HEART RATE VARIABILITY 
& 
ATHLETE MONITORING

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**Overview**

- Athlete monitoring
- Physiological aspects of HRV
- HRV measurement fundamentals
- Relevant Athletic Training HRV Literature
- Application of HRV to health, performance, and injury in baseball pitchers and firefighters
Athlete Monitoring

➢ What is athlete monitoring?
➢ Monitoring what?
  • Training load, performance, injury
➢ For what purpose?
  • Reduce injury, improve recovery, optimize performance, avoid fatigue, minimize risk for overreaching and overtraining
➢ How?
  • Questionnaires, RPE, fatigue scales, heart rate, bar velocity, workload quantification, movement screens
  • Wearable technology

Is this a new concept or practice?
  • Yes......and no....and Why now?

Athlete Monitoring

- Growth of Sport Sciences
  - Dashboard of metrics
  - What are the inputs and outputs
  - Still need to know the individual

What is HRV?

- Heart Rate
  - A simple average number of beats in a given time period
  - In figure below, 9 QRS complexes in 6 seconds * 10 = AVERAGE HR of 90 bpm
- Heart Rate Variability (HRV)
  - Quantifies the time (ms) between R-waves from consecutive QRS complexes
  - Inter-beat interval (IBI) or RR Interval (RR or RRI)

https://www.wikihow.com/Calculate-Heart-Rate-from-ECG
HRV & The Autonomic Nervous System

- Nervous System
  - Central nervous system
    - Brain, spinal cord
  - Peripheral nervous system
    - Afferent division (sensory)
      - Somatic, visceral, special
    - Efferent division
      - Sympathetic (SNS)
      - Parasympathetic (PSNS)
      - Enteric

- ANS Features
  - Blood pressure, breathing, heart rate
  - SNS and PSNS constantly mediating essential functions to optimally match function with task demands

- Autonomic Nervous System (ANS) influences cardiac control via two branches
  - Parasympathetic (PSNS)
    - Vagal Nerve input on the sinoatrial (SA) node
    - Resting State
    - Vagal Tone
    - Increases variability
  - Sympathetic (SNS)
    - Sympathetic nerve endings on myocardium
    - Fight or Flight
    - Decreases variability

- Autonomic Balance
Multi-System Influence


Remember that HRV will have a multi system influence

- Breathing
- Digestion
- Myocardial integrity
- Blood pressure
- Stress, anxiety, excitement
- Fitness
Quantifying HRV

- HRV is quantified with either time domain or frequency indices

**Time domain**
- SDNN
  - standard deviation of all NN Intervals (i.e. RRI)
- RMSSD
  - square root of the mean of the sum of squares of differences between NN intervals
- LnRMSSD
  - natural log of RMSSD
- NN50
  - Number of pairs of adjacent NN intervals differing by more than 50ms (can be converted to pNN50)

In general, Time Domain indices
- Simple to calculate
- Greater confidence with shorter time samples
- Lower RMSSD would suggest less parasympathetic influence or greater sympathetic influence
  - Vagal Tone

**Frequency HRV Indices**
- Low Frequency (LF)
  - 0.04 to 0.15 Hz
- High Frequency (HF)
  - 0.15 to 0.4 Hz
- LF/HF
  - Ratio of the LF to HF

In general, Frequency Domain indices
- More difficult to calculate
- May not be as stable during short time samples
- Lower frequency values associated with less parasympathetic / greater sympathetic influence

**Functional Relationship Between HR and HRV**

Heart Rate

HRV

PNS

SNS

Avoid the On/Off Switch Analogy

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**Measurement Tools**

- Chest Strap and Watch Devices
  - Polar, Garmin
- Wrist Based Devices
  - TomTom Spark3, FitBit, LifeTrak Zoom HRV (arm, wrist, ankle)
- Smart Garments and Straps
  - Hexoskin
  - Zephyr/Medtronic
- Regardless of device, questions to consider include
  - Is this for individual or group/team measurements?
  - Does the device require a resting, non exercise position and state?
  - Is it really measuring HRV or is the device measuring pulse rate variability?
  - How are ectopic beats managed?
  - Do you need/have access to the raw data?
**Measurement Considerations**

- **Position**
  - Supine vs. seated vs. standing vs. exercise

- **Breathing**
  - Paced vs. non-paced

- **Time of Day**
  - Upon waking, morning, mid-day

- **Sample length**
  - ≤1 min, 3 min, 5 mins, >5 mins

- **Environment (Ecologically valid vs. Controlled Lab)**
  - Quiet, music, mobile devices, talking, sleeping

**Methods references**


**Sample Data Collection Procedures**

- **5 minute resting sample**
  - Extract the RR file
  - Send RR file to Kubios HRV program
  - Clean and filter data
  - Analyze for time and frequency domain metrics

- **Then what?**
  - Do you have a “dashboard” to present the data, make day to day comparisons, evaluate trends

**The advantages of available programs**

- Omnisense (Zephyr/Medtronic)
- Polar Flow
- Available apps like Elite HRV
Sample Analysis Approach

Before We Move On…
Methodological Questions?
Applications of HRV to Athletic Training

Recovery

HRV Literature

- According to PubMed.com
  - The first published HRV paper was in 1925
  - From 1925/1948 to 2007, 10,581 papers were published
  - More papers (11,628) have been in the last 9 years than the first 76 years of HRV history
  - Yet, the literature related to HRV and other areas is just beginning to grow: sport (n=1,514), exercise (n=2,894), injury (n=520), concussion (n=22)

**HRV Applications**

**Cardiovascular**
  - Lower HRV associated with greater risk of hypertension
- Routledge (2010). Canadian Journal of Cardiology
  - ↑ in HRV following exercise therapy (cardiovascular, diabetes, healthy)
  - “The sports science concept of the heart rate variability (HRV)-vagal index used to manage exercise sessions (for a goal of performance) could be implemented in cardiac rehabilitation to improve cardiovascular fitness and autonomic nervous system function.”

