An Analysis Of Heart Rate Variabilities Using Open Source Software

A Master’s Thesis Presentation
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Carolina Health Informatics Program
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RTI International Internship Logistics

Timeline
Beginning- June 10, 2019
Research Brief- Mid July, 2019
Poster Presentation- August 12, 2019

Deliverables
• Poster Presentation
• Research Brief
• Weekly meeting
• Lunch Talk
• RTI-wide Mandatory Workshops on Professional Development
An Analysis Of Heart Rate Variability (HRV) Using An Open Source Software
Growth And Adoption Of Wearable Device

• As of June, 2018, 5% of the technologies have been formally validated.

• Biofeedback received helps in improving outcomes using health and fitness technology.

• Most common biofeedback present in all technology is the heart rate.
Rise Of Popularity Of HRV
01 Generate heart rate data using a validated wearable device
02 Analyze this dataset using a validated heart rate variability (HRV) software
03 Interpret the result produced
04 Recommendation -s for future studies

Objective
Phases of HRV Project

EXPLORING HEART RATE VARIABILITY (HRV)
Sympathetic Nervous System and Parasympathetic Nervous System

Brake = Parasympathetic

Gas = Sympathetic
Understanding Heart Rate or R-R or interbeat (IBI) variation

Variation among successive heartbeats is defined as Heart Rate Variability (HRV)
Importance of HRV

• Indicator of Autonomic Nervous System (ANS) Activity
• Pre-Diagnostic Tool for the following:
  • Cardiac abnormalities
  • Treating Asthma
  • Functional Gastrointestinal Disorders
  • Psychological Disorders
• Biofeedback from HRV is used for Performance Enhancement
Phases of HRV project
Data Acquisition

Conventional way of measuring HR data consisted of multiple electrodes of the electrocardiogram (ECG) that placed on patience chest.

With rise of new technology data is gathered using wearable devices that contains photoplethysmogram (PPG) Sensors. This allows patient to be mobile and data is collected continuously.
Empatica E4 Wristband

- Unhindered Monitoring
- Precise Data Collection
- Tags Physiological Events
- Easy Access (CSV files)
- Readily available at RTI
Phases of HRV project

- Exploring Heart Rate Variability (HRV)
- Data Generation
- Literature Reviews of Open Source Software
Literature Search Process

Word cloud shows keywords used to search literature reviews in various search engines. Use of the keyword ‘HRV’ generated maximum number of articles.
Literature Review Process

Literature reviews using search engines PubMed, Google Scholar, UNC Library Catalog

Inclusion Criteria:
Paper in scientific journal
• Free HRV-Softwares
• Full English text only
Published 2010 and beyond

Output Data Format
Users
Prog. Language
Operating System
# HRV Softwares

<table>
<thead>
<tr>
<th>Software</th>
<th>Operating System</th>
<th>Output Data Format</th>
<th>Programming Language</th>
<th>User</th>
<th>Total No. Of Lit. Reviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kubios</td>
<td>Linus Windows Mac OS X</td>
<td>MAT files ASCII files .pdf file</td>
<td>MATLAB</td>
<td>Any user</td>
<td>5838</td>
</tr>
<tr>
<td>RHRV</td>
<td>UNIX Windws MacOS</td>
<td>ASCII files WFDB</td>
<td>R</td>
<td>Physicians with concrete clinical studies in mind</td>
<td>418</td>
</tr>
<tr>
<td>gHRV</td>
<td>Linux windows MacOS</td>
<td>.txt files</td>
<td>Python</td>
<td>Researchers, clinical professional with no programming skills</td>
<td>193</td>
</tr>
</tbody>
</table>
Phases of HRV project

- Exploring Heart Rate Variability (HRV)
- Data Generation
- Literature Reviews of Open Source Software
- Results from Analysis Using Kubios
Results Generated Using Kubios

