T. Küpper

Borg's rating of perceived exertion - what does it measure and does it work at altitude?

Institute for Occupational, Social & Environmental Medicine, RWTH Aachen Technical University / Germany
&
Faculty of Travel Medicine, Royal College of Physicians and Surgeons Glasgow, Schottland

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Borg Scale (RPE)

- Version for endurance (training) -

6.	No exertion at all
7.	Extremely light
8.	--
9.	Very light
10.	--
11.	Light
12.	--
13.	Somewhat hard
14.	--
15.	Hard (heavy)
16.	--
17.	Very hard
18.	--
19.	Extremely hard
20.	Maximal exertion

- RPE = Rating of Perceived Exertion
- First scale: 1 – 20 → not linear to power or workload
  - Since 1970: 6 – 20
- Plausibility check:
  - RPE x 10 ≈ heart rate (HR)
- Endurance training → most effective at 11 - 14

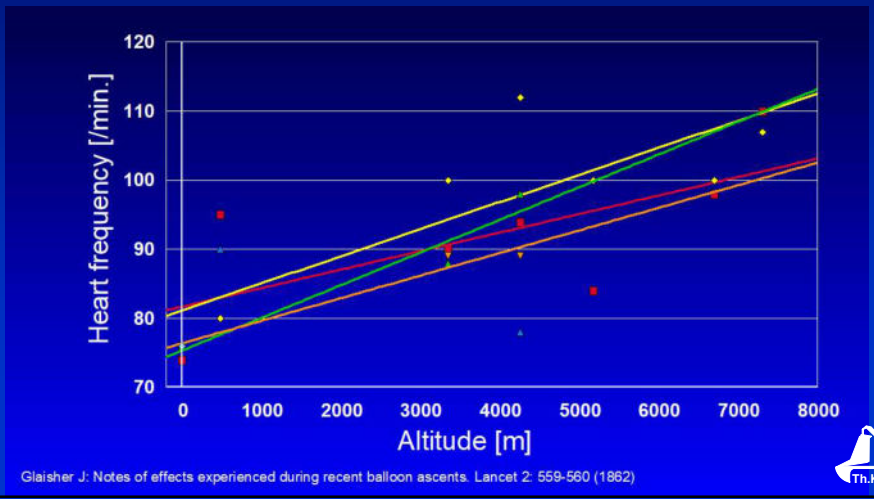
Situation at altitude

1. HF at rest increased
2. HF_{max} decreased

Consequence:
- Range of possible workload limited with the starting point (HF_{rest}) shifted to higher values

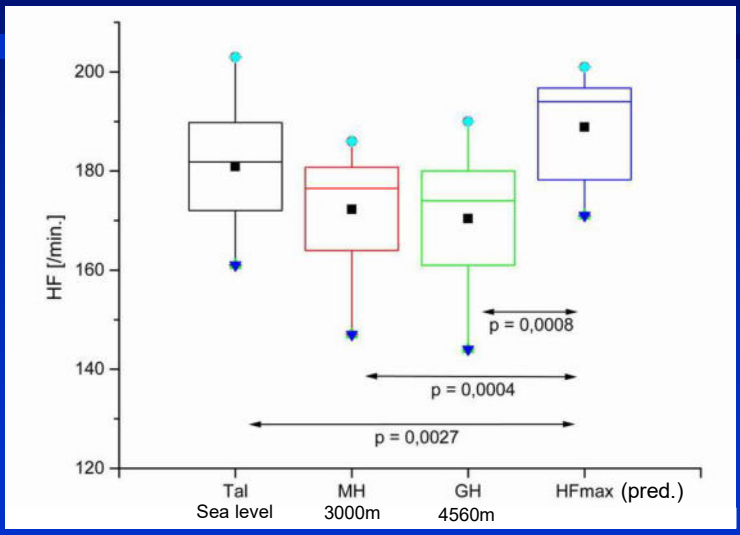
Questions:
1. Is there a bias when RPE scales are used?
2. If not: Which system indicates the body the level of RPE?

Pulse rate at altitude



Glaisher J: Notes of effects experienced during recent balloon ascents. Lancet 2: 559-560 (1862)

HRmax at altitude

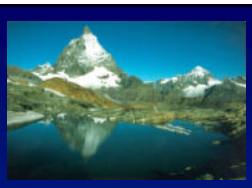


Küpper T. Workload and professional requirements for alpine rescue. Professoral thesis, 2006

