HEART RATE VARIABILITY AND PERCEIVED STRESS IN CHILDREN: COMPARISON OF TRADITIONAL VERSUS CIRCADIAN MEASURES

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#APS2018LOU
HEART RATE VARIABILITY (HRV)

• Beat-to-beat variation in timing of consecutive heart beats

• Pharmacological blockade (atropine) of vagal tone results in lower HRV than during parasympathetic withdrawal (HF: 0.198 vs. 0.501, p<.02)

• HF (or respiratory sinus arrhythmia; RSA) reflects primarily vagal modulation
  Berntson, Cacioppo, Quigley (1993) Psychophysiology, 30, p183

<table>
<thead>
<tr>
<th></th>
<th>Saline</th>
<th>Atropine</th>
<th>Metoprolol</th>
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<tbody>
<tr>
<td>HR</td>
<td>72.3</td>
<td>118.7</td>
<td>61.2</td>
</tr>
<tr>
<td>HP</td>
<td>847</td>
<td>507</td>
<td>999</td>
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<tr>
<td>HF HRV</td>
<td>6.7</td>
<td>1.1</td>
<td>7.1</td>
</tr>
<tr>
<td>LF HRV</td>
<td>5.7</td>
<td>1.0</td>
<td>5.1</td>
</tr>
</tbody>
</table>
HEART RATE VARIABILITY IN CHILDREN

• Normative values of HRV in children have been reported. Important covariates include heart rate (β=−0.60), pubertal stage (β=−0.11), time of day (β=−0.19) & resting blood pressure (β=−0.11)

• Vagal tone in infancy and childhood is a strong predictor of future resting RSA

• HRV measures exhibit generally robust reproducibility over time (particularly HF, rMSSD)
HEART RATE VARIABILITY & STRESS IN YOUTH

• Lower HRV (HFms²) is associated with more adverse life events ($\beta=-.187; p = .017$), emotions (anxiety, sadness, anger; $\beta=-.147; p=.006$), and higher overall cortisol ($\beta=-.052; p=.011$)

• Greater decrease in RSA during stress, lower RSA in the future ($\beta=.43; p<.001$)

• LF and LF:HF moderate relation between cortisol and perceived stress
  Rotenberg & McGrath (2016)
  Biological psychology, 117, p 16.
BLOOD PRESSURE DIPPING

- Healthy nighttime decrease below 10% threshold of daytime blood pressure (BP) and “non-dippers” are at increased cardiovascular risk

- Among children with normal BP, obese children (5.5% ± 3.8 systolic dip) non dippers

- Also children with obstructive sleep (7.4% ± 7.3 systolic dip) non dippers regardless of sleep stage
BLOOD PRESSURE DIPPING

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• Among children with normal BP, obese children (5.5% ± 3.8 systolic dip) non dippers

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CIRCADIAN RHYTHM OF HEART RATE VARIABILITY

• Night as restorative and protective period of vagal dominance – free running sleep experiment results in reduced vagal tone (−17.03% ± 3.47 HF decrease after return to normal sleep)

• Emergence of circadian rhythm of HRV begins at 1 and is more prominent by 4 years of age (pNN50, VLF, LF, rMSSD and HF all p<.05; mean, RR p<0.0001)

• Within older children, acrophase of vagal tone happens around 3 a.m.
  (HF=03:06; Mean RR=02:54)
  Archives of Disease in Childhood, 83, p 179.
REMAINING QUESTIONS & STUDY RATIONALE

- Circadian rhythm of HRV develops in childhood
- Stress in childhood associated with lower HRV
- In adults association of stress and HRV indicates evidence for circadian rhythm

STUDY OBJECTIVES AND HYPOTHESES

- Compare traditionally derived day, night and circadian pattern
- Greater parasympathetic activation at night
- Higher stress associated with lower traditionally used averages of HRV (HF value for daytime and nighttime)
- Circadian markers better associated with stress (MESOR, amplitude and acrophase)
PARTICIPANTS

• Healthy Heart Project
  Pediatric Public Health Psychology Lab
  Concordia University, Montreal, QC, Canada

• Ongoing, longitudinal cohort study assessing early cardiovascular risk factors during childhood and adolescence
  Rotenberg & McGrath (2016) Biological psychology. 117, p 16

• Community recruitment (neighborhoods & schools)
  \( N = 69 \) children (55% boys).

• Mean age 13.04 years (9 – 17 years old)

• Exclude serious psychopathology or medical conditions
SLEEP

- Wrist accelerometry (Actiwatch 2®) worn for 14 days (24 hrs), records movement & light exposure (lux), daily sleep log completed in tandem with accelerometer

- Actigraphy psychometrically valid; High accuracy (86%) and sensitivity (97%), compared to polysomnography in adults

- Scoring 30sec epochs following standardized protocol to define rest interval (lights on, lights off); ICC>.95
  Mcgrath, Noel, Burdayron (2017) Sleep Medecine, 40(S1), p e218
HEART RATE VARIABILITY

• 30-hours ambulatory ECG monitor recording (Grass, TREA), Lead II Configuration

• Kubios software use for data editing (manual inspection, smoothness prior method, medium filter for artifact correction)

• Kubios yields high correspondence compared to other HRV scoring software ($ICC_{avg} = 0.91; r_{avg} = 0.96$)

• Data processed by Fast Fourier Transform (FFT) spectral analysis method

![Figure 3. Power spectrum of heart rate variability. (PSD = power spectral density)](image)
PERCEIVED STRESS

Youth completed questionnaire and daily log about perceived stress.

