Job stress bio-monitoring methods: heart rate variability (HRV) and the autonomic response

Jesper Kristiansen

Objectives

After the presentation you will:

• Know what heart rate variability is and how it is measured.
• Have a basic understanding of the physiology behind HRV.
• Understand how HRV is related to activity in the parasympathetic and sympathetic branches of the autonomic nervous system.
• Know of different ways to apply HRV measurements in research.
Job stress and cardiovascular disease

Two primary physiological stress reaction systems

The hypothalamus-pituitary-adrenal (HPA) axis

The autonomic nervous system (ANS)

A definition of stress:
Stress is the body’s multi-system response to any challenge that overwhelms, or is judged likely to overwhelm, selective homeostatic response mechanisms (TA Day, Prog Neuro-Psychopharm Biol Psych 2005; 29: 1195 – 1200).

HPA and ANS play key roles in mediating this multisystem response!

The autonomic nervous system

Sympathetic and parasympathetic nervous system (SNS and PNS)
Old view on SNS/PNS

One-dimensional reciprocal response system:

SNS LOW → PNS → SNS HIGH → PNS LOW

"brake", resting, energy storing → "speed-up", activating, energy releasing

Autonomic space (Berntson)

Example: Co-activation of PNS and SNS at low stimulus intensity

Heart rate variability (HRV)

- Changes in blood pressure, heart rate etc.: Result of the combined changes in PNS and SNS
- HRV: Individual contributions from PNS and SNS can be obtained.
1. HRV basics

HRV = Heart rate variability

The cardiac conduction system (from: Levick (2003). An Introduction to Cardiovascular Physiology, 4th ed.)
Regulation of HR
Intrinsic heart rate of the denervated heart is almost constant and around 100 bpm.


Regulation of HR
The decaying membrane potential of pacemaker cells in the sino-atrial node is the basis for regulation of HR.

\( i_K \): potassium current; \( i_f \): "funny" current (mainly Na\(^+\)); \( i_{Ca,T} \): Transient Ca\(^{2+}\) channel current; \( i_{Ca,L} \): Long-lasting Ca\(^{2+}\) channel current. *: Pacemaker potential
Central control of the heart rate

The cardiovascular center is located in the Medulla oblangata.

Input to cardiovascular center:
- From higher brain centers (cerebral cortex, limbic systems, and hypothalamus)
- From sensory receptors (baroreceptors, chemoreceptors, proprioceptors)

Output to the heart:
- Increased rate of spontaneous depolarizations in SA (AV) node
- Increased contractility of atria and ventricles
- Decreased rate of spontaneous depolarizations in SA (AV) node

ANS regulation of HR

Sympathetic noradrenaline (NA) binds to β1-adrenergic receptors.
Parasympathetic acetylcholine (ACh) binds to M2-muscarinic receptors.

2nd messenger (slow)

ANS regulation of HR

Parasympathetic acetylcholine (ACh) opens $K_{Ach}$ channel – hyperpolarizes the membrane potential.

No 2nd messenger (fast)


ANS regulation of HR

HR responses to PVN stimulation in rats

Summary – so far

- Beat-to-beat variability in HR ("instantaneous heart rate") is governed by modulations in SNS and PNS activity.
- Due to the dependency of a 2nd messenger system the modulations of SNS activity has lower maximum frequency than PNS modulations.
- Hence, an analysis of the frequency content of HRV will reveal the contributions from PNS (high frequency modulations of instantaneous HR) and SNS (slow frequency modulations).

2. Analysis of HRV
R-R interval variability measures

Tachogram: R-R intervals

Segment or "epoch", length depends on the study from few min – >24 hr)

You should not compare HRV calculated for different epoch lengths!
R-R interval variability measures

- HRV: The variability of all N-N intervals (e.g., SDNN)
- Other ECG-derived measures:
  - Measures of the power N-N interval variability at different frequencies (e.g., HF power, LF power, RMSSD)
  - Measures describing other aspects of the N-N interval variability (chaotic, randomness etc.) (e.g., ApE)
  - Other measures derived from the ECG (e.g., heart rate turbulence).