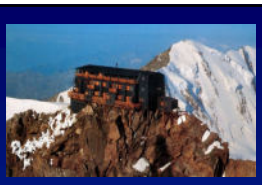
Validation of the scale at altitude

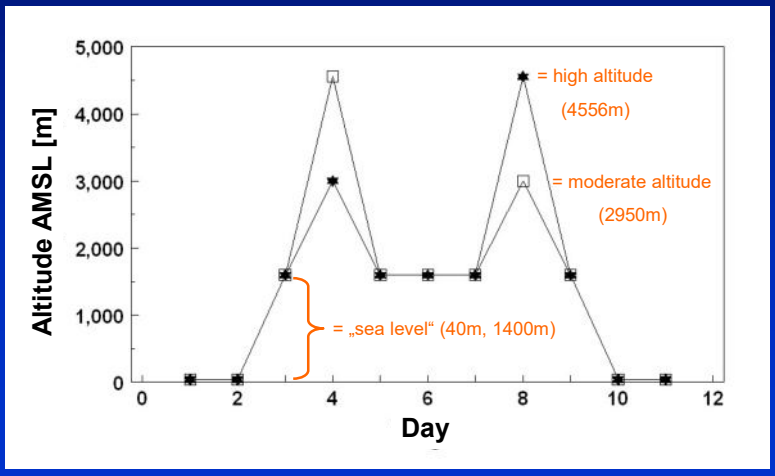
Material and Methods

- Collective
- Measurements
  - Spiroergometry with lactate analysis → 40W steps for 3' until exhaustion
  - Data: HF, lactate, blood pressure (BP), SaO_2, pO_2, Rf, VT…
  - Borg values (RPE)
- Statistical evaluation
  - p<0.05 defined as significant
  - covariance-analytic model (→ which factor?)
  - T-test (→ accuracy)
  - Maloney-Rastogi-Test (→ reliability)
  - Bland-Altman-plots (→ validity)
- Altitude profile



Altitude profile





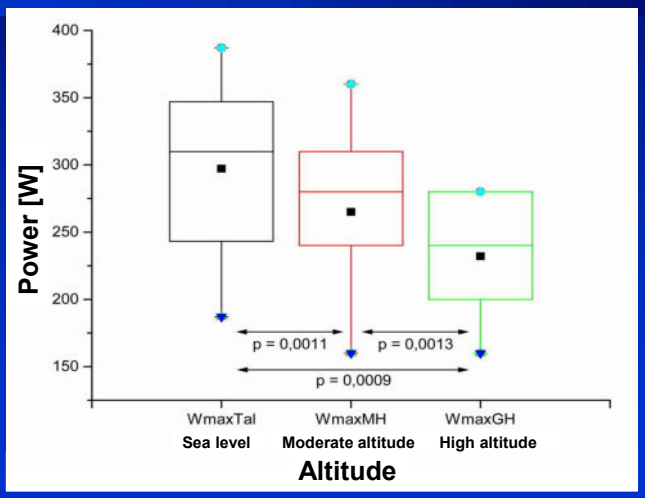
Validation of the scale at altitude

Data evaluation

- Boxplots
  - summary of all factors influencing maximal power at different altitudes
  - decrease from sea level to moderate altitude < decrease from moderate altitude to high altitude
  - power decrease: -12.4%/1000 hm ($p<0.05$ for all altitude steps)
- Bland-Altman-Plots
  - Each compares the results of two locations with different altitude
  - Average of two RPE against difference of two RPE
  - Only few values outside the limits of agreement (95%-interval)

Validation of the scale at altitude

➔ Max. power at different altitudes



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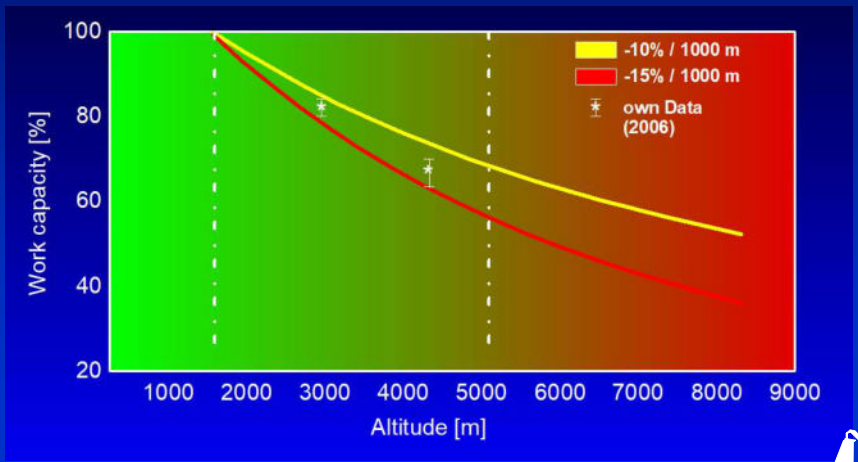
Validation of the scale at altitude

➔ Max. power at different altitudes



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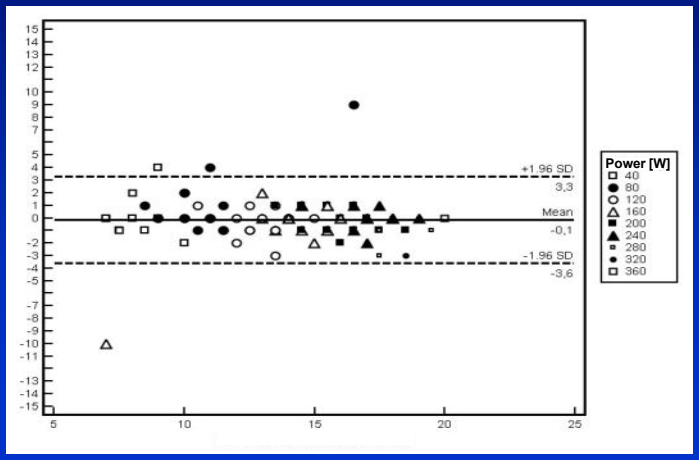
Validation of the scale at altitude