Stress Past Month
- Perceived Stress Scale (10-item)
- Completed once at first lab visit
- Previously used with children and adolescents (Cronbach’s $\alpha=.81$)

Daily Stress & Stress Variability
- Perceived Stress Scale (4-item)
- Completed daily as part of daily log
- Cronbach’s $\alpha$
  - Literature: 0.77
  - Sample: 0.90
ANALYSES

• Cosinor analysis for circadian parameters

• Mean level difference within individuals in *daytime* and *nighttime* HF HRV to assess vagal dominance

• Test linear association between traditional HRV averages (*day, night*) and stress (*month, daily, variability*)

• Test linear association between circadian parameters (*mesor, amplitude, acrophase*) and stress (*month, daily, variability*)

• Models controlled for sex, BMI (Z-score), age
RESULTS

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRV daytime</td>
<td>38.77 (10.83)</td>
<td>14.71</td>
<td>64.13</td>
</tr>
<tr>
<td>HRV nighttime</td>
<td>50.68 (16.32)</td>
<td>18.48</td>
<td>82.86</td>
</tr>
<tr>
<td>Mesor</td>
<td>0.75 (0.09)</td>
<td>0.59</td>
<td>0.95</td>
</tr>
<tr>
<td>Amplitude</td>
<td>−0.90 (0.18)</td>
<td>−1.27</td>
<td>−0.37</td>
</tr>
<tr>
<td>Acrophase</td>
<td>4.03 (1.40)</td>
<td>−0.49</td>
<td>7.57</td>
</tr>
<tr>
<td>Stress month</td>
<td>1.82 (0.46)</td>
<td>0.30</td>
<td>2.80</td>
</tr>
<tr>
<td>Daily stress</td>
<td>1.92 (0.62)</td>
<td>0.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Daytime VS Nighttime HRV

Hedges’ \( g = .860 \)

Error Bars = Standard deviation; ** = \( p < .000 \)
TRADITIONAL DAYTIME & NIGHTTIME SEGMENTS

Only daytime average associated with variation in daily stress

**Traditional Daytime Segments**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>β</th>
<th>t</th>
<th>p</th>
<th>η²</th>
<th>R² adj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>.124</td>
<td>1.01</td>
<td>.315</td>
<td>.014</td>
<td>.030</td>
</tr>
<tr>
<td>BMI</td>
<td>−.007</td>
<td>0.12</td>
<td>.952</td>
<td>.000</td>
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<tr>
<td>Age</td>
<td>−.234</td>
<td>−1.96</td>
<td>.054</td>
<td>.054</td>
<td></td>
</tr>
</tbody>
</table>

1 Stress month   | .108| 0.82 | .417| .010| .021   |
2 Daily stress   | .102| 0.83 | .408| .010| .016   |
3 Stress variability | .245| 2.07 | .043| .059| .068   |

**Traditional Nighttime Segments**

<table>
<thead>
<tr>
<th>Predictor</th>
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<th>t</th>
<th>p</th>
<th>η²</th>
<th>R² adj</th>
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<tr>
<td>Sex</td>
<td>.037</td>
<td>0.30</td>
<td>.767</td>
<td>.001</td>
<td>.020</td>
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<tr>
<td>BMI</td>
<td>−.122</td>
<td>−0.99</td>
<td>.328</td>
<td>.014</td>
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<tr>
<td>Age</td>
<td>−.216</td>
<td>−1.79</td>
<td>.078</td>
<td>.046</td>
<td></td>
</tr>
</tbody>
</table>

1 Stress month   | .118| 0.89 | .376| .012| .017   |
2 Daily stress   | −.119| −0.98| .330| .014| .016   |
3 Stress variability | .156| 1.28 | .204| .024| .027   |
CIRCADIAN MEASURES: MESOR AND AMPLITUDE

Only *amplitude* significantly associated with stress day

### Circadian *amplitude*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( p )</th>
<th>( \eta^2 )</th>
<th>( R^2 ) adj</th>
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<td>Sex</td>
<td>-.219</td>
<td>-1.84</td>
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<tr>
<td>BMI</td>
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<td>.085</td>
<td>.042</td>
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<tr>
<td>Age</td>
<td>.150</td>
<td>1.30</td>
<td>.200</td>
<td>.023</td>
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<tr>
<td>1 Stress month</td>
<td>-.042</td>
<td>-0.33</td>
<td>.742</td>
<td>.001</td>
<td>.088</td>
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<tr>
<td><strong>2 Daily stress</strong></td>
<td><strong>-.232</strong></td>
<td><strong>-2.03</strong></td>
<td><strong>.047</strong></td>
<td><strong>.055</strong></td>
<td><strong>.130</strong></td>
</tr>
<tr>
<td>3 Stress variability</td>
<td>.007</td>
<td>0.06</td>
<td>.952</td>
<td>.000</td>
<td>.073</td>
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</table>