<table>
<thead>
<tr>
<th>Variable (units)</th>
<th>Definition</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDNN (ms)</td>
<td>Standard deviation of all N-N intervals</td>
<td>Total variability (HRV)</td>
</tr>
<tr>
<td>SDANN (ms)</td>
<td>The standard deviation of all 5 min epoch averages of N-N intervals.</td>
<td>Low frequent modulation of HR</td>
</tr>
<tr>
<td>SDNN index (ms)</td>
<td>The average of the standard deviations of N-N intervals in all 5 min epochs.</td>
<td>Low frequent modulation of HR</td>
</tr>
<tr>
<td>RMSSD (ms)</td>
<td>The square root of the mean of squared differences of successive N-N intervals</td>
<td>High frequent modulation of HR</td>
</tr>
<tr>
<td>pNN50 (%)</td>
<td>Percentage of all successive N-N intervals with length larger than 50 ms.</td>
<td>High frequent modulation of HR</td>
</tr>
</tbody>
</table>
Frequency domain measures extracts frequency information by Fast Fourier Transformation analysis (FFT) or autoregressive modelling.

HRV power spectrum

The figure illustrates the frequency spectrum of heart rate variability (HRV) with different frequency bands:

- **VLF** (Very Low Frequency)
- **LF** (Low Frequency)
- **HF** (High Frequency)

These bands are typically analyzed to understand the underlying physiological processes and their impact on cardiovascular health.
## Frequency domain measures

<table>
<thead>
<tr>
<th>Variable (units)</th>
<th>Definition</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total power (ms$^2$)</td>
<td>Total area under the power density function (0.003 – 0.04 Hz)</td>
<td>Total variability (HRV), equal to (SDNN)$^2$</td>
</tr>
<tr>
<td>HFP or HF (ms$^2$)</td>
<td>Area under the power density function in the frequency range 0.15 – 0.4 Hz</td>
<td>Parasympathetic modulation of HR (respiratory sinus arrhythmia)</td>
</tr>
<tr>
<td>LFP or LF (ms$^2$)</td>
<td>Area under the power density function in the frequency range 0.04 – 0.15 Hz</td>
<td>Sympathetic modulation of HR with contribution from parasympathetic activity</td>
</tr>
<tr>
<td>VLF (ms$^2$)</td>
<td>Area under the power density function in the frequency range 0.003 – 0.04 Hz</td>
<td>Modulation of HR by slow blood pressure regulating systems</td>
</tr>
<tr>
<td>HF n.u. (normalized units)</td>
<td>HF/(TP-VLF)</td>
<td>Same as HF</td>
</tr>
<tr>
<td>LF n.u. (normalized units)</td>
<td>LF/(TP-VLF)</td>
<td>Same as LF</td>
</tr>
<tr>
<td>LF/HF</td>
<td>LF/HF</td>
<td>&quot;Autonomic balance&quot;, i.e. the balance between sympathetic and parasympathetic activity</td>
</tr>
</tbody>
</table>

### FFT needs:

- Minimum 10-20 oscillations to determine power, *i.e.*, 60-120 s for HF power, 250-500 s for LF power.
- Stationarity, *i.e.*, no change in mean RR-period, variance, etc.
- Equidistant sampling, *i.e.*, the RR-intervals are sampled at times $t_1$,...,$t_i$, $t_{i+1}$,...,$t_n$ etc. separated by the same $\Delta t$. 
Time domain vs. frequency domain

- Many measures strongly correlated (e.g., SDNN – total power, RMSSD – HF, RMSSD – pNN50 etc.)
- Difficult to interpret frequency components of HR for long segments (VLF and ULF dominates the power spectrum)
- The estimation of the power spectrum require stationarity of the signal
- Power spectrum analysis: 5 min segments are preferred (down to 2 min possible for HF only!).


3. Origins of HRV
Respiratory sinus arrhythmia (RSA)

- Earliest known type of HRV (Hales, 1733)
- Fast heart rate (tachycardia) during inspiration
- Slow heart rate (bradycardia) during expiration.

The frequency of the HF component is entrained to the respiration frequency


Respiratory sinus arrhythmia

- The exact mechanism causing RSA is not known, but central are:
  - variation of venous return the heart (preload) caused by the "respiratory pump", in combination with
  - reflexes that control HR (Bainbridge reflex and baroreceptor reflexes)
- RSA is therefore an index of the gain of the baroreceptor cardiac vagal reflex responses.

