Chapter 9.

Conclusion, limitations of the study, further scope

9.1 Conclusion from statistical findings

The coefficient of correlation for HRV indices and LVEF for different cohorts are as listed in table 9.1.

Table-9.1 regression analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Heart rate</th>
<th>SDNN</th>
<th>HF Power</th>
<th>LF power</th>
<th>Sympatho-vagal Balance</th>
<th>Orthostatic stress index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>-0.063</td>
<td>0.035</td>
<td>0.0323</td>
<td>0.409</td>
<td>-0.309</td>
<td>0.515</td>
</tr>
<tr>
<td>Diabetic</td>
<td>-0.161</td>
<td>0.106</td>
<td>0.0544</td>
<td>-0.055</td>
<td>0.197</td>
<td>0.020</td>
</tr>
<tr>
<td>Diabetic with IHD &amp;INHD</td>
<td>-0.091</td>
<td>0.174</td>
<td>01205</td>
<td>0.0513</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Diabetic &amp; hypertensive</td>
<td>-0.327</td>
<td>0.032</td>
<td>0.0736</td>
<td>0.305</td>
<td>0.097</td>
<td></td>
</tr>
<tr>
<td>Hypertensive</td>
<td>-0.023</td>
<td>0.160</td>
<td>-0.093</td>
<td>0.028</td>
<td>-0.343</td>
<td>0.151</td>
</tr>
</tbody>
</table>

In normal cohort,

1) The medium level linearity relationship exists between sympathetic power and LVEF.

2) The medium level linearity relationship exists between sympatho vagal ratio and LVEF.

3) The medium level linearity relationship exists between orthostatic stress index and LVEF.

4) Orthostatic stress index contributes by 26.52% to LVEF outcome.

In diabetic and hypertensive cohort,

1) The medium level linearity relationship exists between heart rate and LVEF.

Conclusion: No significant results of disease cohort.
After regrouping the data, regression analysis results are as listed in table 9.2.

Table-9.2 regression analysis after regrouping of cohorts.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>0.064</td>
<td>0.3673</td>
<td>0.053</td>
</tr>
<tr>
<td>SDNN</td>
<td>0.0477</td>
<td>0.2174</td>
<td>0.138</td>
</tr>
<tr>
<td>HF Power</td>
<td>0.174</td>
<td>0.459</td>
<td>0.121</td>
</tr>
<tr>
<td>LF Power</td>
<td>0.329</td>
<td>0.051</td>
<td>0.021</td>
</tr>
<tr>
<td>Sympatho vagal balance</td>
<td>0.107</td>
<td>0.2489</td>
<td>0.00003</td>
</tr>
<tr>
<td>Orthostatic stress index</td>
<td>0.2654</td>
<td>0.020</td>
<td>0.023</td>
</tr>
</tbody>
</table>

**Conclusion:** In normal cohort,

1) Sympathetic power contributes by 32.9% to LVEF outcome.

2) Orthostatic stress index contributes by 26.54% to LVEF outcome.

(In case of other disease groups, though the regression index is higher the threshold value of the 25%, the error is high. The linear model is not valid.)
Multiple regression analysis results are as listed in table 9.3.

Table-9.3 Multiple regression analysis.

<table>
<thead>
<tr>
<th>Multiple regression- heart rate, LF power and SDNN versus LVEF</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal cohort</td>
<td>0.6272</td>
<td><strong>0.3934</strong></td>
</tr>
<tr>
<td>Diabetic with and without MI</td>
<td>0.4125</td>
<td>0.6423</td>
</tr>
<tr>
<td>Hypertensive with and without diabetes</td>
<td>0.1741</td>
<td>0.0303</td>
</tr>
</tbody>
</table>

**Conclusion:**

In normal cohort, heart rate, sympatho vagal balance and SDNN contribute the LVEF outcome by 39.34%.

(In diabetic cohort, with and without MI, higher level of linearity exists between heart rate, sympatho vagal balance and SDNN with the LVEF. Though the R² value is significantly high, since the error is more than 0.05, the model is considered unfit.)

Exponential regression analysis results are as shown in the table 9.4.

