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

Marco Altini

Supervisors and examiners:

Prof.dr. Thomas Janssen

Drs. Sander Berk, Applied Scientist Dutch Triathlon Federation

Dr. Jos de Koning

Training 101

Training 101

Training 101

Training 101

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)

MONITORING INDIVIDUAL RESPONSES AND TRAINING ADAPTATION

- 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

Approach

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

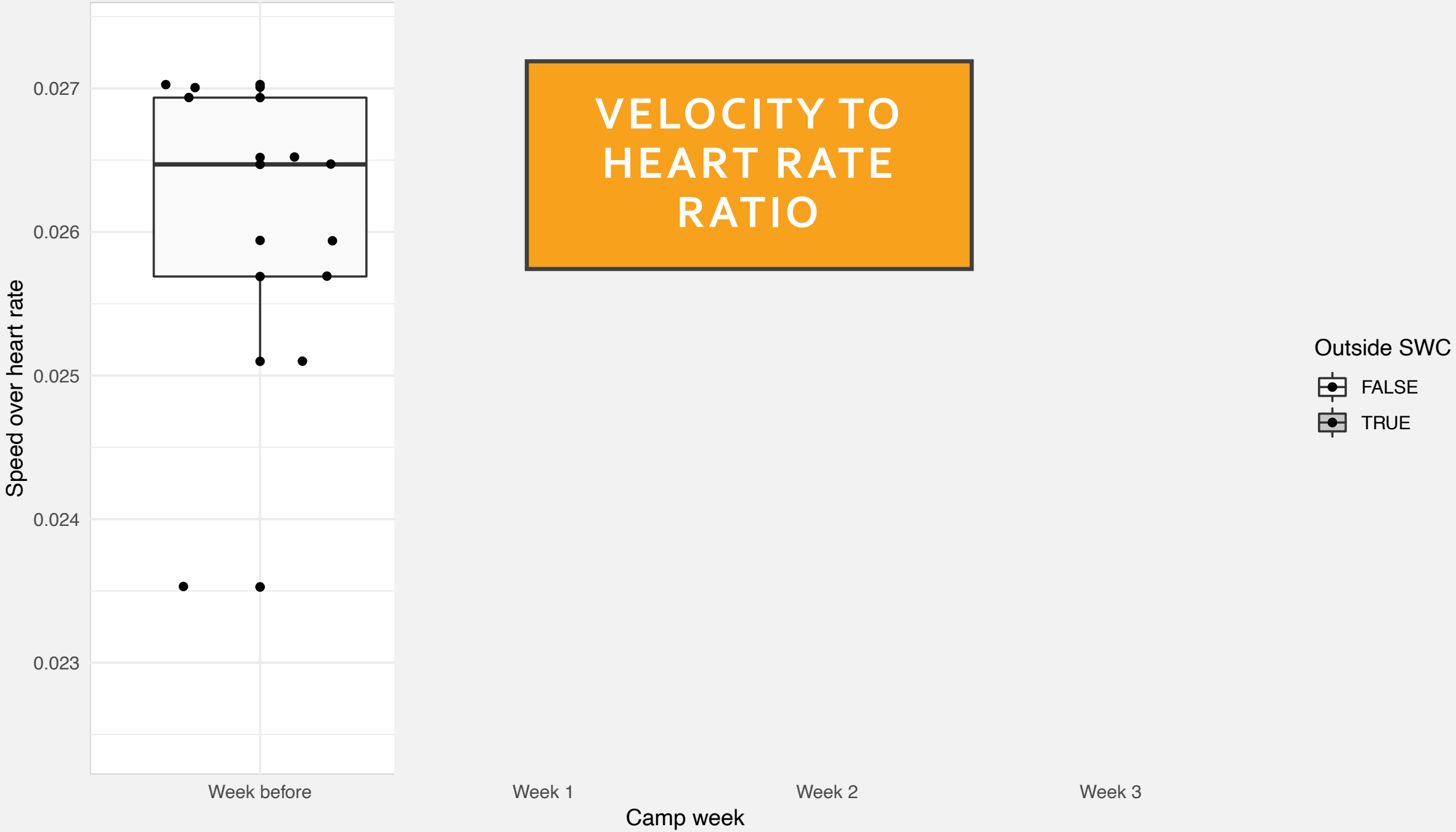
Methods | Participants

- **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

Methods | Training adaptation

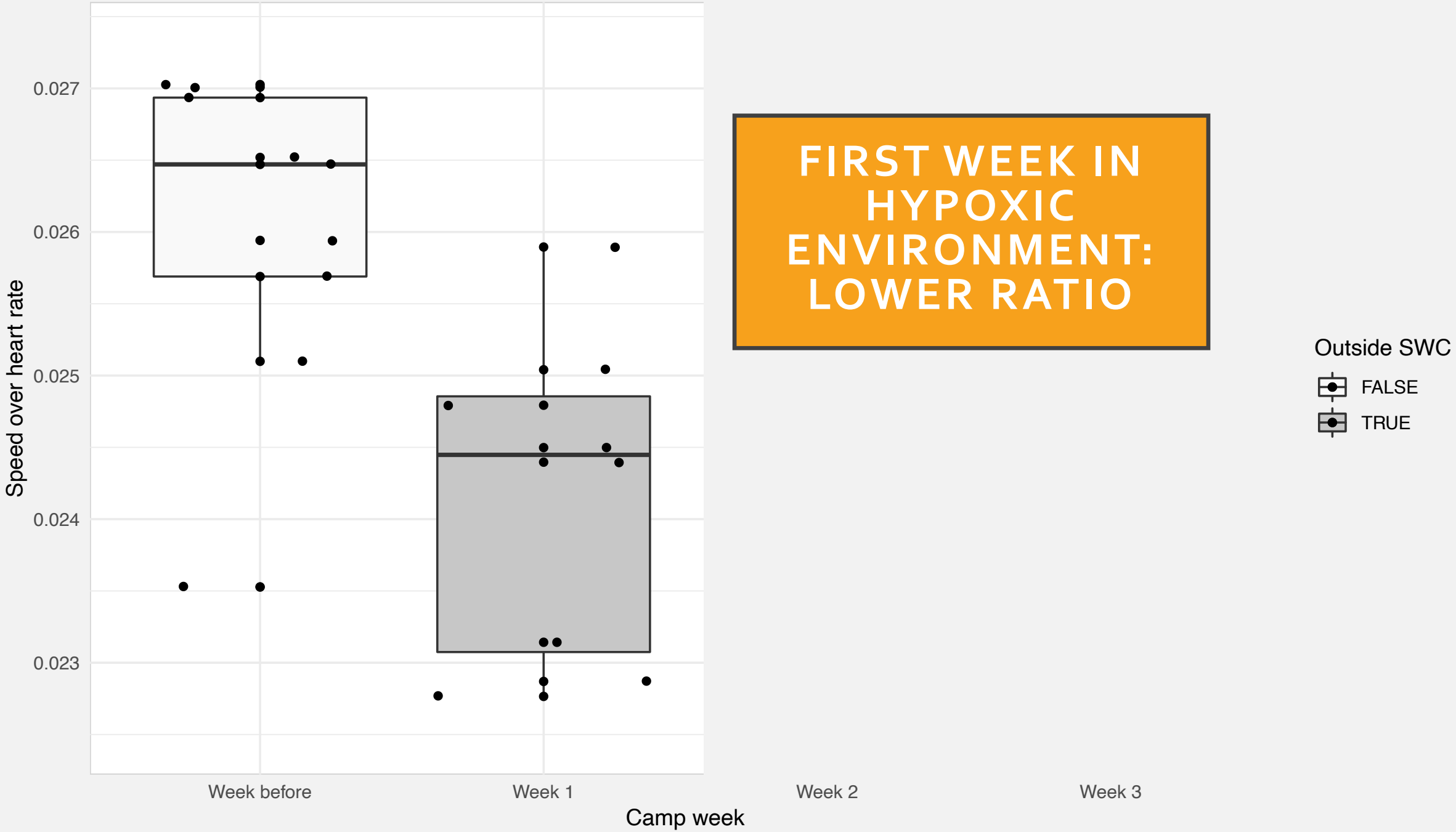
- Workouts GPS and heart rate data have been analyzed to determine individual training adaptation at the end of the camp
- **A ratio between velocity and heart rate within an athlete's smallest worthwhile change means that the athlete adapted**

