



## Current & future methods in endurance training to improve & maintain performance

**Billy Sperlich**  
Integrative & Experimental Exercise Science | University of Würzburg  
Speaker of Section Training Science | German Society of Sport Science



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**My Research Focus**



**Volume, Frequency, Intensity Distribution**  
to improve endurance performance

**Future Technology**  
for personalized training prescription

1. Improve fatigue resistance
2. Avoid overtraining
3. Prevent injuries
4. Identify talents

➔ Enhance Fitness (performance) and maintain health

- TRAINING
- BEHAVIOUR
- NUTRITION
- ENVIRONMENT
- MENTAL SKILL
- TECHNOLOGY

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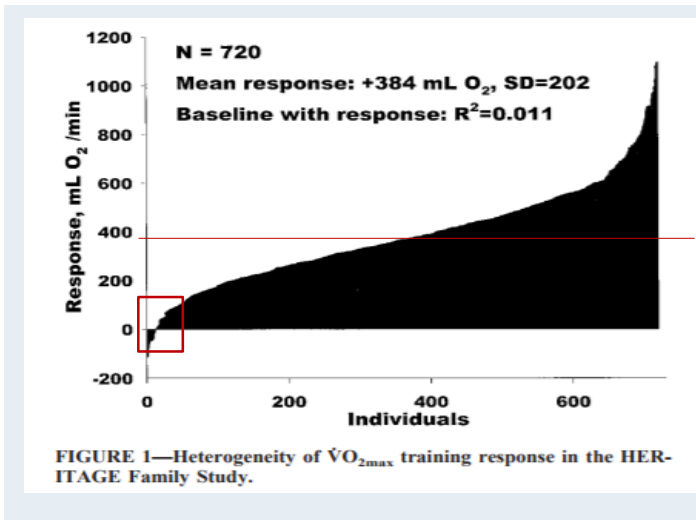
# Warm-up

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### Individual response - Recreational

#### Individual differences in response to regular physical activity

CLAUDE BOUCHARD and TUOMO RANKINEN  
 Pennington Biomedical Research Center, Baton Rouge, LA  
 Med Sci Sports Exerc. 2001 Jun;33(6 Suppl):S446-51; discussion S452-3.



+17% after 60 sessions in 20  
 Wo (55-75%  $VO_{2max}$ ; 30-50 min)

#### # Take Home :

- Huge variance
- (Non)/-Responder
- ”Negative” responder

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### Issues when comparing different sports

Body mass ↑ (absolute)  
 Sitting => BM isn't „carried“  
 Greater MVC  
 Concentric: approx. 50-120 strokes/min  
 TUT: approx. < 1000 ms/stroke  
 „Load“: approx. 90% BM/Stroke  
 ca. 0.9-1.5 Kilotons/week

Body mass ↓ (relative)  
 BM is carried  
 Lower MVC  
 Con./excent. ca. 200 strokes/min  
 TUT: ca. 120-180 ms/step  
 „Load“: approx. 300% BM/step  
 approx. 30 Megatons/week

„moderate“ load  
 => sessions/week: 25-30h

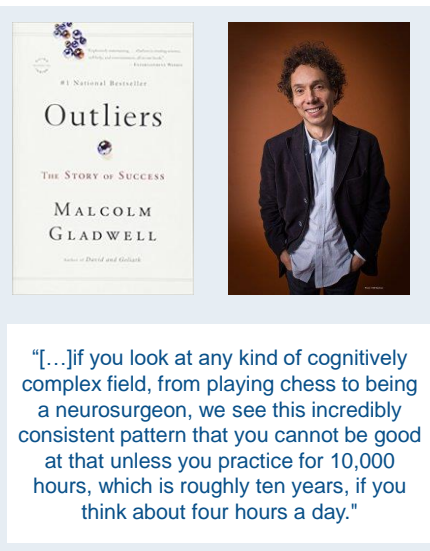
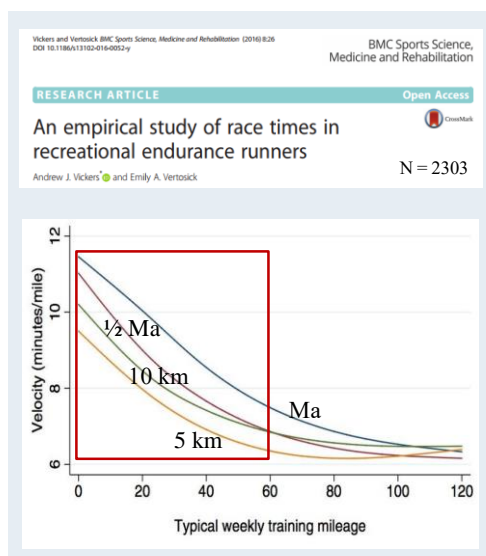
High load  
 „bone-breaking“  
 => sessions/week: 10-12h