Table-9.4 Exponential regression analysis

<table>
<thead>
<tr>
<th></th>
<th>Normal cohort R-square</th>
<th>Diabetic with and without MI. R-square</th>
<th>Hypertensive with and without diabetes. R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>0.081</td>
<td>0.203</td>
<td>0.2</td>
</tr>
<tr>
<td>SDNN</td>
<td>0.04</td>
<td><strong>0.332</strong></td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>Normal cohort</td>
<td>Diabetic with and without MI</td>
<td>Hypertensive with and without diabetes</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
<td>------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>HF Power</td>
<td>0.203</td>
<td>0.119</td>
<td>0.117</td>
</tr>
<tr>
<td>LF Power</td>
<td>0.308</td>
<td>0.152</td>
<td>0.167</td>
</tr>
<tr>
<td>Sympatho vagal balance</td>
<td>0.11</td>
<td>0.12</td>
<td>0.058</td>
</tr>
<tr>
<td>Othostatic stress index</td>
<td>0.118</td>
<td>0.063</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Exponential variation in Heart rate, SDNN and HF power jointly contribute to 42.36% of the LVEF outcome in normal cohort. (In diabetic cohort with and without myocardial ischemia/infarction, though $R^2$ is high, error is more than 0.05.)

**Conclusion:** In normal cohort, LF power contribute 30.8% of LVEF outcome in exponential regression and SDNN heart rate and LF power together contribute to the LVEF outcome by 39.34%.

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal cohort</td>
<td>0.6508</td>
<td>0.4236</td>
</tr>
<tr>
<td>Diabetic with and without MI</td>
<td>0.6528</td>
<td>0.4262</td>
</tr>
<tr>
<td>Hypertensive with and without diabetes</td>
<td>0.2043</td>
<td>0.041753</td>
</tr>
</tbody>
</table>

**Conclusion:** In case of normal cohort, heart rate, SDNN and HF power together contribute the LVEF outcome by 42.36%.
In case of, diabetic with and without myocardial ischemia/ infarction, heart rate, SDNN and HF power contribute the LVEF outcome by 42.62%.

**Final conclusion:**

**Sympathetic Power in normal cohort contributes to 32.9% of the LVEF outcome in linear regression model.**

Linear variation in Heart rate, SDNN and LF power jointly contribute to 39.34% of the LVEF outcome in normal cohort.

Exponential variation in Heart rate, SDNN and LF power jointly contribute to 42.36% of the LVEF outcome in normal cohort and 42.62% in diabetic cohort with and without myocardial ischemia/ infarction.

**9.2 Conclusion from the mathematical model**

The shift in the neuro-humoral balance is computed in case of diabetic cohort with and without myocardial ischemia/infarction. A novel algorithm is used to ensure that computations of the sympathetic and parasympathetic power are not derived from LF and HF spectral bands.

Mathematical model is proposed to demonstrate reduced neural conduction in diabetic condition. The same is demonstrated through practical results.

Effect of increase in parasympathetic power on LVEF in diabetic pathology is demonstrated through the data.

The finding –‘Contractility is function of left ventricular geometry in diabetic condition’ is demonstrated by geometrical model of left ventricle and the experimental results.

The Left ventricular wall thickness changes i.e. $\frac{\Delta R}{R}$ contribute by 25.35% to the contractility outcome in diabetic condition.
**Final overall Conclusion**

The HRV indices can diagnose the shift in the neuro-humoral balance, the increase in parasympathetic power and decrease in total power in diabetic condition.

Shift in the neuro-humoral balance initiates microvascular pathology and macrovascular indicates inadequacy of the blood supply. The reduced blood supply indicates the compromised performance of the target organ.

Increase in parasympathetic power reduces the diastolic filling rate and indicates necrosis.

Reduced total power at SA node indicates the compromised performance of heart and insufficient pumping.

Increase in heart rate indicates the insufficient blood supply and overload on heart.

In case of hypertensive subjects, increase in sympathetic power is an early indicator of compromised heart performance.

Increase in SDNN is one of the significant markers in case of hypertensive subjects. SDNN in maintained at lower values by pharmacological intervention so that heart is not strained. Hence, SDNN cannot be considered as reliable marker.

The Left ventricular posterior wall thickness changes i.e. $\Delta R \over R$ contribute by 25.35% to the contractility outcome in diabetic condition.

The HRV indices are useful preclinical tools that can assess diabetic autonomous neuropathy and cardiac health in case of diabetic subjects with and without hypertension and myocardial ischemia/infarction. They are effective in controlling the morbidity and mortality rate in case of diabetic subjects with and without hypertension and myocardial ischemia/infarction.

**9.3 Limitations of the study**

If the same subject’s data had been recorded for more than one time, the findings would have been more specific. The type of medication and sugar levels are not recorded and analysis lacks analytical aspect on effects of glycemic control and pharmacological effects.
9.4 Further scope

Similar study can be performed with taking care of the limitations mentioned and for more number of subjects and other diseases. Effects of diabetes on brain and other target organs and their correlation with HRV indices can be studied. This can be further developed into noninvasive analysis for early detection of other diabetic complications on several target organs.