Cardiovascular Autonomic Function Analysis by using HRV and its Relationship with BGL in Non-Diabetic Young Adults

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Abstract—High blood glucose level (BGL) is considered a major risk factor worldwide, as it is responsible for a number of cardiac and chronic diseases, including Diabetes. Blood glucose level affects Heart Rate Variability (HRV) which is an analysis tool, used to evaluate sympathetic and parasympathetic tone of the autonomic nervous system (ANS) by determining the variation of time intervals in consecutive R-R peaks in Electrocardiogram. It became popular because of its large number of medical applications and as it provides detailed quantitative information of various parameters regarding cardiac disorders and arrhythmic status of cardiac rhythm. Therefore, this study emphasized on identification of the relationship between HRV parameter and BGL in fasting and postprandial 2Hr interval. In this study, volunteers were divided in two groups as control group and study group. Control group and study group consists 20 and 10 students of age 22±4 years respectively. Their Electrocardiogram was recorded for fasting and postprandial cases. Time domain, frequency domain and non-linear HRV analysis of 5-min segment of ECG signal was performed with the help of “KUBIOS HRV 2.2” software. This study revealed significance in the relationship of BGL with the ANS activity ratio and cardiovascular variations especially in fasting case among non-diabetic young adults.

Keywords—Blood glucose level, Heart rate variability, Fasting and Postprandial plasma glucose level, Energy ratio of Autonomic nervous system, Sympathovagal balance.

I. INTRODUCTION

The bio-potential generated on the body surface by the electrical activity of the heart is termed as Electrocardiogram (ECG) signal. The ECG signal is a periodic signal composed of 6 segments P, Q, R, S, T, U waves. Every segment has its own importance with unique information about cardiac status of the subject. By using real time Pam-Tomkins algorithm, reliable recognition of QRS complex is possible [1]. HRV analysis is a technique which is used to calculate the alterations occur in heart rate by estimating R-R interval time variations. Indicators of an abnormality may be present at any random time interval [2], which may go unnoticed in a regular ECG, but it impacts the HRV and thus can be accounted for. HRV became a popular investigational and medical tool because its variation patterns may have indications of number of chronic diseases e.g. cardiovascular diseases, diabetes etc. [3]. HRV has extensive potential to access the significance of fluctuations in ANS with various cardiovascular variations [4]. The balance between ANS activities specifies the cardiac and physical status of body. HRV analysis is non-stationary and non-linear in nature. It is observed that non-linear HRV analysis methods allow better indications of warning as well as cause of fluctuations in HRV [5-7].

Past cardiac studies have witnessed the effect of dietary intake on sympathetic nervous system [8]. Post meal muscle nerve activity exhibited a stronger response with insulin secretion simultaneously. ANS activity depends upon BGL as well as various type of food intake significantly [9]. Some studies also exhibited cardiovascular variation and BGL relationship in healthy young adults [10, 11]. Power spectral analysis of HRV is performed, using R-R interval distribution from long duration ECG. Another parameter, Energy ratio of low to high frequency band indicating the ratio of parasympathetic to sympathetic tone, is significant in HRV analysis [12]. Some studies suggested that food intake and energy expenditure linked were with one another [13, 14]. So, BGL may have a relationship with energy ratio of sympathetic over parasympathetic activity as HRV parameter. So, this study is proposed to explore the impact of Blood Glucose Level on Energy ratio of ANS activities in case of Fasting and Postprandial 2Hr interval on non-diabetic young adults. This study depicts the estimation of BGL range in study group on the basis of relationship curve of control group, which is an extension of prior work.

II. MATERIALS AND METHODS

A. Methodology

The HRV analysis starts with the calculations of R-R interval time series. A 5 min ECG segment was recorded with the help of hardware developed for the analysis. Flowchart of the proposed work is shown in Fig.1.
B. Hardware Description

1) Circuit diagram

2) Circuit description: To acquire the ECG signal from the subject, AD620AN instrumentation amplifier was used. After AD620AN, signal was filtered via High pass filter at 0.05 Hz to remove baseline shifts and Notch filter to eliminate the power frequency of 50 Hz respectively. For the interfacing ARDUINO UNO board was used at a sampling frequency of 500Hz.

