Heart rate variability is representative of training adaptation to an altitude camp in elite triathletes

Marco Altini

Supervisors and examiners:
Prof. dr. Thomas Janssen
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Training 101

- STIMULUS
- RESPONSE
- ADAPTATION
Training 101

- STIMULUS
- RESPONSE
- ADAPTATION
Training 101

STIMULUS  RESPONSE  ADAPTATION
Training 101

- STIMULUS
- RESPONSE
- ADAPTATION
Training camp at altitude

- Training stimulus and ideal adaptation:
  - Hypoxic environment
  - Spending enough time at altitude triggers an increase in red blood cells
  - More red blood cells results in improved oxygen-carrying capacity
  - Higher oxygen-carrying capacity leads to better performance
Individual variability

- **Individual responses can differ** based on many factors
  - Novelty and volume of the stimulus, presence of **other non-training related stressors**
  - Knowing which athletes positively (or negatively) **respond** to a certain stimulus allows the coaching staff to plan accordingly, implement changes and truly individualize training

- How can we determine individual responses?
Heart rate variability (HRV)

- The body maintains a state of balance (**homeostasis**) by regulating many functions via the autonomic nervous system.
- A stressor (heavy training for example) can **suppress** parasympathetic activity, which can be measured in terms of **heart modulation** (HRV).
- Increased **stress** typically results in **higher resting heart rate**, reduced HRV, increased coefficient of variation (CV).
Research question

Are changes in resting heart rate and HRV during the beginning of a three-week training camp at altitude representative of training adaptation at the end of the training camp in elite triathletes?

If so, we could implement changes early on during the camp to further individualize training.
1. Define adaptation to the training camp
2. Determine which athletes adapted to the training camp. Split them in 2 groups (adapted vs not adapted)
3. Determine if there are differences in resting HR and HRV between the athletes that adapted and the athletes that did not adapt
Methods | Participants

- 4 elite triathletes
- 2 training camps at altitude in Namibia (1655m, in January 2019 and 2020)
- 7 individual responses to the camp
  - Missing data for one athlete
- 2 years of daily HRV measurements and workouts
• Workouts GPS and heart rate data have been analyzed to determine individual training adaptation at the end of the camp.

• A ratio between velocity and heart rate within an athlete’s smallest worthwhile change means that the athlete adapted.
Velocity over heart rate for all running workouts, grouped by camp week

VELOCITY TO HEART RATE RATIO

Outside SWC
- FALSE
- TRUE

Week before
- Week 1
- Week 2
- Week 3

Camp week
Velocity over heart rate for all running workouts, grouped by camp week

**FIRST WEEK IN HYPOXIC ENVIRONMENT:** LOWER RATIO
Velocity over heart rate for all running workouts, grouped by camp week

WEEK TWO: STARTING TO ADAPT

Outside SWC
FALSE
TRUE
Velocity over heart rate for all running workouts, grouped by camp week

LAST WEEK, RATIO WITHIN THE SWC: ADAPTED
Individual variability

Velocity over heart rate for all running workouts, grouped by phase

ADAPTED
Individual variability

- Outside SWC: FALSE
- True

Velocity over heart rate for all running workouts, grouped by phase

**Phase**
- Week before
- First week
- Last week

- **ADAPTED**
- **DID NOT ADAPT**
Methods | Resting physiology

- **HRV4Training app**
- **Morning test**, 1 minute right after waking up
- **rMSSD** as a marker of parasympathetic activity
  - HRV feature, captures the fast action of the vagus nerve
  - Used also to compute the coefficient of variation (CV HRV)
- **Resting heart rate**
Methods | Resting physiology
Heart rate response

Daily heart rate, color-coded by training camp phase

INCREASE IN HEART RATE
### Heart rate variability response

#### Daily rMSSD, color-coded by training camp phase

<table>
<thead>
<tr>
<th>Date</th>
<th>Heart rate (bpm)</th>
<th>Phase</th>
<th>Daily heart rate, color-coded by training camp phase</th>
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<table>
<thead>
<tr>
<th>Date</th>
<th>rMSSD (ms)</th>
<th>Phase</th>
<th>Daily rMSSD, color-coded by training camp phase</th>
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**REDUCTION IN HRV, HIGHER DAY TO DAY VARIABILITY (CV HRV)**
Methods | Data analysis

• Difference in resting physiology (HR, HRV, CV HRV) between the week before the camp (baseline) and the first week of the camp for the 2 groups
• Do the metrics differ between groups? Do the athletes that adapted show a more favorable physiological response?
• Statistical analysis: t-tests
Results

• Based on workouts data, 4 responses were within the SWC (adapted) while 3 did not adapt.

• Resting HR was significantly more elevated for athletes that did not adapt (+4.6 bpm vs +0.5 bpm, p = 0.023).

• The CV rMSSD also increased by a greater extent for athletes that did not adapt (+10%, 3%, p = 0.015).
Results

GREATER HEART RATE INCREASE WHEN NOT ADAPTING ($p = 0.023$)
GREATER HRV DECREASE WHEN NOT ADAPTING (p > 0.05)
Results

GREATER CV HRV INCREASE WHEN NOT ADAPTING (p = 0.015)
Discussion

• Inter-individual variability makes it difficult to predict (functional) training adaptation

• Higher resting heart rate, higher CV HRV most likely associated to greater disruption in homeostasis, poor response of athletes that will fail to adapt

• Similar findings in other sports / conditions (e.g. after the off-season)

• Limited sample size
Conclusions

• In this study, a **more favorable physiological response** was reported already in the first week of the training camp for athletes that eventually adapted.

• Based on these findings, training could be manipulated and further individualized in the non-responders early during the camp.

• Might be applicable to other stressors (heat, higher volume, etc.)
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1. Accuracy of the HRV measurement
2. Same
3. Same
4. Training load (constant between the two phases, hence not a confounder)
COSMED Quark T12, Full ECG @ 500 Hz vs HRV4Training PPG with beat detection
Article Type: Original report

Title: Comparison of heart rate variability recording with smart phone photoplethysmographic, Polar H7 chest strap and electrocardiogram methods.

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0.99 correlation