system is more active and lower LF value is observed under relaxation or rest where the parasympathetic system is more active.

4. Results and Discussion:

In this paper, we research on the heart rate variability due to the sympathetic nervous system that is caused due to academic stress. We have focused on low frequency values as it is related to the sympathetic nervous system that is related to stress and its values are recorded and plotted to note the difference between the staff and students. For this the stress was introduced by doing exercise. So, there were variations in the HRV between the staff and students that was analysed using frequency model having parameters like HF, LF, LF/HF ratio.

4.1 Comparative analysis of the effect of occupational stress on HRV using box and whisker plots:

The comparison of frequency domain analysis with LF, HF, LF/HF ratio with box and whisker plot was done. It is used to describe the distribution values of the quartiles in HRV time series. The box plot of the LF Components, HF Components and LF/HF Ratio are shown from the Figure 3 to 5.

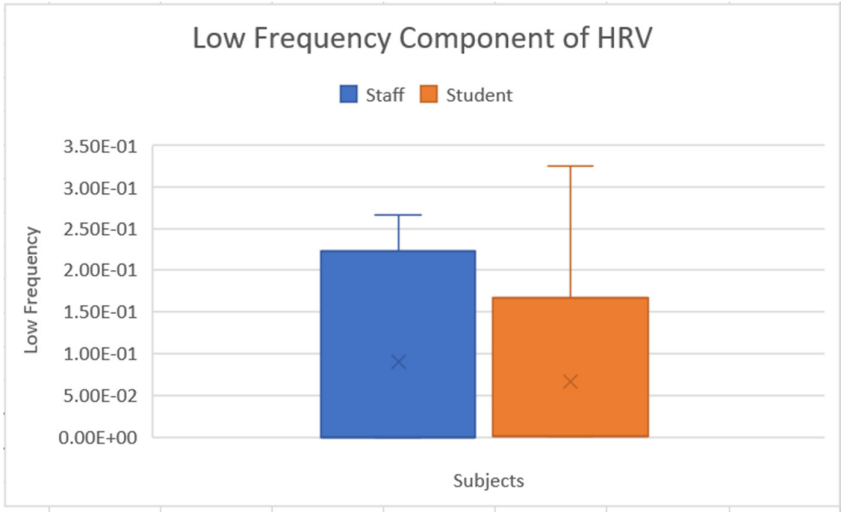

Figure 3: Occupational Stress on LF Components of HRV

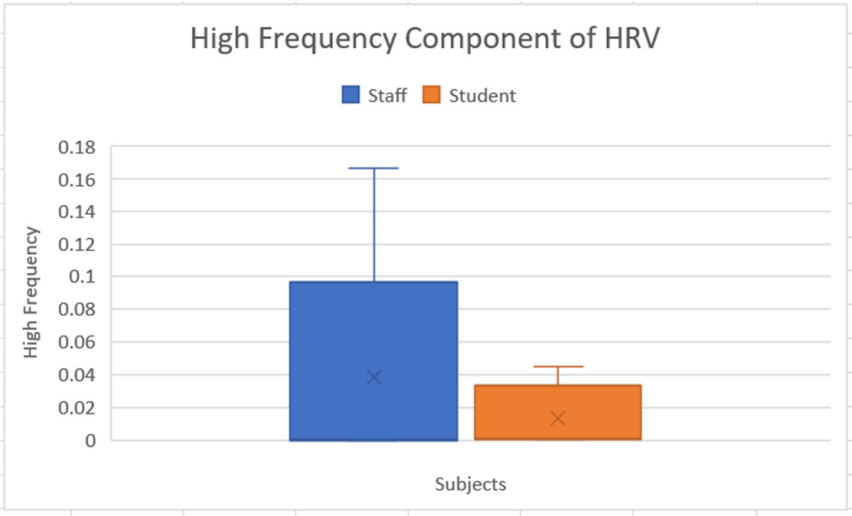

Figure 4: Occupational Stress on HF components of HRV

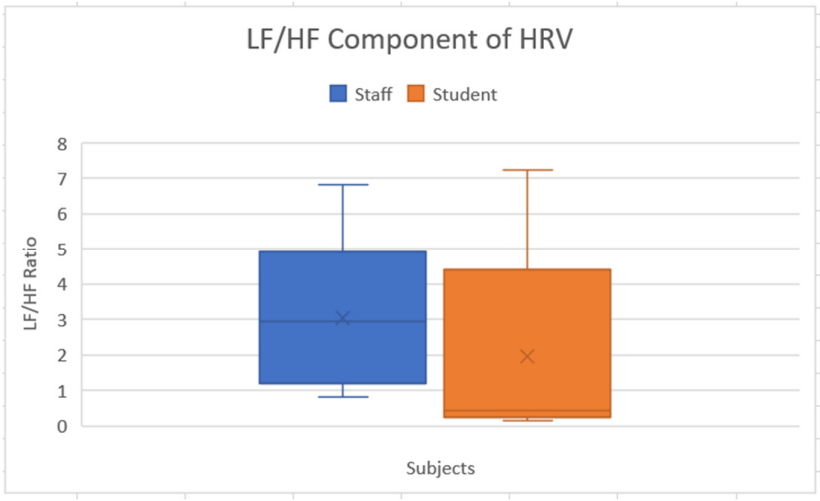

Figure 5: Occupational Stress on LF/HF Ratio of HRV

All these data's represents that the staff has a higher LF value compared to the students that shows the increased sympathetic and parasympathetic activities on the staff. Therefore, it is clearly indicated that HRV is changed from staff to student.

4.2 Comparative analysis of the occupational stress on HRV using paired t-test:

The main aim of this paper is to detect the autonomic regulations of heart of people under occupational stress especially staff under academic stress using HRV analysis. The mean values of the subjects are indicated in Table 1. It is noted from this table that the mean values of staff LF value is higher than that of students.

Groups	Staff	Student
Mean	0.1304	0.000143
SD	0.0954	0.000038
N	10	10

Table 1: Mean values of HRV analysis in staff and student

Further the statistical analysis of significance was done using paired t test. The statistical significance level was used as 5% means that p value less than 0.05. Therefore it was found that the p value for LR value is statistically different ($p<0.05$). The p value was found to be 0.0378 with degree of freedom 9.