3) Study population: 20 healthy young adult volunteers age 22±4 years, both male and female were selected for the control group and 10 young adults of the same age selected for the study group. A written consent was taken from the participants along with some basic information as age, gender, family history of diabetes and any drug intake were also taken as record. In control group at the time of ECG, their BGL was known but in study group their BGL was unknown in fasting and postprandial 2Hr interval cases. For the fasting case, they all were instructed for an overnight 8 hours of fasting, their ECG was recorded followed by BGL measurement and then 75gm glucose was provided in form of meal. After 2hr of meal again their postprandial BGL and ECG were recorded. For both of the cases 10 minutes long ECG recorded from which 5-minute noise free segment chosen for further analysis.

4) Signal processing: ECG signal was processed in MATLAB, by using Pan-Tompkins algorithm (required tuning was been done to process the recorded data) to determine R-R interval. Further, non-significant data was discarded. Significant R-R interval data file further processed in KUBIOS HRV 2.2 software for time domain, frequency domain and non-linear approach. KUBIOS HRV 2.2 software is an open source program and available for students and researchers. Energy ratio was calculated using distribution curve drawn by using edited R-R interval data. As the levels of distribution curve indicate the instantaneous voltage, with respect to mean R-R, side lobes were found and by using area concept energy contained by side lobes was calculated and found a relationship curve between energy ratio and BGL.

III. RESULTS

The waveform from the hardware was recorded at the sampling frequency of 500Hz. Recorded waveform was plotted and further process was done by applying modified Pan-Tompkins algorithm in MATLAB. The hardware recorded ECG waveform is shown in Fig.3:
All the parameters in time, frequency and non-linear domain have their own significance. LF and HF are the spectral components, not fixed as they may vary with changes occur in heart period during autonomic modulations. HF component correlates with primarily parasympathetic activity and LF correlates with both sympathetic as well as parasympathetic activities. Non-linear analysis parameters SD1 and SD2 are decimators of the Poincare plot. SD1 influenced with HF and SD2 correlates LF which indicates sympathetic and parasympathetic activity of ANS. SD1/SD2 ratio indicates the randomness in behavior. The effect of glucose intake on HRV has shown in Table I. R-R interval found higher in case of fasting as compare to postprandial 2Hr interval case.

According to Table I, RR interval decreases in postprandial stage, compared to fasting, in both study and control group. Thus HR increases after glucose ingestion. This is due to increase in the sympathetic tone as represented by LF power and decreasing of parasympathetic tone as represented by HF power and SD1 from fasting to PP2H stage.

From fasting to PP2H when R-R interval is decreases, sympathetic activity increases and relative parasympathetic activity decreases. Relative parasympathetic activity represents HF component in HRV and improved SD1 as well. After HRV analysis, energy ratio has been calculated from the R-R interval which indicates ratio of sympathetic over parasympathetic activities of ANS as HRV parameter. For fasting condition, Energy ratio of sympathovagal activity varies significantly with blood glucose level within the normal range (70 ≤BGL≤ 90). However, beyond the normal range (BGL>90) relationship loses its significance as shown in Fig. 5.

### Table I: Parameter Characteristics of Control and Study Group

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control Group</th>
<th>Study Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fasting</td>
<td>PP2H</td>
</tr>
<tr>
<td>Mean RR (ms)</td>
<td>804.48±89.78</td>
<td>709.155±86.245</td>
</tr>
<tr>
<td>Mean HR (Beats/min)</td>
<td>75.81±8.054</td>
<td>86.172±11.860</td>
</tr>
<tr>
<td>LF (ms$^2$)</td>
<td>546.3</td>
<td>709.2</td>
</tr>
<tr>
<td>HF (ms$^2$)</td>
<td>1169.75</td>
<td>509.5</td>
</tr>
<tr>
<td>LF/HF</td>
<td>0.467</td>
<td>1.391</td>
</tr>
<tr>
<td>SD1</td>
<td>34.73±19.404</td>
<td>23.18±11.393</td>
</tr>
<tr>
<td>SD2</td>
<td>65.51±23.755</td>
<td>51.32±18.074</td>
</tr>
</tbody>
</table>

Mean RR, Mean HR, SD1, SD2 Data represented as mean ± Standard deviation
In Postprandial BGL, no specific trend was found which may signify a relationship. The curve shown in Fig. 6 is showing randomness in behavior in case of postprandial 2Hr interval.