10s fluctuations in HR

- Discovered much later than RSA (Penaz et al., 1968)

10s fluctuations in HR

- Oscillations caused by resonance between HR and different blood pressure regulating systems, e.g.:
  - baroreceptor reflex
  - renin-angiotensin system
  - local endothelial NO system
- Afferent nerve signal from these blood pressure regulating systems are integrated in the CNS.
- The HR is result of the balance between efferent nerve traffic from sympathetic and parasympathetic nerves (sympatho-vagal balance).

Frequency domain measures

- HF spectral power is modulated by parasympathetic activity only
- LF spectral power is modulated by both sympathetic and parasympathetic activity
- LF/HF reflects sympatho-vagal balance.
Summary: HRV measures

- HRV is derived from analysis of (normal) R-R intervals, e.g., recorded from an ECG.
- HR oscillates with many frequencies (complex pattern in tachogram) that reflects the influence of different blood pressure systems.
- Rapid fluctuations (HF, 0.4 – 0.15 Hz) is caused by vagal activity.
- Slow fluctuations (LF, 0.15 – 0.04 Hz) is caused by a mixture of sympathetic and vagal activity.
- Slower fluctuations is caused by even slower regulatory systems (e.g., temperature fluctuations, day-night periodicity).

4. Factors that influence HRV
Body posture and HRV

Supine rest

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Power [mV^2]</th>
<th>Power [n.u.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLF</td>
<td>0.06</td>
<td>188</td>
</tr>
<tr>
<td>LF</td>
<td>0.11</td>
<td>479</td>
</tr>
<tr>
<td>HF</td>
<td>0.24</td>
<td>450</td>
</tr>
</tbody>
</table>

After head up tilt

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Power [mV^2]</th>
<th>Power [n.u.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLF</td>
<td>0.06</td>
<td>182</td>
</tr>
<tr>
<td>LF</td>
<td>0.09</td>
<td>413</td>
</tr>
<tr>
<td>HF</td>
<td>0.24</td>
<td>107</td>
</tr>
</tbody>
</table>

LF/HF = 1.06

LF/HF = 3.66

Physical exercise and HRV


Left panels:
Filled symbols: Sedentary subjects.
Open symbols: Athletes.

Physical exercise and HRV

Regulation of HR during exercise depends on:

- Size of the active muscle mass
- Type of exercise (single bout, repeated, static vs. dynamic)
- Intensity of the exercise
- Body position during exercise.

Regulation of HR during exercise depends on:

HRV and gender

Low frequency components of HRV are lower, and high frequency components higher, in women compared men.

Crude and adjusted mean values (± SD) of LF, HF and total power in men and women.

<table>
<thead>
<tr>
<th></th>
<th>Crude (men n=149)</th>
<th>Crude (women n=137)</th>
<th>p value</th>
<th>Adjusted for age and heart rate (men n=149)</th>
<th>Adjusted for age and heart rate (women n=137)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF power, mm²</td>
<td>3.04±0.64</td>
<td>4.72±1.07</td>
<td>&lt;0.001</td>
<td>5.09±0.92</td>
<td>4.77±0.92</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LF as N%</td>
<td>67.9±14.7</td>
<td>58.2±18.6</td>
<td>&lt;0.0001</td>
<td>67.9±14.7</td>
<td>58.1±16.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HF power, mm²</td>
<td>4.52±1.03</td>
<td>4.33±1.08</td>
<td>0.38</td>
<td>4.17±0.90</td>
<td>4.39±0.90</td>
<td>0.05</td>
</tr>
<tr>
<td>HF as N%</td>
<td>32.1±16.7</td>
<td>41.7±19.6</td>
<td>&lt;0.0001</td>
<td>32.1±16.6</td>
<td>41.8±16.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total power, mm²</td>
<td>6.17±0.83</td>
<td>6.05±0.89</td>
<td>0.1</td>
<td>6.16±0.75</td>
<td>6.07±0.76</td>
<td>0.21</td>
</tr>
</tbody>
</table>

HRV and HR, age

LF and HF decrease with HR and age

Regression coefficients (b) and partial R^2 values of factors related to LF and HF power in forward stepwise regression model

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 449)</th>
<th>Women (n = 137)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>partial R^2</td>
</tr>
<tr>
<td>LF power, m/s^2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>-0.025</td>
<td>0.06</td>
</tr>
<tr>
<td>BMI</td>
<td>-0.05</td>
<td>0.053</td>
</tr>
<tr>
<td>Age</td>
<td>-0.026</td>
<td>0.026</td>
</tr>
<tr>
<td>HF power, m/s^2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>-0.03</td>
<td>0.15</td>
</tr>
<tr>
<td>Age</td>
<td>-0.03</td>
<td>0.038</td>
</tr>
<tr>
<td>HDL</td>
<td>0.01</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| LF power = Arou at Low Frequency (0.04 to <0.15 Hz); HF power = area at high frequency (0.15 to <0.40); the values for the area were mutually log-transformed and expressed as ln m/s^2.