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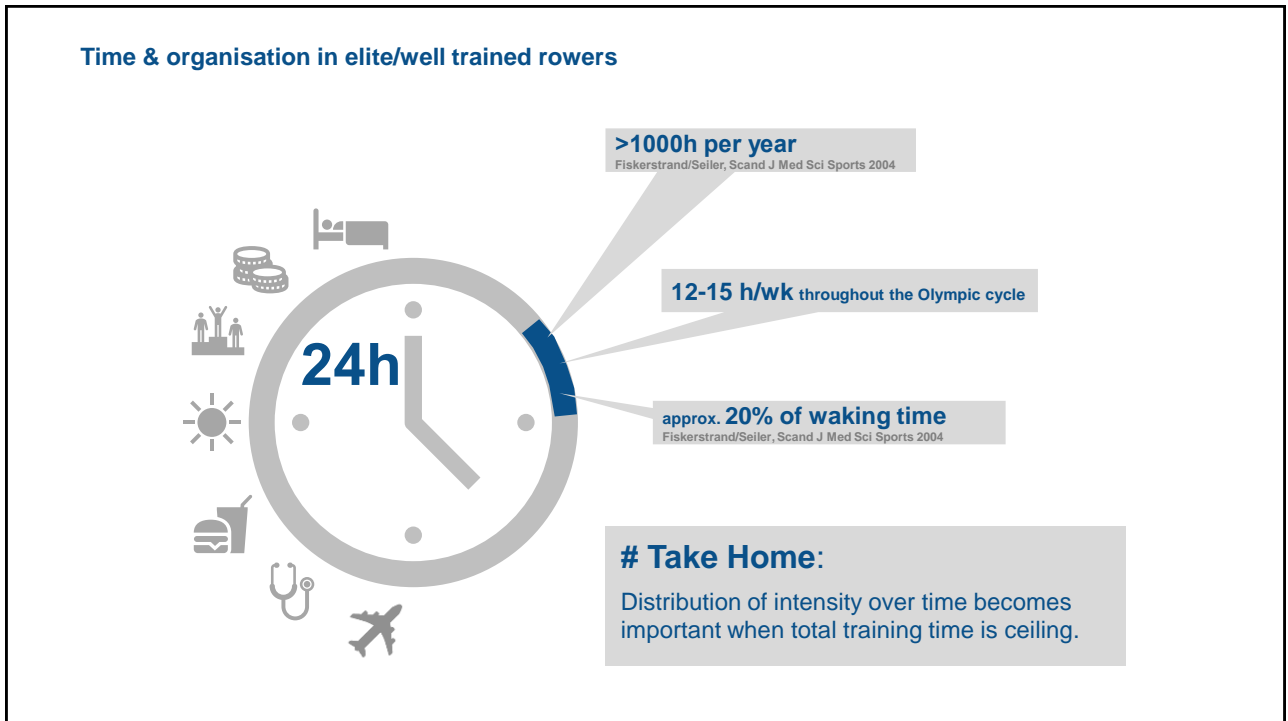
# Volume

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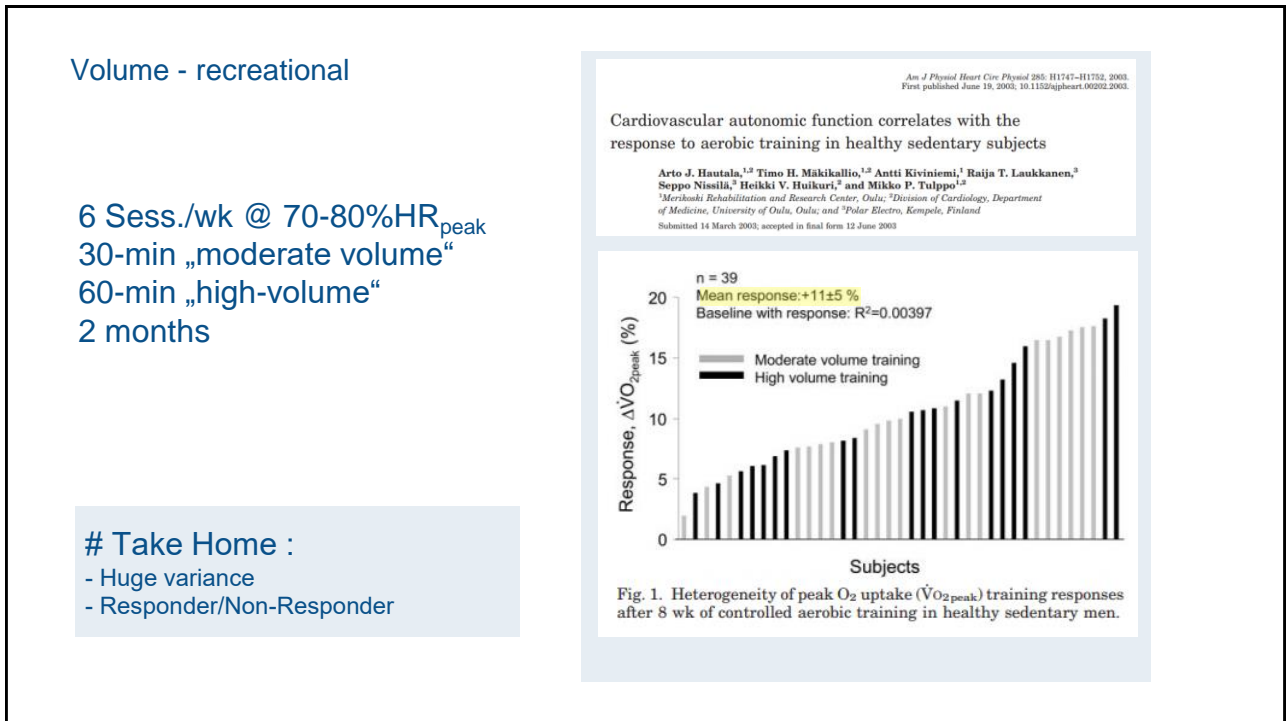
„Elite“ takes time & „miles“