In case of postprandial, sympathetic activity increases and sympathovagal balance also tends to increase. SD2/SD1 ratio correlated to sympathovagal balance, which indicates the randomness in behavior. Because of the randomness in behavior, relationship curve became insignificant which is insufficient to comment about as shown in Fig. 8.

On further analysis of BGL with Non-linear HRV parameters, there is a significant relationship found which indicates a relationship between BGL and SD2/SD1 in case of fasting. In certain limit when BGL≤90, curve follows a specific increasing trend and depicts the conclusion about a relationship which exist between BGL and HRV parameter in young adults as shown in Fig. 7.

According to fasting responses as shown in Fig. 5 and Fig. 7, Energy ratio and SD ratio curve showing identical relationship with BGL. On Further analysis of Energy ratio with Non-linear HRV parameter ratio, there is a significant relationship found which indicates increasing relationship between both of
the parameters. This curve shows the inter-relationship between both of the parameters, as the Energy ratio increases SD ratio also increases with that which indicates the change in sympathovagal balance of ANS system.

Moreover, Fig. 6 and Fig. 8 indicate the energy ratio curve and SD ratio curve have identical relationship with BGL in case of postprandial also. Fig.10 shows the inter-relationship between both of the parameter, as the Energy ratio increases SD ratio also increases same as the case of fasting which indicates proportionality between these two parameters in both cases fasting as well as postprandial.

IV. DISCUSSION

It was observed that, with glucose intake sympathetic activities increases and parasympathetic activities decreases, which was responsible for increment in HR. Therefore, overall mean HR is higher in post-prandial case as compared to fasting case. From the Table I, it appears that R-R interval decreases in the case of postprandial. As R-R interval decreases, relative parasympathetic activity also decreases. SD1 and HF-HRV both correlated with the parasympathetic activity. Therefore, SD1 and HF decreases with decrement in R-R interval in case of postprandial.

In case of Fasting, it is observable that there is a relationship exists between energy ratio and BGL. When BGL is in certain limit (for fasting case 72mg/dL to 90mg/dL) Energy ratio increases significantly with BGL, in an exponential pattern. Although, when BGL goes higher than a certain limit, Energy ratio became almost constant and loses the trend. Moreover, the curve between BGL and SD ratio also draw the conclusion upon the upper analysis, which verifies the results of BGL v/s Energy ratio behavior. In non-linear analysis, Poincare parameter ratio SD2/SD1 also has a significant relationship with the BGL which indicates the randomness in the curve behavior. SD2/SD1 also indicates the ratio of ANS activities, as SD1 correlates with the primarily parasympathetic activity and SD2 correlates with the sympathetic and parasympathetic activities. In fasting curve there is a significant increment in SD ratio with respect to BGL, which indicates linearity in behavior when BGL is in certain limit (BGL≤90) and above certain limit with increment in BGL the curve became almost constant. This indicates the same behavior as BGL v/s Energy ratio relationship curve. Further, in case of postprandial the same curve between BGL and SD ratio shows randomness in itself. There’s no significant behavior found which indicates with the glucose intake as sympathovagal balance increases, randomness also increases and curve loses its significance. However, Energy ratio and SD ratio both indicates ratio of ANS activities and have same relationship with BGL which depicts the significant relationship between cardiovascular autonomic variation and BGL in case of fasting.

V. CONCLUSION

These results drive towards a conclusion that in young adults, a relationship exists between HRV parameters as Energy ratio and BGL in the case of Fasting. Whereas According to L. J. Rothberg et al, there is no specific and significant relationship between BGL and any parameter of HRV in non-diabetic subjects [15], but in contrast to it, above study and analysis indicate quadratic relationship trend between energy ratio and BGL in HRV analysis. However, as Fasting to PP2H, sympathetic activity increases with the increment in LF/HF ratio which correlates with SD2/SD1. From the above analysis SD2/SD1 has proportionality with the Energy ratio. As Energy ratio and SD ratio both indicates the sympathovagal balance, both have significantly same relationship with BGL. When sympathovagal balance increases because of increment in sympathetic activity, randomness also increases and effectiveness of relationship curve (BGL v/s Energy ratio and BGL v/s SD2/SD1) loses its significance in the case of PP2H in non-diabetic young adults.

REFERENCES