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HRV has a diurnal rhythm

Low frequency components of HRV are lower, and high frequency components higher, at night compared to day

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
<th>Day/Night difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± Standard deviation</td>
<td>Mean ± Standard deviation</td>
<td>Without adjustment for basal HR</td>
</tr>
<tr>
<td>Heart rate (beats·min⁻¹)</td>
<td>83.9 ± 10.2</td>
<td>85.6 ± 10.5</td>
<td>*** -</td>
</tr>
<tr>
<td>Total domain HRV (pNN50)</td>
<td>7.4 ± 3.1</td>
<td>15.0 ± 15.6</td>
<td>*** -</td>
</tr>
<tr>
<td>HRV (SD1)</td>
<td>40.3 ± 38.1</td>
<td>60.1 ± 53.8</td>
<td>*** -</td>
</tr>
<tr>
<td>HRV (SD2)</td>
<td>91.2 ± 114.7</td>
<td>100.6 ± 104.6</td>
<td>*** -</td>
</tr>
<tr>
<td>High frequency HRV (m/s^2)</td>
<td>0.2 ± 0.14</td>
<td>0.6 ± 0.21</td>
<td>*** -</td>
</tr>
<tr>
<td>Low frequency HRV (m/s^2)</td>
<td>0.1 ± 0.08</td>
<td>0.2 ± 0.08</td>
<td>*** -</td>
</tr>
</tbody>
</table>

For abbreviations see Methods. NN50: non-normalized units. For statistical analysis: p(pNN50, Arou50, total power, low frequency power, high frequency power, low frequency/total power) were non-parametricized to obtain normality, as described in the Methods. Significance of day/night difference: *P<0.05, **P<0.01, ***P<0.001, ns=no significance.

5. Examples on research applications of HRV:

a) Experimental studies of mental load

HRV and mental challenge
Increase in LF n.u. and a decrease in HF n.u. during color-word test (CWT) compared to rest condition.

HRV and mental challenge

Decrease in HF n.u. and increase in LF/HF during computer-based drawing task under time pressure (M-works) and logical reasoning task compared to rest condition.

Quiet. Office background noise (65 dBA).

Conditions: (Kristiansen et al., Int Arch Occup Environ Health, in press)

5. Examples on research applications of HRV:

b) Cardiovascular risk in healthy populations
Absence of sinus arrhythmia (SA) associated with increased cardiovascular risk

Social status and CVD risk

Social status \[\rightarrow\] CVD risk

Social status \[\rightarrow\] Lifestyle \[\rightarrow\] CVD risk

Social status \[\rightarrow\] Psychosocial factors \[\rightarrow\] CVD risk

Social status \[\rightarrow\] Lifestyle \[\rightarrow\] Psychosocial factors \[\rightarrow\] Autonomic regulation \[\rightarrow\] CVD risk

Mediators
The Whitehall II study

**Does Autonomic Function Link Social Position to Coronary Risk?**

Harry Hemingway, FRCP; Harris Shipley, MD; Eric Brunner, PhD; Amin Britton, PhD; Mark Meek, Mark Marmot, FRCP


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**TABLE 2. Behavioral and Psychosocial Factors and Age-Adjusted Means of Heart Rate and HRV**