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

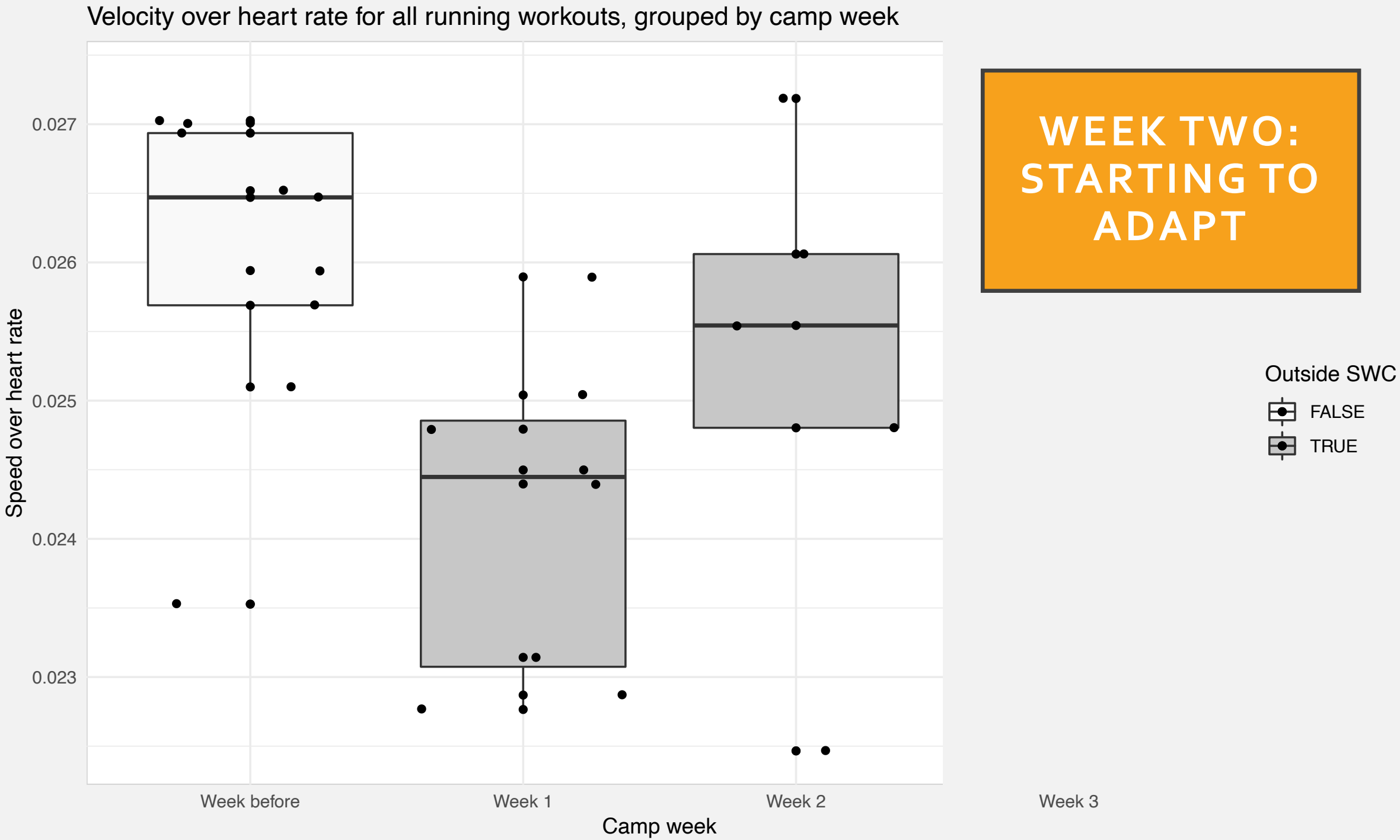


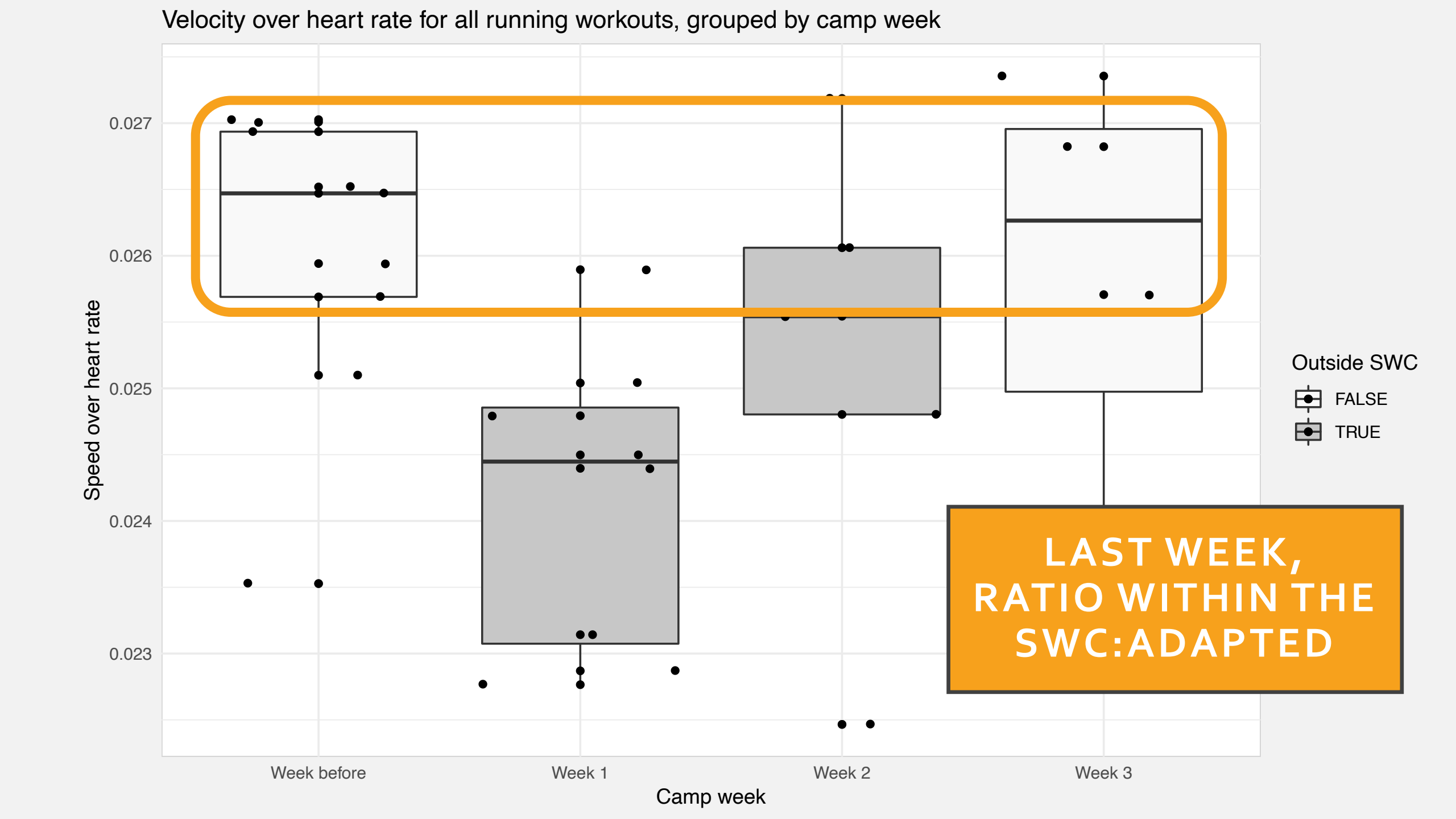
VELOCITY TO HEART RATE RATIO

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

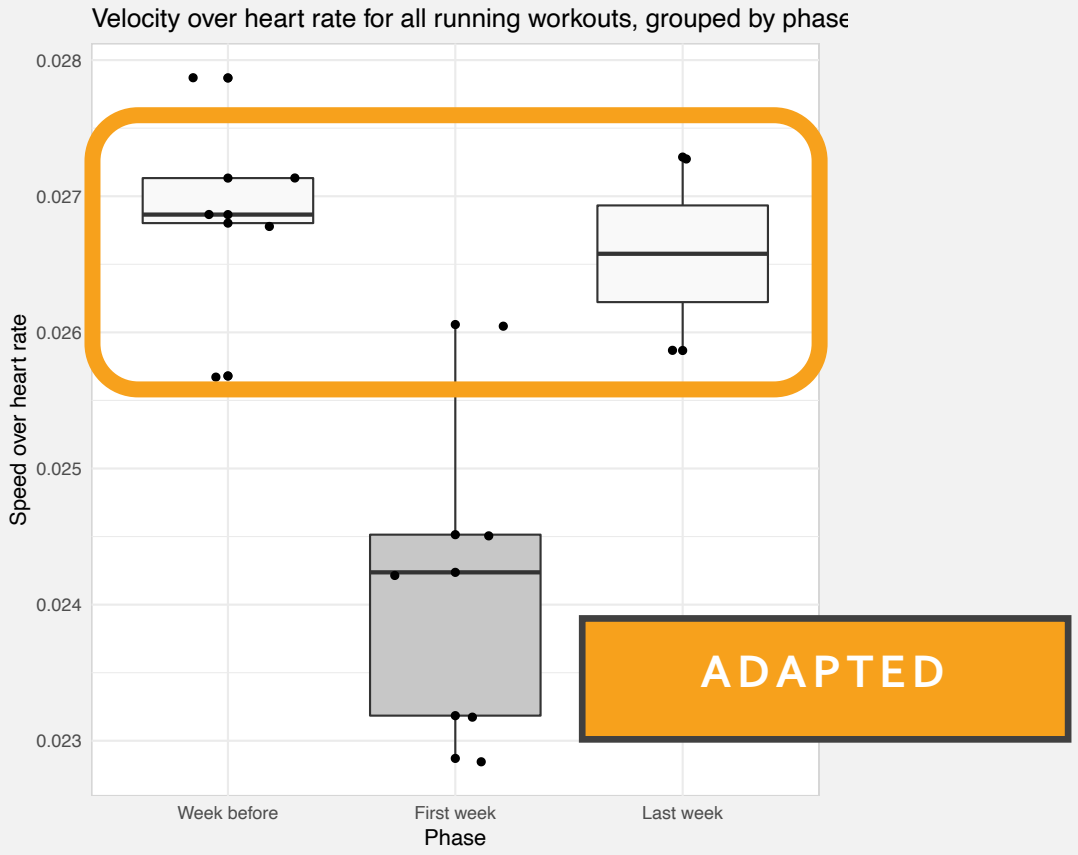


FIRST WEEK IN HYPOXIC ENVIRONMENT: LOWER RATIO

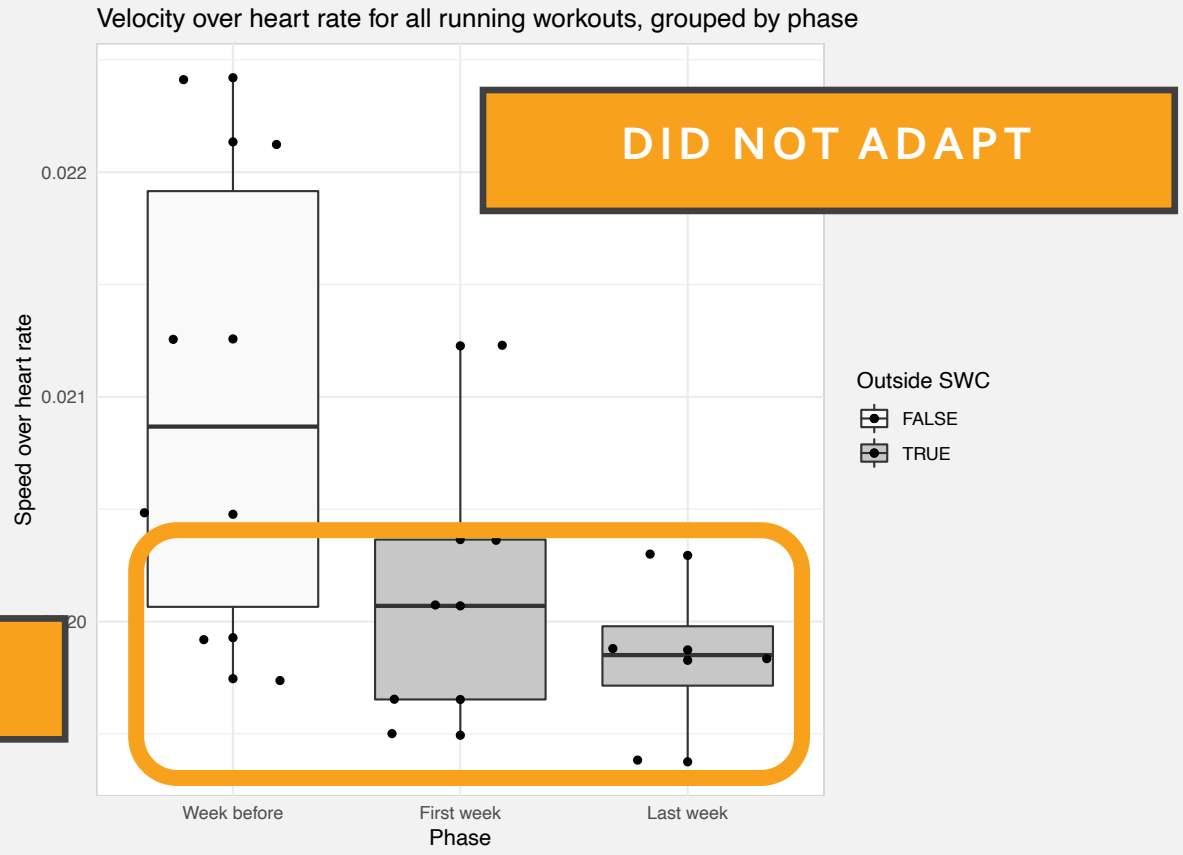

Velocity over heart rate for all running workouts, grouped by camp week
Speed over heart rate
0.027
0.026
0.025
0.024
0.023
Week before
Week 1
Week 2
Week 3
Camp week
WEEK TWO: STARTING TO ADAPT
Outside SWC
FALSE
TRUE


Velocity over heart rate for all running workouts, grouped by camp week
Speed over heart rate
0.027
0.026
0.025
0.024
0.023
Week before
Week 1
Week 2
Week 3
Camp week
Outside SWC
FALSE
TRUE
LAST WEEK, RATIO WITHIN THE SWC:ADAPTED

