BIOMEDICAL ENGINEERING
RECENT DEVELOPMENTS

Otto C. Wilson
Binh Q. Tran
Jafar Vossoughi
Editors

MEDICAL and ENGINEERING
PUBLISHERS, Inc, PO Box 74, Sunshine, MD 20833 USA
HEART RATE VARIABILITY SIGNAL PARAMETERS QUANTIFY SKIN COOLING EFFECT OF ENERGY PATCHES DURING REST AND EXERCISE IN YOUNG HEALTHY INDIVIDUALS

Homer Nazeran PhD, CPEng (Biomed.)
Electrical and Computer Engineering, The University of Texas at El Paso, El Paso Texas 79968

ABSTRACT

Heart rate variability (HRV) signal analysis provides a non-invasive and sensitive marker of autonomic nervous system (ANS) activity. Spectral parameters of HRV signal are used to quantify the balance between sympathetic and parasympathetic (sympathovagal) influences under various physiologic conditions. ECG signals were acquired, filtered and further processed to derive the HRV signal. The low frequency (LF), high frequency (HF), and their ratio LF/HF were calculated to assess the parasympathetic dominance or the skin cooling effect of a set of non-transdermal Energy Patches on young healthy individuals during Rest and immediately after mild Exercise. HRV data acquired from 20 young healthy volunteers (10 males and 10 females, 19-25 years of age), in a double-blind placebo-controlled study, were used to evaluate the skin cooling effect of these wearable devices on the ANS during rest and immediately after mild exercise while wearing active (A) and placebo (P) patches. Data from condition (A) and condition (P) were compared using statistical analysis (one-sample inference). The LF/HF decreased significantly both during rest and immediately after mild exercise in condition (A) compared to condition (P) with \( p < 0.01 \) with a statistical power of at least 85%. This study shows that the normalized LF/HF derived from spectral analysis of HRV signals could be used to quantify the parasympathetic dominance or the localized skin cooling effect of non-transdermal energy patches during rest and immediately after mild exercise in young healthy individuals.

Keywords: Heart rate variability signal analysis, Localized skin cooling effects, Non-transdermal energy patches, Autonomic nervous activity, Wearable devices

INTRODUCTION

The autonomic nervous system (ANS) is structurally and functionally subdivided into two antagonistic divisions: sympathetic and parasympathetic. The sympathetic division responds to fight-or-flight situations, increasing heart rate (HR) and blood pressure (BP), among others, under stressful conditions. The parasympathetic division is responsible for relaxation and energy conservation (i.e., decreasing HR and BP). The heart as well as other organs, receives opposing influences from these two arms of the ANS. This dual innervation underpins a fine and continuous regulatory system and simply means an increase in the activity of one division results in a smooth and reciprocal decrease in the activity of the other. The dynamic interplay between the two divisions increases or decreases the HR depending on the predominance of one over the other.

Heart Rate Variability (HRV) signal refers to beat-to-beat variation of heart rate and represents the cyclical changes in HR. As HR is modulated by both parasympathetic and sympathetic inputs, HRV can be utilized as an indirect and non-invasive marker of autonomic regulation and control under different physiological conditions [1]. High HRV reflects an ANS that is adaptable and dynamically responsive to change whereas reduced HRV is indicative of an abnormal or restricted ability of the ANS in maintaining homeostasis [2, 3]. Pharmacological studies and spectral analysis of the HRV signal have revealed two clear peaks in its power spectrum: a high frequency (HF) and a low frequency (LF) component. The HF peak which is typically centered around 0.25 Hz (0.15 – 0.4 Hz) arises...
standard deviation of $\pm 49\%$ of the mean. With these values a statistical power of at least 85% at a significance level $\alpha$ or $p < 0.01$ was achieved. This level of significance reflects a very significant effect. As a value of $\alpha$ or $p = 0.05$ is considered statistically significant, the results in these subjects reflect a statistically significant effect with a power of 90%.

