How to Analyze Stress from Heart Rate & Heart Rate Variability: A Review of Physiology
STRESS AFFECTS THE AUTONOMIC NERVOUS SYSTEM
TERMINOLOGY

- **Heart rate** (HR): heartbeat frequency as beats per minute (bpm)
- **Heartbeat** (R-R interval): time between consecutive heartbeats (R-waves) in milliseconds (ms)
- **Heart rate variability** (HRV): beat-to-beat variation in the time between consecutive R-R intervals
Heart Rate Variability: A Window to the Body

- Lifestyle assessment is based on analysis or heart rate variability (HRV).
- HRV means the variation in time between consecutive heartbeats.
- Heart rate variability is regulated by the autonomic nervous system and affected e.g. by age, physical condition and stress.
- Firstbeat utilizes HRV to make a model of the body’s physiological states.
- HRV is used to estimate:
  - respiration frequency
  - oxygen uptake
  - energy expenditure
  - training effect (EPOC)
  - recovery and stress
Heart rate & heart rate variability (HRV)

Heart rate 61 beats/min

RR-I 1000 ms → HR 60 beats/min
RR-I 500 ms → HR 120 beats/min
RR-I 400 ms → HR 150 beats/min
INFLUENCE OF RESPIRATION ON HEART RATE

The figure shows how the cyclic variation of respiration (RSA, respiratory sinus arrhythmia) affects heart rate variability.

Exhalation: HR drops RRI lengthens HRV grows
Inhalations: HR increases RRI shortens HRV gets smaller
WHEN HR DROPS, HRV GETS BIGGER

- In a healthy, fit adult, HRV usually grows during rest.
- Sleeptime recovery (its quality) is weakened by various stressors, such as stress, sleep problems, illnesses, medications, alcohol, weak physical condition and overweight.
FACTORS AFFECTING HEART RATE VARIABILITY

- Stress
- Health / diseases / Physical condition
- Heritance

(Lindholm 2007)
HEART RATE ALONE DOES NOT REVEAL OVERLOAD

Before the overload:
- Avg. HR 48
- Avg. HRV 82 ms
- HRV is big → indicates good recovery and health

2 months later:
- Avg. HR 47 bpm
- Avg. HRV 12 ms
- HRV dramatically reduced: obvious signs of overload / no signs of recovery

Uusitalo 2000,
Suomen Lääkärilehti
EFFECT OF AGE ON HEART RATE VARIABILITY

**Good**
RMSSD is in the highest 50% of your age group average

**Moderate**
RMSSD is between 10 and 50% of your age group average

**Poor**
RMSSD is in the lowest 10% of your age group average
AUTONOMIC NERVOUS SYSTEM

Sympathetic nervous system
- Speeds up bodily functions
  - Heart rate $\uparrow$
  - Heart rate variability $\downarrow$
- Stress reactions

Parasympathetic nervous system
- Calms down bodily functions
  - Heart rate $\downarrow$
  - Heart rate variability $\uparrow$
- Recovery
The result reflects changes that take place in the autonomic nervous system.

When the activation level is elevated, the activity of the sympathetic nervous system increases → a stress reaction.

Time periods when the parasympathetic nervous system is dominant are identified as recovery.

There is no right or wrong way to react to a situation! It’s more essential to determine if the reaction is meaningful (e.g. whether recovery state is seen during a relaxation activity or sleep).
LIFESTYLE ASSESSMENT GRAPH AND HEART RATE VARIABILITY (RMSSD)

Case Shift work
DIGITAL MODEL OF BODY’S REACTIONS

∑

HRV indexes, respiration frequency, VO2 etc...

- Does the segment contain physical activity? (%VO2max...)
  - YES: Physical activity
  - EI

- Does the segment contain signs of recovery? (%HRmax, HRV...)
  - YES: Recovery
  - EI

- Does the segment contain signs of stress? (%HRmax, HRV, respiration...)
  - YES: Stress
  - NO: Other state
## Definition of Physiological States

### Stress Reactions

Increased activation level in the body caused by stress reactions. The reaction can be positive or negative. Sympathetic dominance.

- High heart rate, increased respiration frequency, low heart rate variability, oxygen uptake <20% of maximal capacity (VO2max).

### Recovery

Lowered activation level & calming down of the body. Nighttime sleep and relaxing breaks are important recovery periods. Parasympathetic dominance.

- Low heart rate, low respiration frequency, high heart rate variability, oxygen uptake <20% VO2max.

### Physical Activity

Physical stress / activity during which the intensity is > 30% of maximal capacity.

- **Daily Physical Activity**
  - Low-level physical stress/activity during which the intensity is 20-30% of maximal performance.

### Other State

Other state (white) is typically recovery from exercise, short awakenings during sleep or missing data periods (for example during a shower).
CAUSES OF STRESS / STRESS REACTIONS

Physical stressors (internal)
- Fatigue
- Overload / overtraining
- Burnout
- Pain
- Acute infections
- Chronic illnessess
- Dehydration
- Digestion
- Pregnancy

Physical stressors (external)
- Heavy exercise training
- Lack of sleep
- Physical workload
- Stimulants e.g. coffee
- Medications
- Alcohol or other substances, hangover
- Sauna
- Temperature, noise, altitude
- Jetlag

Psychological stressors
- Anxiety, depression, sorrow
- Negative emotions
- Traumatic events
- Work stress
- Psychological conditions
- Fear, tension
- Relationship problems
- Excitement e.g. falling in love

Social stressors
- Pressures
- Lack of social support
- Presentation / speech
- Fear of social situations
FIRSTBEAT ANALYSIS DOES NOT DIFFERENTIATE BETWEEN POSITIVE AND NEGATIVE STRESS