Individual variability



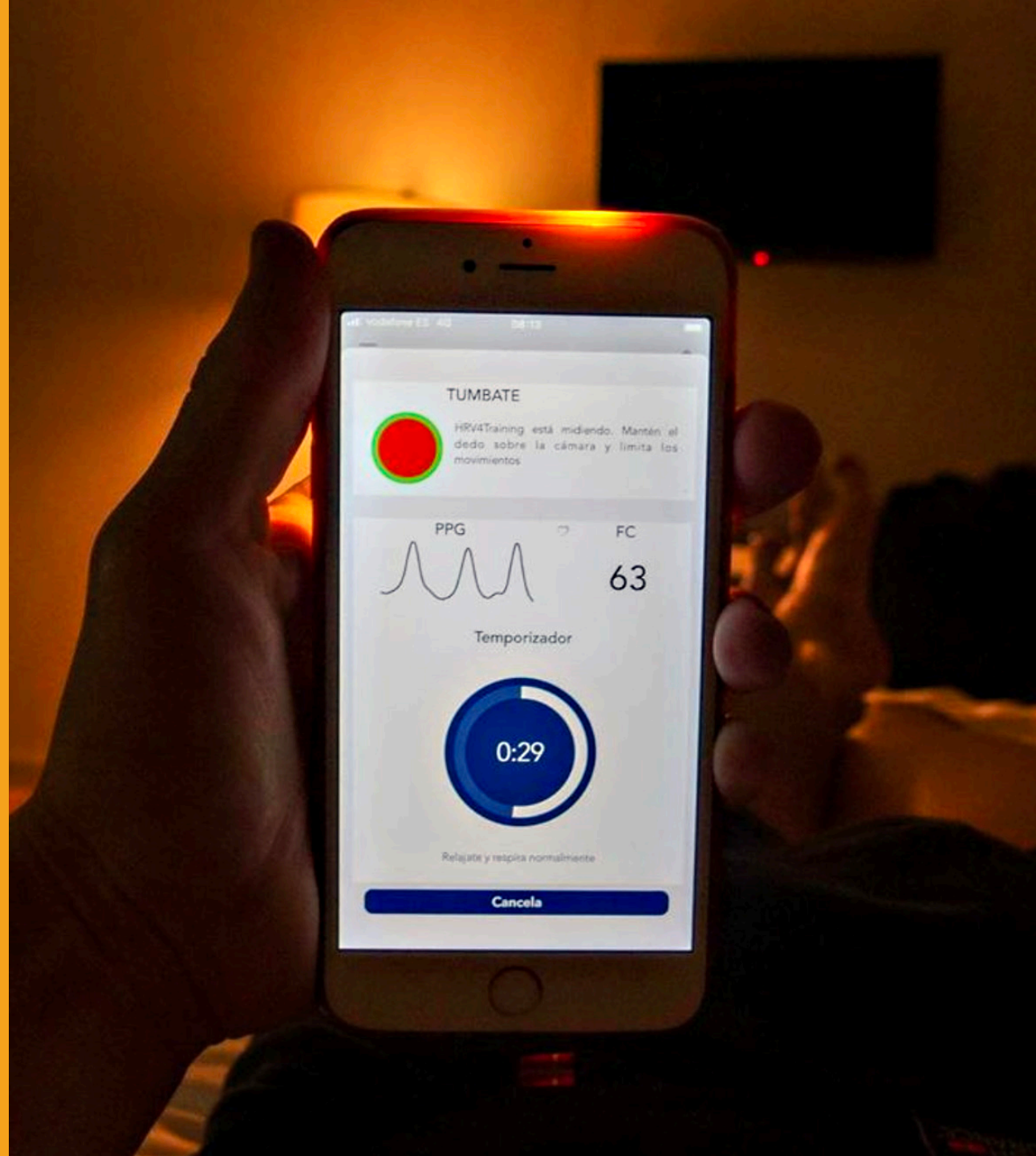
Individual variability



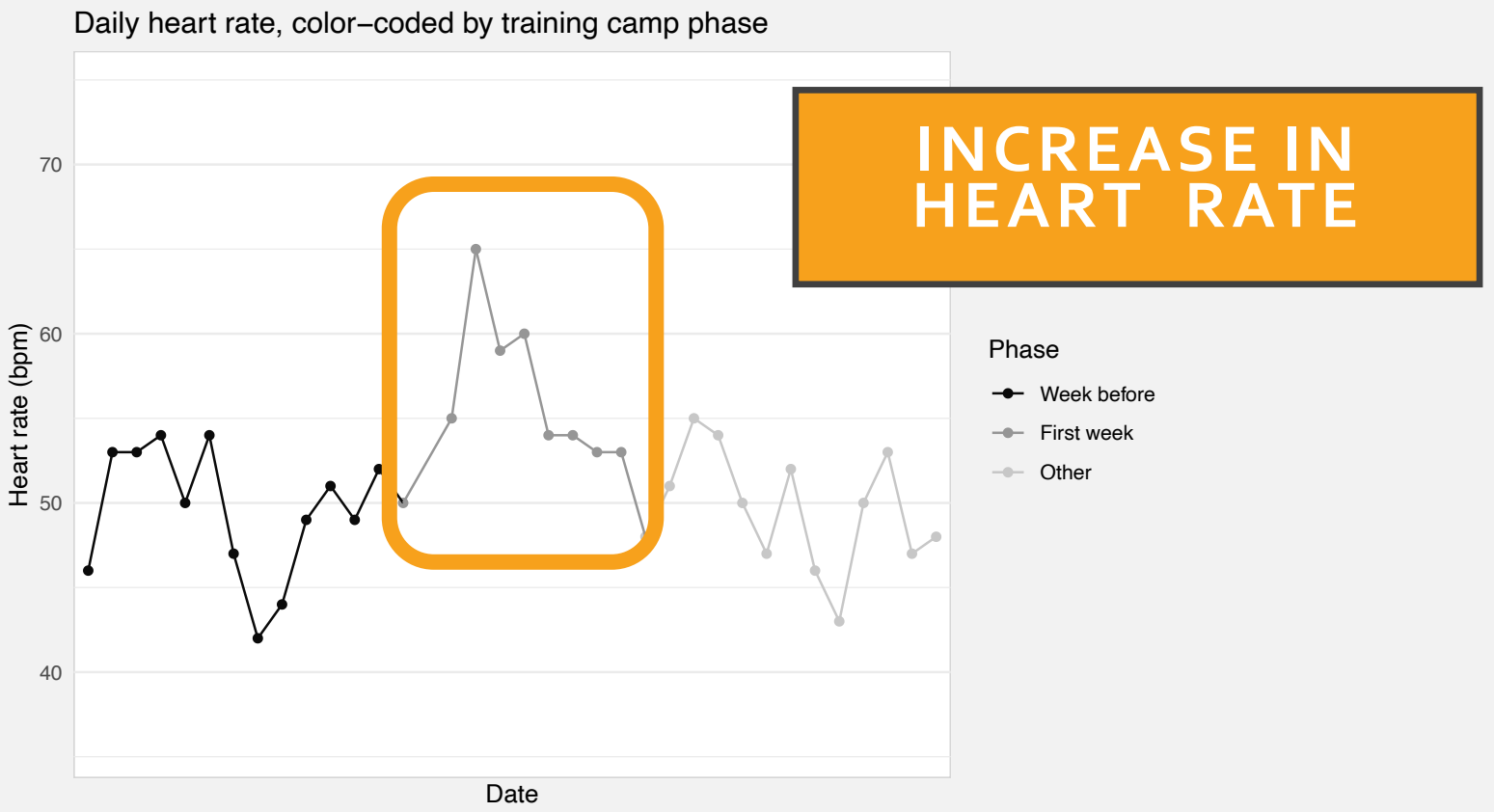
Methods | Resting physiology

- **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**

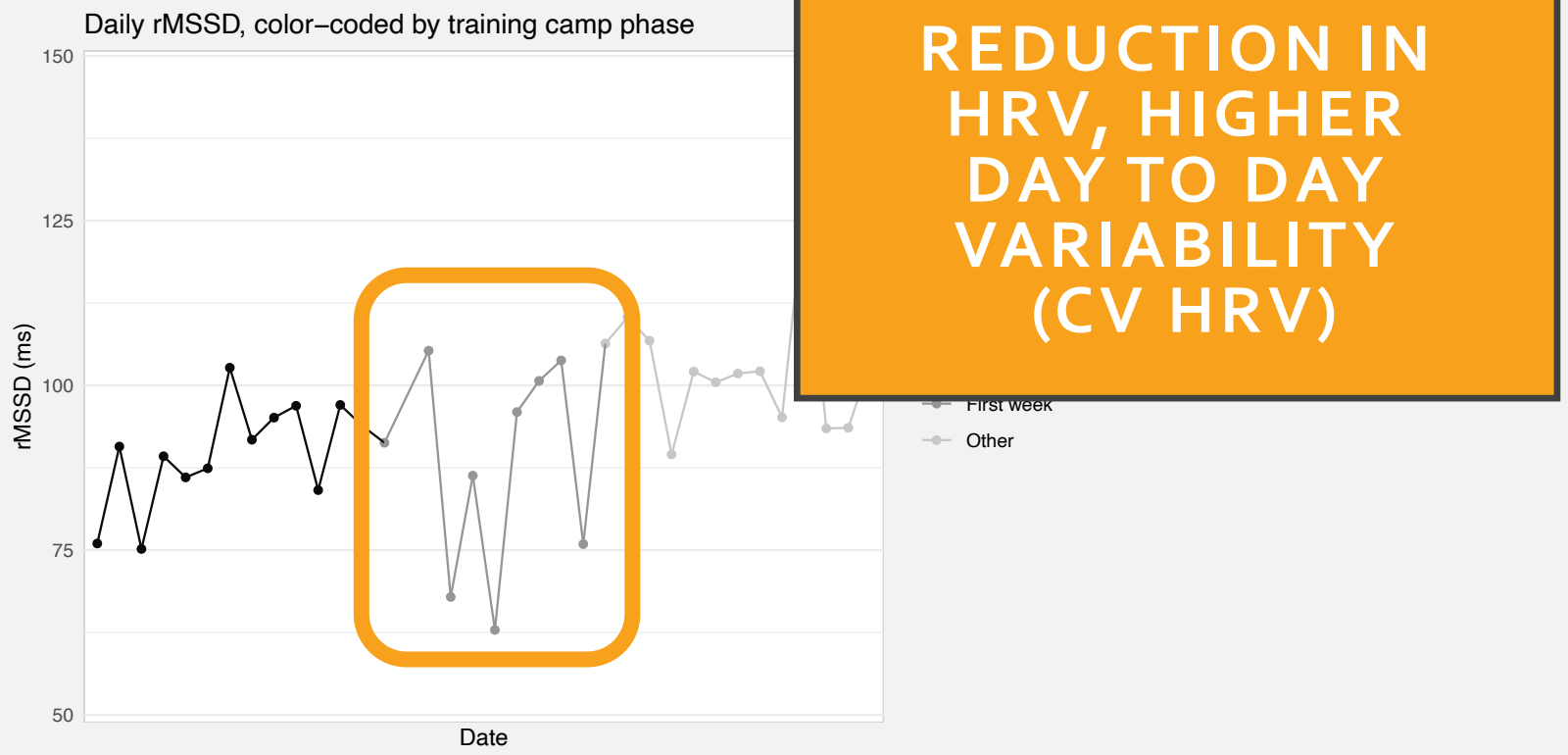
Methods | Resting physiology



Heart rate response



Heart rate variability response



REDUCTION IN HRV, HIGHER DAY TO DAY VARIABILITY (CV HRV)