<table>
<thead>
<tr>
<th>Behavioral factors</th>
<th>Participants, n</th>
<th>Heart Rate, bpm</th>
<th>SDNN, ms</th>
<th>LF Power, ms²</th>
<th>HF Power, ms²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current smoker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1001</td>
<td>68.7 (68.2-69.2)</td>
<td>34.5 (33.8-35.1)</td>
<td>352 (310-346)</td>
<td>116 (112-121)</td>
</tr>
<tr>
<td>Yes</td>
<td>193</td>
<td>70.8 (70.1-72.2)</td>
<td>31.6 (29.7-33.5)</td>
<td>271 (237-306)</td>
<td>96 (82-112)</td>
</tr>
<tr>
<td><em>P</em></td>
<td></td>
<td>0.02</td>
<td>0.007</td>
<td>0.014</td>
<td>0.004</td>
</tr>
<tr>
<td>Vigorous exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some</td>
<td>714</td>
<td>66.4 (65.8-67.2)</td>
<td>36.1 (34.8-37.2)</td>
<td>365 (338-389)</td>
<td>131 (121-142)</td>
</tr>
<tr>
<td>Little / none</td>
<td>1529</td>
<td>70.3 (69.7-70.9)</td>
<td>33.2 (32.4-34.0)</td>
<td>306 (292-326)</td>
<td>106 (102-114)</td>
</tr>
<tr>
<td><em>P</em></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>High alcohol consumption</td>
<td>1758</td>
<td>68.4 (67.8-68.9)</td>
<td>34.7 (34.0-35.4)</td>
<td>356 (324-355)</td>
<td>121 (116-128)</td>
</tr>
<tr>
<td>Yes</td>
<td>391</td>
<td>71.2 (70.1-72.2)</td>
<td>32.0 (30.8-33.4)</td>
<td>278 (255-306)</td>
<td>95 (84-104)</td>
</tr>
<tr>
<td><em>P</em></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values in parentheses are 95% CIs.

*Job control was estimated only in those 1461 participants still working.*
The Whitehall II study

### TABLE 2. Behavioral and Psychosocial Factors and Age-Adjusted Means of Heart Rate and HRV (continued from previous slide)

<table>
<thead>
<tr>
<th>Behavioral factors</th>
<th>Participants, n</th>
<th>Mean Heart Rate, bpm</th>
<th>SDNN, ms</th>
<th>LF Power, ms²</th>
<th>HF Power, ms²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor diet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1610</td>
<td>68.3 (67.7–68.9)</td>
<td>34.6 (33.9–35.4)</td>
<td>330 (321–351)</td>
<td>120 (115–125)</td>
</tr>
<tr>
<td>Yes</td>
<td>488</td>
<td>70.8 (69.9–71.5)</td>
<td>31.0 (30.3–31.6)</td>
<td>300 (276–326)</td>
<td>105 (100–110)</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.001</td>
<td>0.05</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Psychosocial factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1424</td>
<td>68.4 (68.1–68.7)</td>
<td>34.5 (33.8–35.3)</td>
<td>335 (319–351)</td>
<td>110 (112–125)</td>
</tr>
<tr>
<td>Yes</td>
<td>711</td>
<td>68.2 (68.0–70.1)</td>
<td>33.6 (32.0–35.1)</td>
<td>313 (292–335)</td>
<td>112 (105–122)</td>
</tr>
<tr>
<td>P</td>
<td>0.3</td>
<td>0.18</td>
<td>0.12</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Low social networks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1482</td>
<td>68.5 (67.9–69.0)</td>
<td>34.5 (33.7–35.2)</td>
<td>333 (317–348)</td>
<td>120 (115–127)</td>
</tr>
<tr>
<td>Yes</td>
<td>584</td>
<td>68.5 (68.4–70.4)</td>
<td>33.4 (32.3–34.6)</td>
<td>307 (284–331)</td>
<td>107 (99–117)</td>
</tr>
<tr>
<td>P</td>
<td>0.07</td>
<td>0.15</td>
<td>0.09</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Low job control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1190</td>
<td>68.1 (67.5–68.7)</td>
<td>36.3 (35.5–37.2)</td>
<td>379 (360–399)</td>
<td>133 (125–141)</td>
</tr>
<tr>
<td>Yes</td>
<td>271</td>
<td>70.4 (69.6–72.1)</td>
<td>33.7 (32.0–35.4)</td>
<td>319 (286–355)</td>
<td>114 (101–136)</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.001</td>
<td>0.004</td>
<td>0.006</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

Values in parentheses are 95% CIs.

*Job control was estimated only in those 1461 participants still working.

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The Whitehall II study

Notes on the HRV measurements:

- HRV recordings performed on 2344 men at the screening clinic.
- 5-min recordings sampled at 500 Hz.
- Ectopic beats detected and removed by a mathematical algorithm (automatic).
Effect of ectopic beats, pauses, artifacts etc.

Examples of common non-sinus rhythms

It is necessary to remove such non-sinus beats (pauses) when estimating the spectral power components of HRV!