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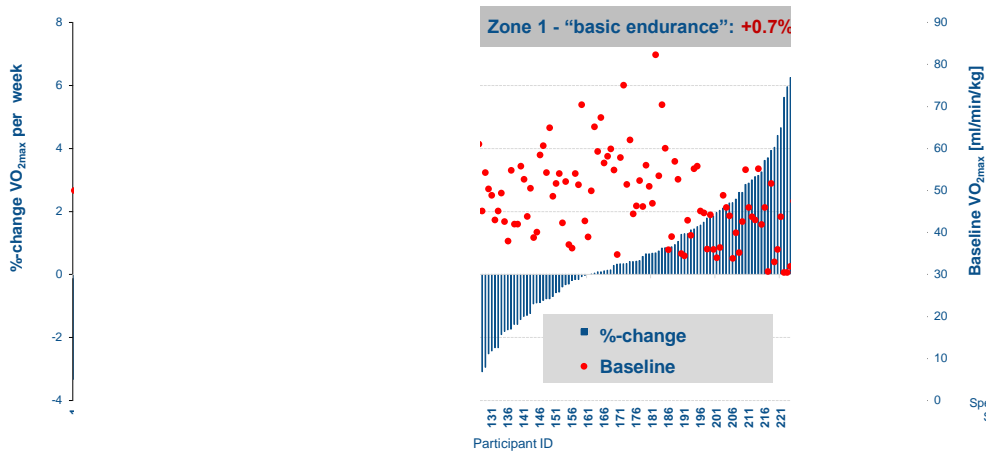


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### Pre-post VO<sub>2max</sub> (3-9 weeks; 2-5 sessions/week, n=265)

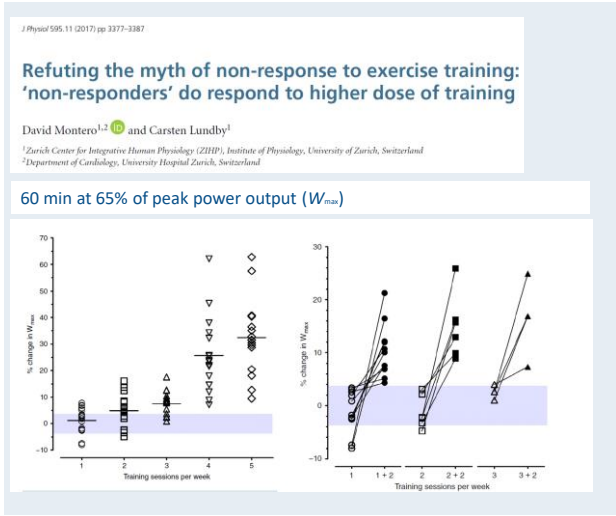


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# Frequency

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### Frequency – example from recreational cycling