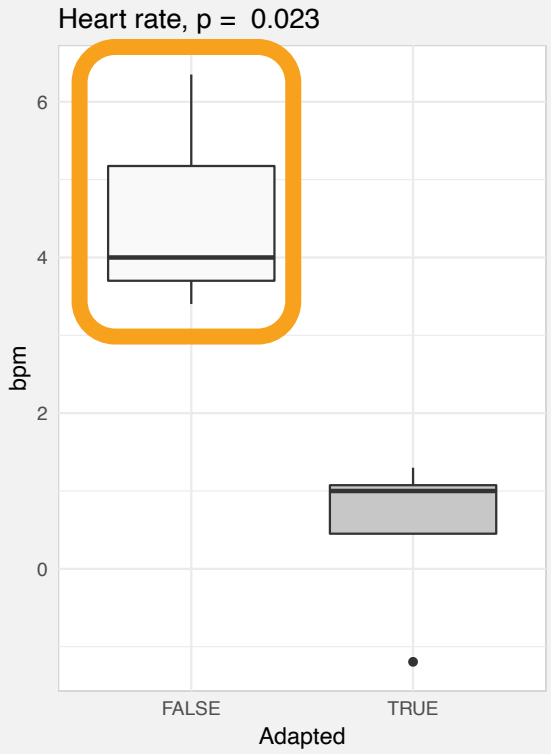
Methods | Data analysis

- **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

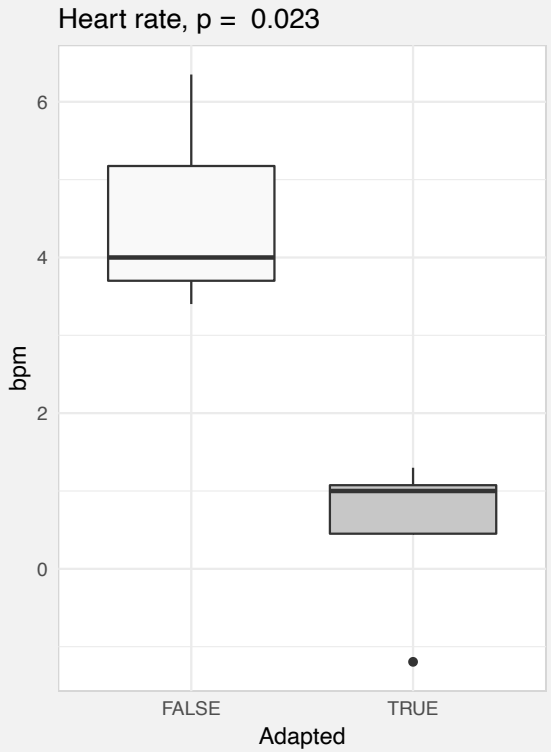
- Based on workouts data, **4 responses were within the SWC (adapted) while 3 did not adapt**
- Resting **HR was significantly more elevated** for athletes that did not adapt (+4.6 bpm vs +0.5 bpm, p = 0.023)
- **The CV rMSSD also increased by a greater extent** for athletes that did not adapt (+10%, 3%, p = 0.015).

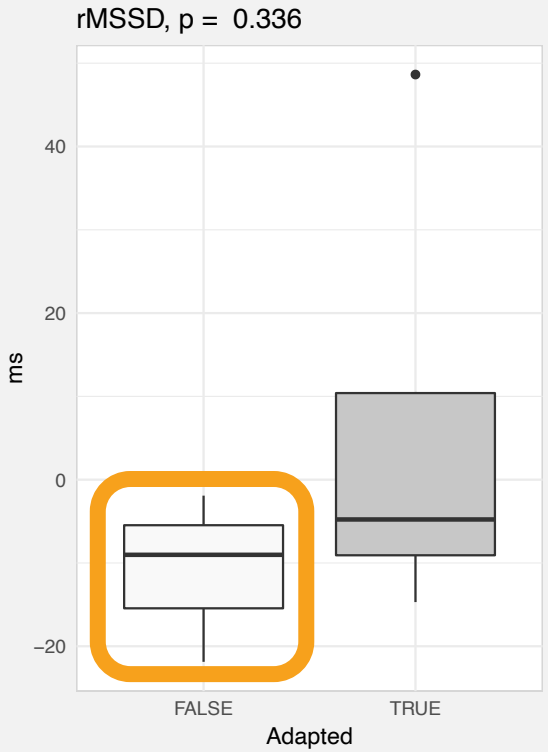
Results



GREATER HEART RATE INCREASE WHEN NOT ADAPTING (p = 0.023)