### Circadian *MESOR*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( p )</th>
<th>( \eta^2 )</th>
<th>( R^2 ) adj</th>
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</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-.295</td>
<td>-2.73</td>
<td>.008</td>
<td>.084</td>
<td>.248</td>
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<tr>
<td>BMI</td>
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<td>-0.58</td>
<td>.566</td>
<td>.003</td>
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<tr>
<td>Age</td>
<td>.415</td>
<td>3.94</td>
<td>.000</td>
<td>.176</td>
<td></td>
</tr>
<tr>
<td>1 Stress month</td>
<td>.134</td>
<td>1.17</td>
<td>.245</td>
<td>.015</td>
<td>.262</td>
</tr>
<tr>
<td>2 Daily stress</td>
<td>-.153</td>
<td>-1.43</td>
<td>.158</td>
<td>.024</td>
<td>.242</td>
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<tr>
<td>3 Stress variability</td>
<td>-.146</td>
<td>-1.36</td>
<td>.178</td>
<td>.022</td>
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</table>
**CIRCADIAN MEASURES: ACROPHASE**

Associated with *stress over past month* and *variation in daily stress*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>$\beta$</th>
<th>$t$</th>
<th>$p$</th>
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<tr>
<td>BMI</td>
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<td>-0.607</td>
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<td>.005</td>
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<tr>
<td>Age</td>
<td>-.028</td>
<td>-0.230</td>
<td>.819</td>
<td>.001</td>
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<tr>
<td><strong>1 Stress month</strong></td>
<td>-.291</td>
<td>-2.238</td>
<td>.029</td>
<td>.071</td>
<td>.046</td>
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<tr>
<td><strong>2 Daily stress</strong></td>
<td>.029</td>
<td>0.235</td>
<td>.815</td>
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<td>-.035</td>
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<tr>
<td><strong>3 Stress variability</strong></td>
<td>-.247</td>
<td>-2.041</td>
<td>.045</td>
<td>.060</td>
<td>.028</td>
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</tbody>
</table>
SUMMARY

- Parasympathetic dominance at night
- Greater stress variability associated with higher mean HF at day
- Circadian measures more robust association with stress
  - Greater stress variability associated with earlier acrophase
  - Higher stress (month) associated with earlier acrophase
  - Higher stress (daily) associated with lower amplitude
- Effect sizes (low to moderate) comparable to other HRV findings
- Circadian measures facilitate better understanding of association between stress and HRV
DISCUSSION

• Strengths:
  • Full 30-hour recording
  • Comparison of circadian and traditional measurements of HRV
  • Objective markers to define sleep times

• Limitations:
  • ECG recording limited to 30 hours; Period of 24 h assumed
  • Technological limitations preclude measurement of HRV for longer than 30 hours; Necessary to establish directionality of relation (dynamic modeling)
FUTURE DIRECTIONS

• Longer of recordings and consideration of pubertal stages, phase shift, and adolescent development

• Advancement in technologies (data acquisition and storage)

• Evidence to show other underlying rhythms (monthly, seasonal, school schedule) may influence HRV

• Covariation in time between stress and HRV
ACKNOWLEDGEMENTS

Muhammed Idris, PhD, Data Scientifique Postdoc Scholar
Neressa Noel, RPSGT, Sleep Technician
Natasha Hunt, Senior Research Coordinator
Sabrina Giovanniello, Senior Data Coordinator
Pediatric Public Health Psychology Lab
Healthy Heart Project participants
REFERENCES


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Cosinor equation

\[ x_i = M + A \cos (\theta_i + \Phi) + e_i \]

\( M = \) mesor

\( A = \) amplitude

\( \Phi = \) acrophase

\( \theta_i = \) time period \((24h)\)
### Correlation between stress variables

<table>
<thead>
<tr>
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<th>PSS-10</th>
<th>PSS-4 one day</th>
<th>PSS-4 variance</th>
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<tbody>
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<tr>
<td>PSS-4 one day</td>
<td>.086</td>
<td>-</td>
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<tr>
<td>PSS-4 variance</td>
<td>.332**</td>
<td>.201</td>
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Note. **= p<.001

### Correlation between HRV variables

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>1. RSA day</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. RSA night</td>
<td>.430**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Mesor</td>
<td>.000</td>
<td>.065</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Amplitude</td>
<td>-.100</td>
<td>.214</td>
<td>.351**</td>
<td>-</td>
<td></td>
<td></td>
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<tr>
<td>5. Acrophase</td>
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<td>-.009</td>
<td>.378**</td>
<td>-.136</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6. Acrophase to bedtime</td>
<td>.304*</td>
<td>-.106</td>
<td>.177</td>
<td>.049</td>
<td>.517**</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. *= p<.05; **= p<.001