➔ Bland-Altman-Plots

Sea level – moderate altitude

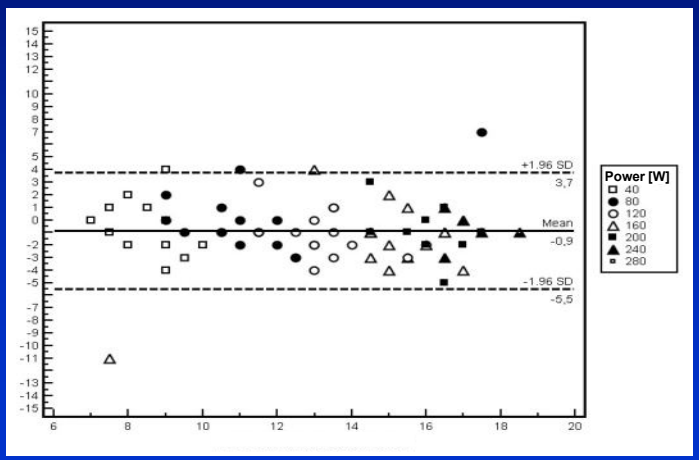


Average at sea level and at moderate altitude

Validation of the scale at altitude

➔ Bland-Altman-Plots

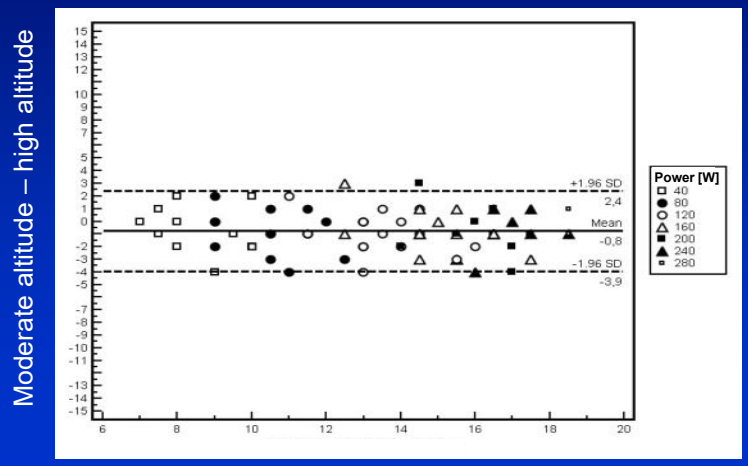
Sea level – high altitude



Average at sea level and at high altitude

Validation of the scale at altitude

➔ Bland-Altman-Plots



Average at moderate altitude and at high altitude

1st conclusion:

- Borg‘s RPE scale does not show a bias when used at altitude / in hypoxia
  - There must be another factor than HF or breathing volume to indicate the actual level of excertion

Arising questions:

1. What does Borg‘s scale really measure?
2. Which factor(s) indicate the actual level of excertion?

2nd conclusion:

- Borg‘s RPE scale is valid at least up to high altitude (5000m)!
  - Corresponds to about 11% O_2 (isobaric conditions at sea level)
  - Probably even > 5000m, but that has not yet been evaluated!

Margherita Hut at Signalkuppe (4560m),
seen from Parrotspitze (4325m)

3rd conclusion:

- Covariance-analytic model
  - Increase of systolic blood pressure (BP) is the most important factor ($p = 0.0356$)
  - Other factors are barely relevant ($p<0.1$): $FeCO_2$, VE, lactate

Possible explanation (hypothesis):

- Right cerebral hemisphere is dominant for negative emotions, impressions and basal autonomic reactions in stress situations
- Hypoxia → stress → activation of sympathic system in the autonomic nervous system
  - Increase of HR, BP, VE, Cortisol, Adrenaline…
    - Increase of systolic BP is the most frequent vegetative reaction in hypoxia
  - Correlation with activation of right cerebral hemisphere (lobus temporalis)
    - Left cerebral hemisphere has inhibitory effect on BP

How to prove the hypothesis?

- Difficult under altitude conditions
  - Weight of equipment!
    - EURAC at Bolzano?
- Direct methods
  - Electroencephalography (EEG) / Magnetoencephalography
    - Measure the electrical or magnetic field changes caused by simultaneous discharges of groups of neurons
- Indirect methods
  - Functional magnetic resonance imaging (fMRI) / positron emission tomography (PET)
    - Measure regional changes in blood flow (regional cerebral blood flow, rCBF) as a measure of neural activity


Thank you for your attention!
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Breithorn North Face (Welzenbach Route), solo
(60°, 1100m)
Th.K.