# Heart Rate Variability During Physical Exercise

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# Why Heart Rate Variability (HRV)?



- HRV is the existent oscillation of the heart rate
  RR interval = time between two heartbeats
  - Time [min]

- HRV is an indicator for
  - Fatigue
  - Overtraining
  - Hydration level
  - ...



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### **Motivation**



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# How are HRV features changing during one hour of running?



Reveals significant differences of variables

## **Study Design**



#### • 295 athletes\*

- 98 female
- 176 male
- Age: 43 ± 11 years
- BMI: 23.1 ± 2.4 kg/m<sup>2</sup>



One hour outdoor run without distance or speed requirements

\* 27 athletes did not answer the questionaire with respect to gender, age and BMI

# **Study Design - Equipment**





Polar RS 800sd
 Watch, chest strap and shoe sensor

- Kinematic data (stride frequency, running speed)
- Physiological data (RR intervals, Heart Rate)

# **Feature Extraction (1)**





Time domain features

RMSSD =

- Average heart rate
- Square root of the mean squared differences of successive RR intervals:



Tachogram (zoomed in)

# **Feature Extraction (2)**



- Frequency domain feature:
  - LF/HF-ratio of normalized power spectral density (PSD)
  - Low frequency (LF) component: 0.04 0.15 Hz
  - High frequency (HF) component: 0.15 0.40 Hz



#### **Research Question**



- HRV features:
  - Heart Rate
  - RMSSD
  - LF/HF-ratio

# How are these three HRV features changing during one hour of running?







- ANOVA = Analysis of Variance
- Aim:

Determines if significant differences between different groups of variables are existent

- Design: ANOVA with repeated measures
- Procedure:
  - Calculation of F statistic
  - Comparison of F-value to the critical value F<sub>c</sub>
  - $F_{C}$  depends on degrees of freedom (df) (Error and Numerator) and significance level  $\alpha$



- In this study: **Repeated Measures Analysis** 
  - Univariate ANOVA with repeated measures
  - Multivariate ANOVA with repeated measures
- Assumptions:
  - Independence of observation
  - Multivariate normality
     → Natural logarithm of RMSSD and LF/HF-ratio
  - Sphericity (Circularity)

→ Only for univariate ANOVA; if violated: Greenhouse & Geisser correction



#### • F values

	Heart Rate	In(RMSSD)	ln(LF/HF)
univariate	1452.1	108.6	294.7
multivariate	796.6	91.8	126.5

#### Degrees of Freedom

	df Numerator	df Error	Critical F-value	þ
univariate	12 <b>→</b> 1	3528 → 294	10.83	< 0.001
multivariate	12	283	2.74	< 0.001

# Significant differences in the means of Heart Rate, RMSSD and LF/HF-ratio over distinct 5 minute sequences

### **Results – Post-Hoc Procedure**



• Determination of significant differences in the segments



- No significant differences for all three parameters
  - Starting in different segments
  - Lasting up to the 12<sup>th</sup> segment
  - For RMSSD: no significant differences after the 2<sup>nd</sup> segment
- $\rightarrow$  Indication of start and end of a workout

# Summary



- Study
  - 295 volunteers
  - Task: one hour outdoor run
- Three HRV features: Heart Rate, RMSSD, LF/HF-ratio
- Evaluation with ANOVA with repeated measures

# How are these three HRV features changing during one hour of running?

 No significant differences for Heart Rate between 35 and 60 minutes RMSSD between 25 and 60 minutes LF/HF-ratio between 30 and 60 minutes



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- Consideration of additional HRV features and a different segment length
- New methods:
  - Detrended Fluctuation Analysis
  - Dynamic Invariants
- Stride frequency and running speed
- Differences between female and male

# Thank you for your attention!





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### Quotations

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