Time Domain

Frequency Domain

Non-Linear Domain
Statistics of R-R interval measuring standard deviation of R-R

Parameters- SDNN (std. dev of N-N), RMSSD(root mean sq. successive dif.) are measured in ms

Indicator of Parasympathetic Activity

Lower than standard value is not considered favorable

Requires 24 hours aka “gold standard” of continuous data collection
Frequency Domain

• Most important domain for short-term analysis of HRV
• Power/Energy calculated from R-R interval within specific frequency bands (PSD-power spectrum density)
  - Parameters - High Frequency (HF) 0.15-0.40Hz is influenced by breathing from 9-24 bpm. Low Frequency (LF) is influenced by 3-9 bpm. HF, LF are measure in normalized units (nu) for comparison.
  - Low LF/HF ratio Parasympathetic Activity
  - High LF/HF ratio Sympathetic Activity
• Data may be collected for both long-term 24 hours or short-term of 5 mins.

**Frequency-Domain Results** (FFT spectrum)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>VLF</th>
<th>LF</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>(Hz)</td>
<td>0.00-0.04</td>
<td>0.04-0.15</td>
<td>0.15-0.40</td>
</tr>
<tr>
<td>Peak frequency</td>
<td>(Hz)</td>
<td>0.037</td>
<td>0.077</td>
<td>0.173</td>
</tr>
<tr>
<td>Power</td>
<td>(ms²)</td>
<td>39342</td>
<td>99176</td>
<td>85888</td>
</tr>
<tr>
<td>Power</td>
<td>(log)</td>
<td>10.580</td>
<td>11.505</td>
<td>11.362</td>
</tr>
<tr>
<td>Power</td>
<td>(%)</td>
<td>17.49</td>
<td>44.10</td>
<td>38.23</td>
</tr>
<tr>
<td>Power</td>
<td>(nu)</td>
<td>53.45</td>
<td>46.34</td>
<td></td>
</tr>
<tr>
<td>Total Power</td>
<td>(ms²)</td>
<td>224908</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Power</td>
<td>(log)</td>
<td>12.323</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LF/HF ratio</td>
<td></td>
<td>1.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDR</td>
<td>(Hz)</td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

![RR Spectrum](image)
Phases Of HRV Project

- Exploring Heart Rate Variability
- Data Generation
- Lit. Review of Open Source Softwares
- Results From Kubios Data Analysis
- Conclusion and Limitations
Limitations

- Very small sample size (n=2)
- <24 hours of data collection
- Single software for data acquisition
- Lack of short-term reference values
Recommendations For Future Study

**Recommendation**
- Increase sample size a min of 30 participants
- Collect data for **24 hours** straight
- Compare and contrast data across various wearable devices
- Analyze data using other softwares
Conclusion

Through this preliminary study I learned the following:

✓ Importance of HRV
✓ Kubios is implemented and most used open source software for analyzing HRV
✓ Metrics in HRV and its importance
✓ Data generated and analyzed via Kubios
✓ Result shows dominance of SNS
• https://www.emarketer.com/content/older-americans-drive-growth-of-wearables

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Thank You!

Questions
Additional Slides
Methods

• HR data collected from three female were ran through Kubios softwares.
• Metrics including LF, HF, SD1 and SD2 were measured.
• Excel to run t-test and correlation were calculated.
Figure show three graphs of HRV result using Kubios from three females
Result

Comparison of LF/HF ratio to SD1/SD2 ratio

- Correlation of LF/HF to SD1/SD2 = 0.22
- Welch Two Sample t-test P-value= 0.71, t = - 0.40
- Fisher Test P-value= 1
• **Findings:** The results show LF/HF ratio and SD1/SD2 ratio are not significantly correlated; however, p-value shows no significant difference between these ratios.

• **Conclusion:** Our results shows both ratios shows similar results i.e. SNS activity.

• **Limitations:** Very small sample size, biological factors have not been taken into consideration.