Thus, it is concluded that HRV is affected by occupational stress in the academic staff. Therefore, a lower HRV, higher LF value is associated with the higher sympathetic activity in staff due to occupational stress.

4.3 Discussion

This work is mainly focused on finding the heart rate variability among the academic personnels. The analysis was done with 10 staff members who are exposed to occupational stress and 10 students from the same academic institution. Once the data was acquired, it was analysed using frequency domain method like LF components, HF components and LF/HF ratio. These are said to be the important parameters to study the stress that is caused by the sympathetic nervous system of the autonomic nervous system.[7] Here we are mainly using the Low Frequency (LF) values because it is said to be associated with the sympathetic nervous system that gets activated during stressful conditions. On the contradictory, High Frequency (HF) value are said to be associated with the parasympathetic nervous system that is active during relaxed state. It also indicates the occurrence of cardiovascular diseases due to this variability. A higher LF value indicates lower HRV that in turn implies that there is higher sympathetic activity and lower parasympathetic activity. This proves that there is occupational stress in the academic personnel.

5. Conclusion:

Occupational stress is a very important factor in cardiovascular health system. Majority of the working professionals have difficulty in workplace that causes physical and mental stress. This stress majorly affects the heart rate because the autonomic nervous system that acts as a coping mechanism to this stress affects the heart rhythm through the sino-atrial node (SAN). So in this paper, we aimed on studying the occupational stress on academic personnel who work in academic institutions against the students who are there in the same institution. Thereby for checking the variability in the heart rates of the staff and students, frequency domain analysis parameters were used such as LF, HF, LF/HF ratio. Mainly the LF values are used as they are said to be associated with the sympathetic nervous system that is active during stress conditions. The results were then statistically proven to be significant ($p<0.05$) and that the occupational stress did cause lower heart rate variability. Hence, it is concluded that occupational stress does lead to reduced heart rate variability and that will directly affect the cardiovascular health.

6. References:

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