5. Examples on research applications of HRV:

c) Cardiovascular risk in healthy working populations

Work stress and CVD risk

*Effects of Work Stress on Ambulatory Blood Pressure, Heart Rate, and Heart Rate Variability*

Taqir G.N., Vijgve, Lutke, J.P., van Dossen, Eco J.C. de Groot


Work stress → Autonomic regulation → Blood pressure → CVD risk
Work stress and HRV

Low RMSSD in white-collar workers with high effort-reward imbalance compared to workers with low imbalance – difference continues on non-workday.

Heart rate (BPM)

Low imbalance (○; n=86) High imbalance (●; n=23)

Non-workday

Work leisure sleep work leisure sleep leisure sleep leisure sleep

Work leisure sleep work leisure sleep leisure sleep leisure sleep

Non-workday

Work stress and HRV

High imbalance (●; n=23)

Low imbalance (○; n=86)
Work stress and HRV

Notes on the HRV measurements:
- Ambulatory ECG recordings performed on 109 men.
- RMSSD used to assess vagal tone at work, leisure time, and sleep.
- Diary information used to code for body posture and activity.

Work stress and autonomic regulation

Job Strain and Autonomic Indices of Cardiovascular Disease Risk

Sean M. Collins, PhD, ScD, MSc; Robert A. Karasick, MD; and Kevin Coetzee, PhD

Work stress and autonomic regulation

HF higher in subjects with low job strain

HRV and work-related stress

Sympathetic indices (incl. LF/HF) increase with strain at work but not with overall strain.
HRV and work-related stress

Notes on the HRV measurements:

- Ambulatory 48-hours ECG recordings performed on 36 men.
- Ectopic beats and artifacts removed by manual screening.
- Spectral components of HRV calculated for 5-min ECG segments (for whole 48-hr recording)
- Diary information used to control for body posture and exertion.

5. Examples on research applications of HRV:

d) Intervention to reduce stress at work
Stress reduction (intervention)

Stress Management at the Worksite: Reversal of Symptoms Profile and Cardiovascular Dysregulation
Daniela Lucini, Silvano Riva, Paolo Perzinelli, Massimo Pagani


Stress reduction (intervention)

White-collar workers in company during downsizing (n=91) and controls (n=79).
Average values for LF and HF at rest and standing induced changes.
Stress reduction (intervention)

White-collar workers in company during downsizing (n=51). Effect of a stress-management program (SMP, n=26) versus sham program (SP=25).

| TABLE 1. Descriptive Statistics of R-R Interval Variability in SMP and SP Groups |
|---------------------|---------------------|---------------------|---------------------|---------------------|
|                     | LF                  | HF                  |
|                     | Mean ± SD            | Mean ± SD            | Mean ± SD            | Mean ± SD            |
| SMP                 | 1004±39             | 2400±360            | 658±218             | 586±355             |
| After               | 967±56              | 2179±228            | 492±185             | 448±78              |
| SP                  | 977±43              | 2077±385            | 615±237             | 587±196             |
| Before              | 999±51              | 2209±290            | 593±417             | 520±47              |

Notes on the HRV measurements:

- 5-10 min ECG recordings performed on 170 men at the worksite (workers) or at home or at the clinic (controls).
- Standing induced changes in HRV used to assess autonomic reactivity.
- Spectral components of HRV calculated for 5-min ECG segments.
Summary - I

- HRV can be applied in both laboratory and field studies.
- Ambulatory measurements and measurements performed in work places or at home are feasible.
- HRV can be measured in the awake state or in the sleep.
- HRV have been applied successfully in studies of psychosocial factors, including workplace stress.
- HRV (or certain HRV metrics) are generally accepted as associated with CVD risk.

Summary - II

- Time domain metrics can be used for long-term recordings, frequency domain metrics for short term recordings.
- Time domain metrics more robust to the influence of ectopic beats, pauses, artifacts, etc., but are more difficult to interpret physiologically.
- Frequency domain HRV metrics can be interpreted physiologically, but ECG needs careful screening before analysis.
Summary - III

- HRV (and derived metrics) are extremely sensitive to
  - Body posture
  - Mental activity
- HRV (and derived metrics) also depends on
  - Age, BMI, sex, physical fitness, and other lifestyle factors
- It is advisable to address the effects of these variables in the study design

Thank you for your attention!