**Concussion**
  - Following head trauma, HRV has been observed to be significantly lower than non-injured control subjects and inversely associated with long-term outcomes
- La Fountaine et al. (2009). *Autonomic Neuroscience: Basic and Clinical*
  - Decrease in HRV in concussed athletes
  - Improvement in autonomic balance will result in decrease in post concussion S&S
  - Higher levels of baseline HRV associated with greater performance on complex neurocognitive tasks of
  - ANS dysfunction identified via HRV in athletes with concussion, even beyond return to play.
**HRV Applications**

**Exercise Prescription**
  - Progressive withdrawal of PSNS with progressive exercise intensity
  - HRV is a beneficial tool in exercise prescription

**Training and Athletes**
  - Increase in HF component at rest in swimmers associated with onset and presence of viral illness
- Chen (2011). *Journal of Strength & Conditioning Research*
  - Pre-competition anxiety identified in BMX athletes by increase in LF
- Di Michele et al (2012). *Journal of Strength & Conditioning Research*
  - HRV can be used to identify anaerobic threshold
  - HIIT was a more effective short-term strategy to increase R-R interval variability than aerobic training

**Treatment Modalities**

**The Influence of Skeletal Muscle Massage on Heart Rate Variability**
- Decrease (p<0.05) in HR from pre to post for the massage (80 ± 11 bpm vs. 74 ± 12 bpm) and control group (77 ± 9 bpm vs. 68 ± 9 bpm).
- Increase (p<0.05) in RR from pre to post for the massage (768.7 ± 108 ms vs. 836.5 ± 152 ms) and control group (792 ± 102 ms vs. 893.4 ± 130 ms).

**Autonomic changes following a short-duration, skeletal muscle massage may not necessarily be due to the actual massage, but more related to the time spent in rest or preference for massage.**

Ebersole, Conlon, Bartz, Meyer (2012). ACSM
HRV & Injury

Inflammation
Cooper et al. (2015). *Brain Behav Immun*
  - Heart Rate Variability Predicts Levels of Inflammatory Markers: Evidence for the Vagal Anti-Inflammatory Pathway

Injury
  - Abnormal somatic tissue response to accumulating trauma may modulate ANS activity at the level of HRV.

Using HRV to Answer Health, Performance, and Injury Questions in Baseball Pitchers & Firefighters
But...how do you define fatigue?

- In general, the only consistency in definition is the reference to “decline in performance”
- Task dependency of fatigue emphasizes the need for ecologically valid approaches to study fatigue
- Fatigue is a process, not a single point
- Specific to the person
HRV & Baseball Pitchers

- Data from 95 players across 4 years
- Over 11,000 days of resting HRV data
- Initially used the methods of Plews et al (2012, 2013, 2014) and Kubios
- Continuously refine process and analysis based on the data

Resting HRV vs Rotation Day

- A pitch outing may alter ANS function on day 2 and recovery should be expected by day 3.
- Increases in HRV in the weeks before the event, during the highest training loads, are likely associated with a positive performance outcome (Plews et al., 2012)

**Group vs. Individual Data**

- HRV is an individually specific biometric
- Each individual may have different “inputs” and “outputs” that account for day to day changes

**ROM, HRV, Aggregate Data**

- Exploring the model presented by Gisselman et al (2016) linking soft tissue injury to HRV
- Aggregate data reveals little relationship between HRV and ROM changes

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ROM, HRV, Individual Data

Conditioning/Fitness Status Does Matter

J.B. WOLFFE MEMORIAL LECTURE

Is the lung built for exercise?

Presented at ACSM Annual Meeting, 1985 (Published in MSSE, 1986)
Consecutive days of decreasing HRV can be corrected with a training load adjustment.

Gabbet suggested that physical hard training develops physical qualities which in turn protect against injuries.

In season adjustments to training load and intensity result in changes to HRV.

Firefighter Health & Performance

Fall 2017 HRV Project

HRV response during recovery after fire

% difference rest to final = 85.3%
% difference start recovery to final = 23.7%

Recovery RRI

RR (ms)

0 1 2 3 4 5 6 7 8 9 10

HRV Pre Fire HRV Post Fire Recovery
**Firefighter Health & Performance**

HRV response during recovery after middle of night auto extrication

- FF#1
  - HRmax = 144
- FF#2
  - HRmax = 126

**In Summary**

- Have clarity in your purpose for using HRV as a metric.
- Understand HRV is not an exact science and will not tell you exactly what is the mechanism of a change.
- HRV is a conversation starter that helps guide you in the right direction.
- Be aware of how an app or product is analyzing the data, how noise is managed.
- Use caution with aggregate data.
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THANK YOU!

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