### TABLE 1. Typical normalized power spectral parameters derived from 5-minute HRV signals acquired from ECGs of a healthy male volunteer under 6 different conditions [16]

<table>
<thead>
<tr>
<th>Condition</th>
<th>LF n.u.</th>
<th>HF n.u.</th>
<th>LF/ HF n.u.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest with no Patches</td>
<td>97.70</td>
<td>2.28</td>
<td>42.75</td>
</tr>
<tr>
<td>Rest with Placebo Patches</td>
<td>97.62</td>
<td>2.31</td>
<td>42.23</td>
</tr>
<tr>
<td>Rest with Energy Patches</td>
<td>96.95</td>
<td>3.01</td>
<td>32.29</td>
</tr>
<tr>
<td>Exercise with no Patches</td>
<td>97.42</td>
<td>2.56</td>
<td>38.03</td>
</tr>
<tr>
<td>Exercise with Placebo Patches</td>
<td>97.97</td>
<td>2.03</td>
<td>48.36</td>
</tr>
<tr>
<td>Exercise with Energy Patches</td>
<td>94.72</td>
<td>5.23</td>
<td>18.10</td>
</tr>
</tbody>
</table>

### TABLE 2. Typical normalized power spectral parameters derived from 5-minute HRV signals acquired from ECGs of a healthy female volunteer under 6 different conditions [16].

<table>
<thead>
<tr>
<th>Condition</th>
<th>LF n.u.</th>
<th>HF n.u.</th>
<th>LF/HF n.u.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest with no Patches</td>
<td>99.15</td>
<td>0.83</td>
<td>119.25</td>
</tr>
<tr>
<td>Rest with Placebo Patches</td>
<td>97.33</td>
<td>2.58</td>
<td>37.61</td>
</tr>
<tr>
<td>Rest with Energy Patches</td>
<td>94.20</td>
<td>5.37</td>
<td>17.54</td>
</tr>
<tr>
<td>Exercise with no Patches</td>
<td>90.58</td>
<td>9.41</td>
<td>9.62</td>
</tr>
<tr>
<td>Exercise with Placebo Patches</td>
<td>96.40</td>
<td>3.54</td>
<td>27.23</td>
</tr>
<tr>
<td>Exercise with Energy Patches</td>
<td>95.32</td>
<td>4.62</td>
<td>20.63</td>
</tr>
</tbody>
</table>

### DISCUSSION AND CONCLUSION

From the spectral parameters of typical datasets and the statistical analysis results for 20 subjects, the following observations could be made:

1. There was a noticeable difference between spectral parameters when the subjects wore the Placebo patches compared with when the subjects wore no patches. Such differences in spectral parameters are indicative of the Placebo Effect. This is an indication of how the subjects responded to the feeling of wearing a patch.

2. There was a decrease in the normalized LF when the subjects wore the Energy patches compared with the condition when the subjects wore the Placebo patches during both Rest and immediately after 5 minutes of mild Exercise.

3. There was an increase in the normalized HF when the subjects wore the Energy patches compared with the condition when the subjects wore the Placebo patches during both Rest and immediately after 5 minutes of mild Exercise.

4. There was a statistically significant decrease in the normalized LF/HF when the subjects wore the Energy patches compared with the condition when the subjects wore the Placebo patches during both Rest and immediately after 5 minutes of mild Exercise.

5. On average, female subjects were more responsive to Energy patches compared to male subjects during Rest. While, on average male subjects were more responsive to Energy patches compared to females after mild Exercise. These differences were not statistically significant.

6. On average, there was a higher reduction in normalized LF/HF after 5 minutes of mild Exercise compared to the reduction in normalized LF/HF during Rest.

Based on these observations it could be concluded that both during Rest and immediately after 5 minutes of mild Exercise, the Energy patches elicited an enhanced parasympathetic response (due to a localized skin cooling effect) which could be quantified by a reduction in normalized LF/HF. A further reduction of normalized LF/HF
immediately after 5 minutes of mild Exercise (as a consequence of more body heat production) compared to Rest may be indicative of the higher activation level of the Energy patches in response to enhanced physical activity resulting in an increased localized skin cooling effect during Exercise. The statistical results revealed that the Energy patches showed a very significant effect ($p < 0.01$) compared to Placebo patches in reducing the normalized LF/HF during Rest and even further after 5 minutes of mild Exercise with a statistical power of at least 85% in this sub-population.

REFERENCES

For the full copy of this paper please contact LifeWave Customer Service at:

(866) 420-6288