Results

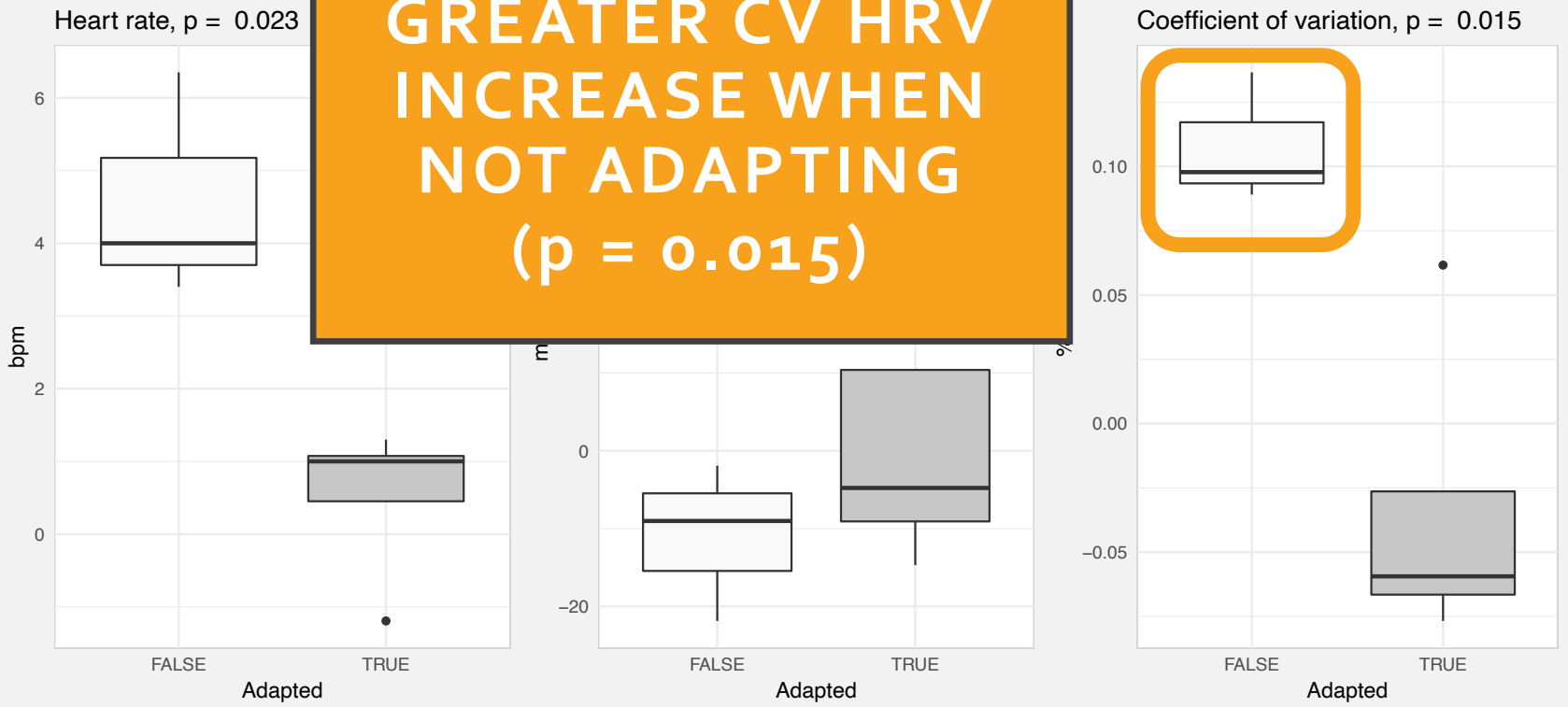




GREATER HRV DECREASE WHEN NOT ADAPTING ($p > 0.05$)

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.)

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

Marco Altini

Supervisors and examiners:

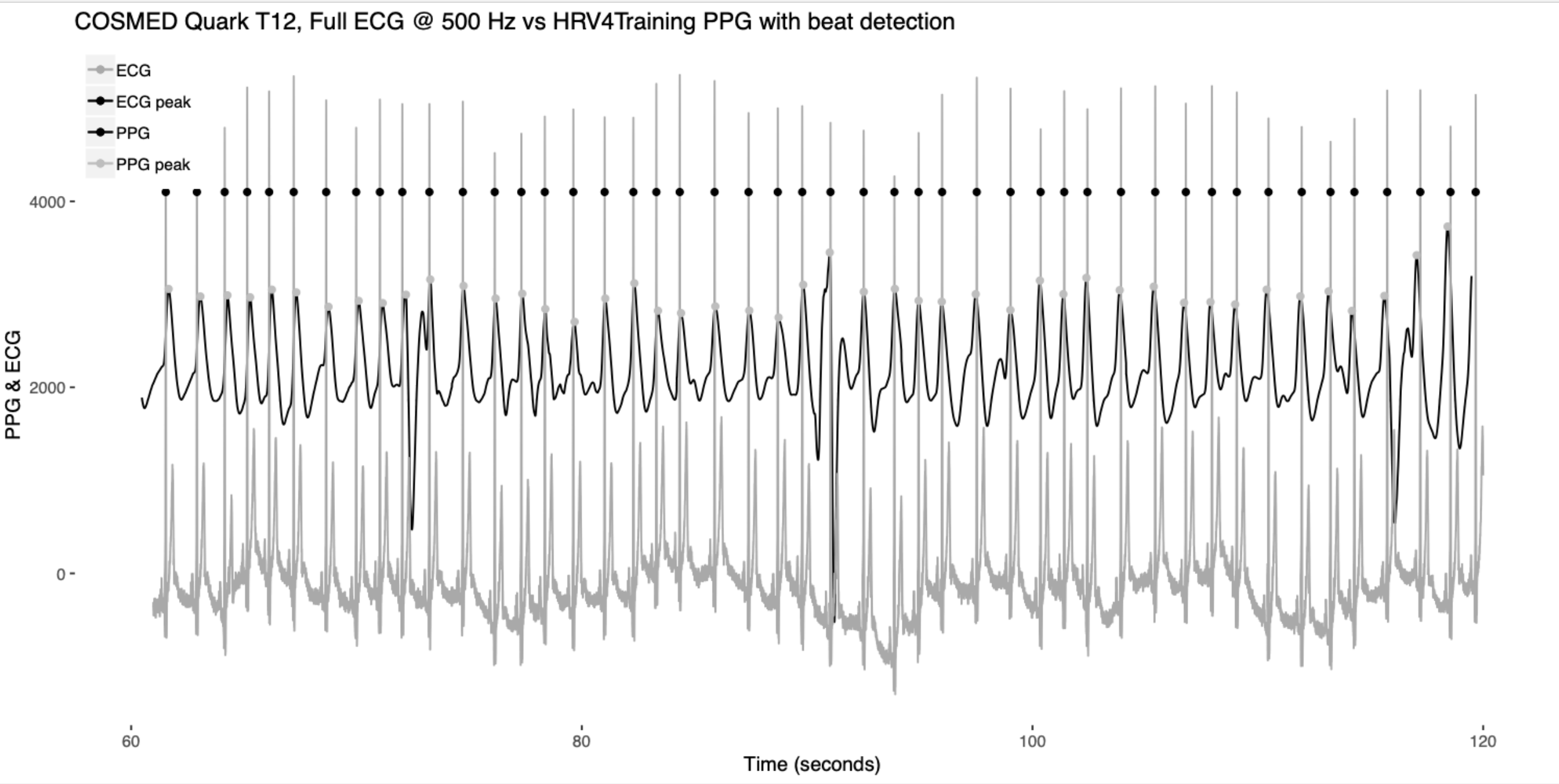
Prof.dr. Thomas Janssen

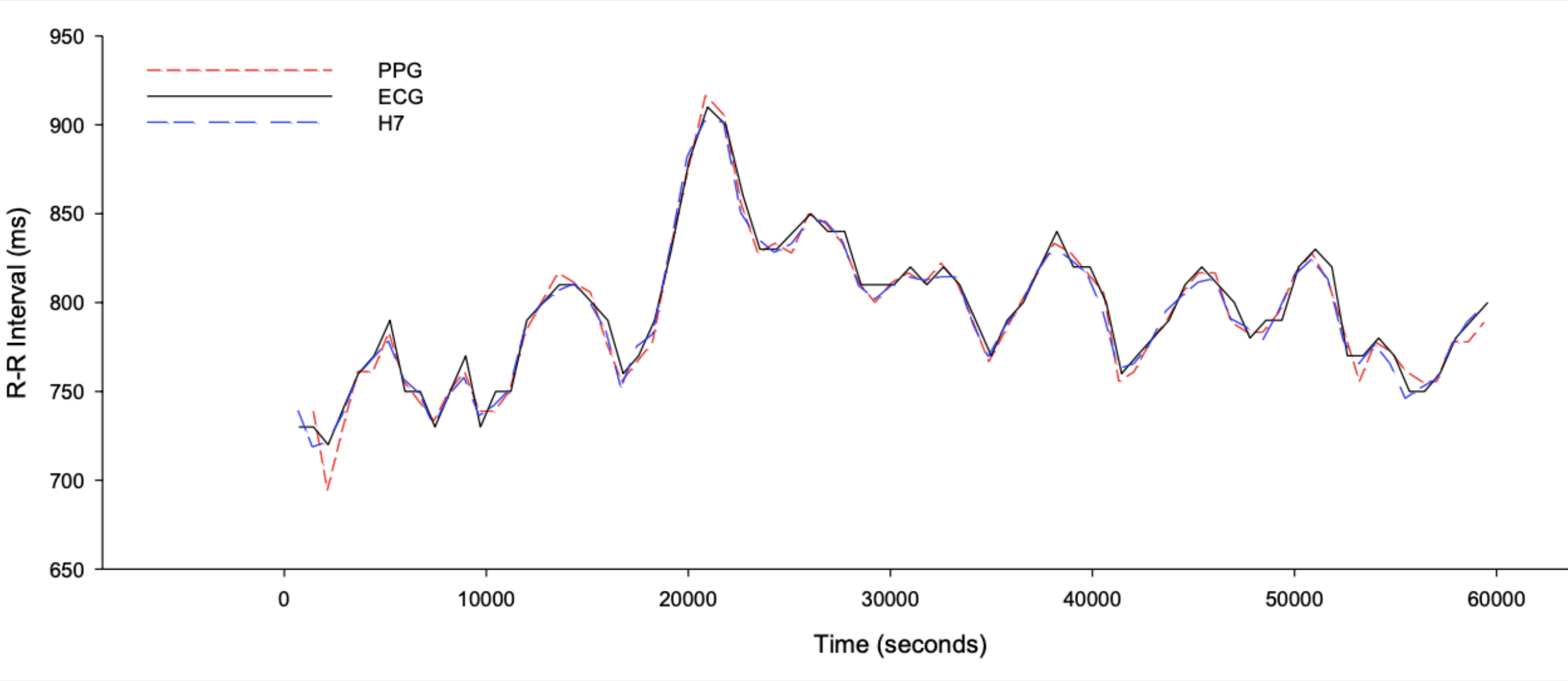
Drs. Sander Berk, Applied Scientist Dutch Triathlon Federation

Dr. Jos de Koning

Backup slides

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
ECG
ECG peak
PPG
PPG peak
4000
2000
0
PPG & ECG
60
80
100
120
Time (seconds)


PPG
ECG
H7
R-R Interval (ms)
950
900
850
800
750
700
650
0
10000
20000
30000
40000
50000
60000
Time (seconds)

Article Type: Original report

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

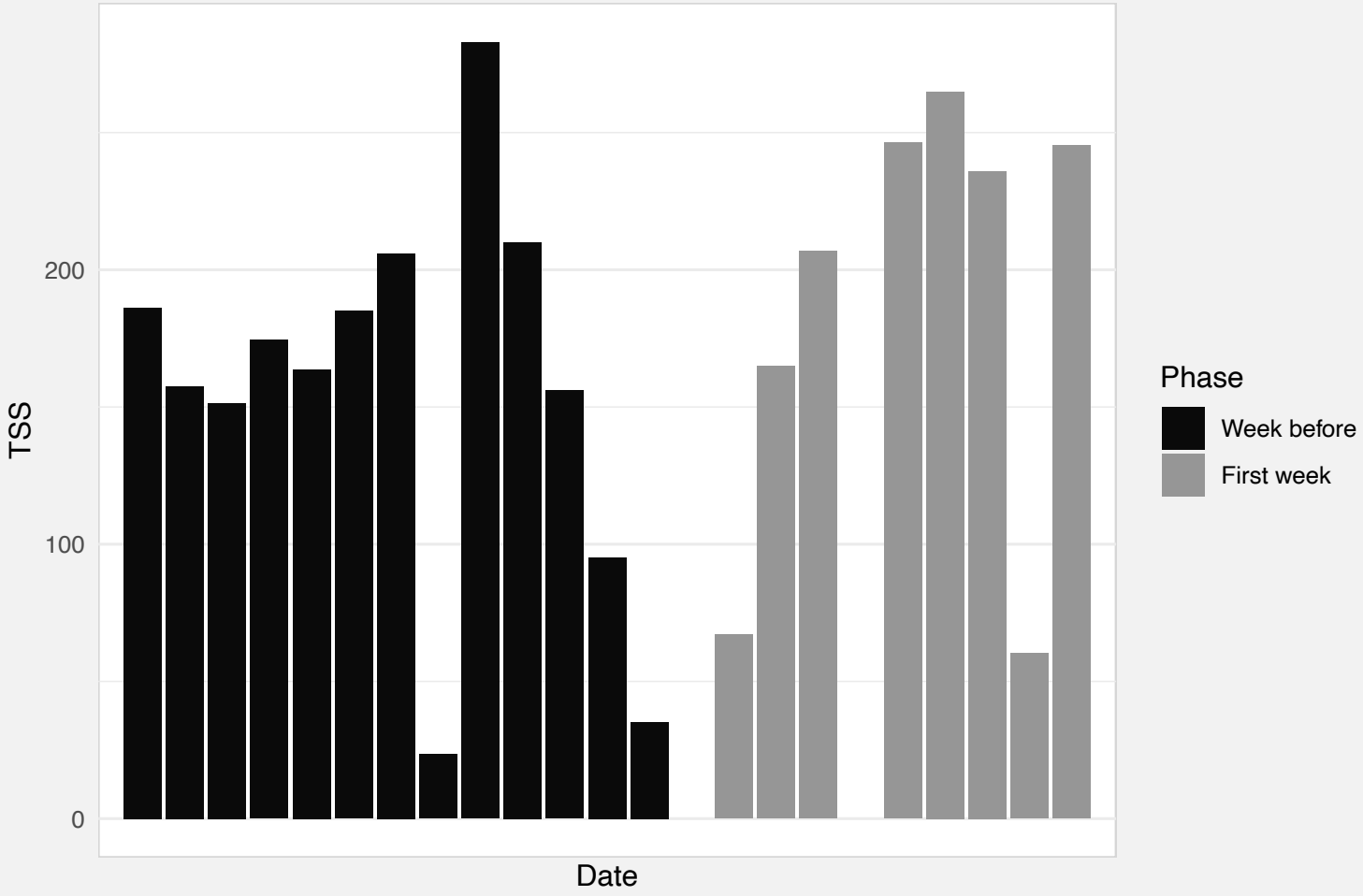
Author: Daniel J. Plews[1, 2, 3], Ben Scott[1,4], Marco Altini[5], Matt Wood[2], Andrew E. Kilding[2] and Paul B. Laursen[1, 2]

Affiliations:

1. High Performance Sport New Zealand, Auckland, New Zealand
2. Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand
3. University of Waikato, Hamilton, New Zealand
4. Loughborough University, Loughborough, United Kingdom
5. ACTLab, University of Passau, Germany

0.99 correlation

Daily workload, color–coded by training camp phase



Daily workload, grouped by training camp phase