# Take Home :  
For some individuals: do more sessions

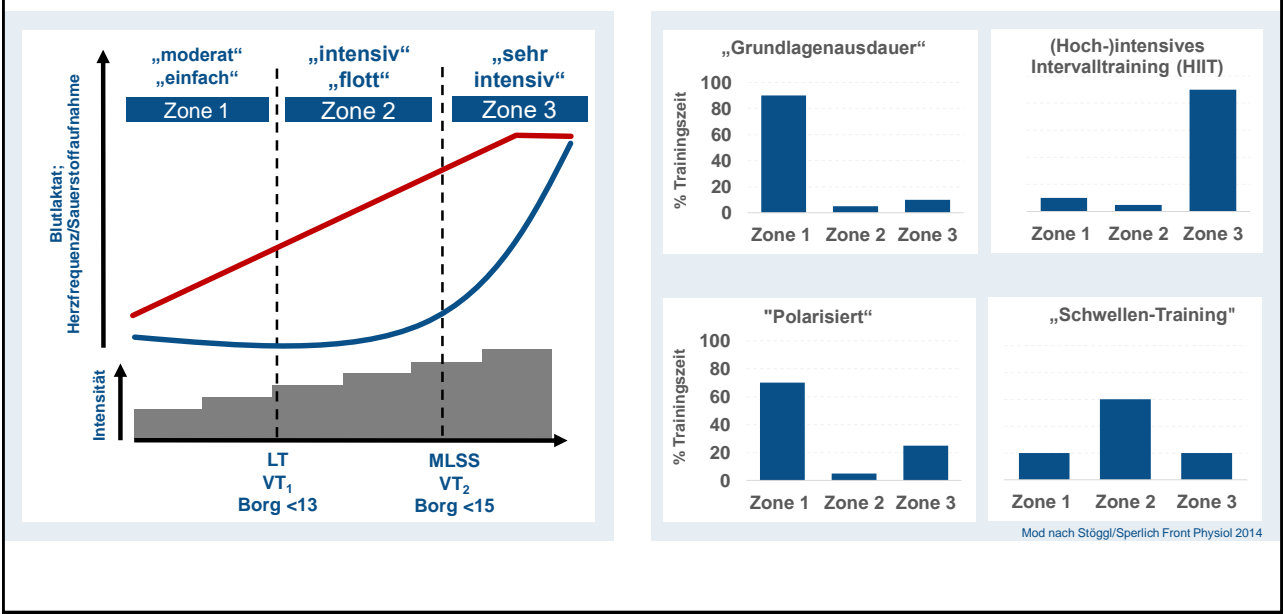
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# Intensity

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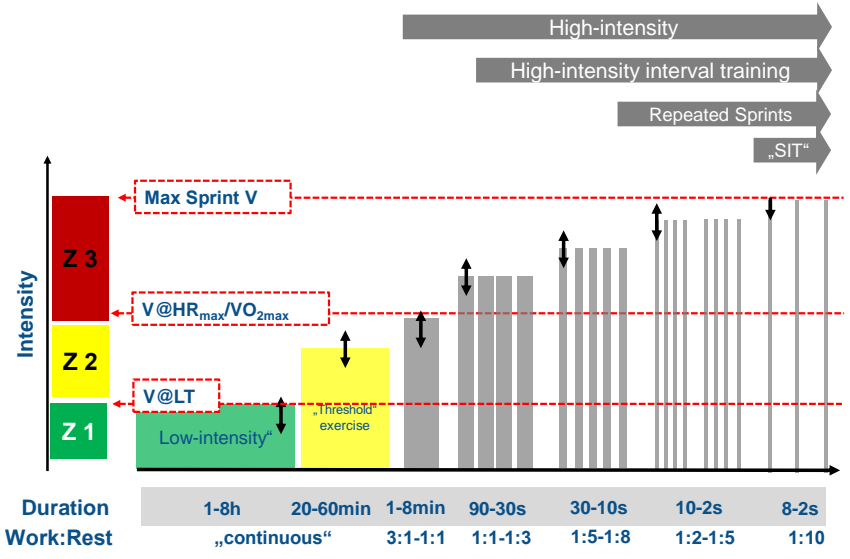


Intensitätsverteilung - Ein einfaches Modell



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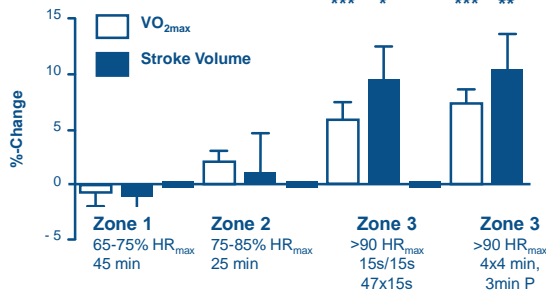
“HIIT” spectrum



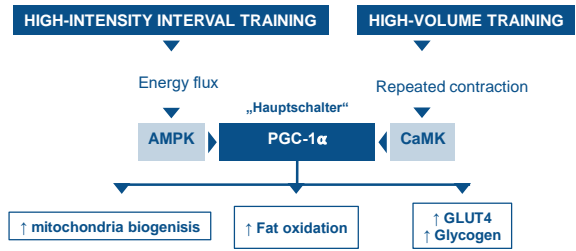
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### HIIT vs moderate-continuous exercise

8 Wo 3x/Wo



Mod. Helgerud et al. MSSE 2006



Mod. Laursen 2010 SJMSS

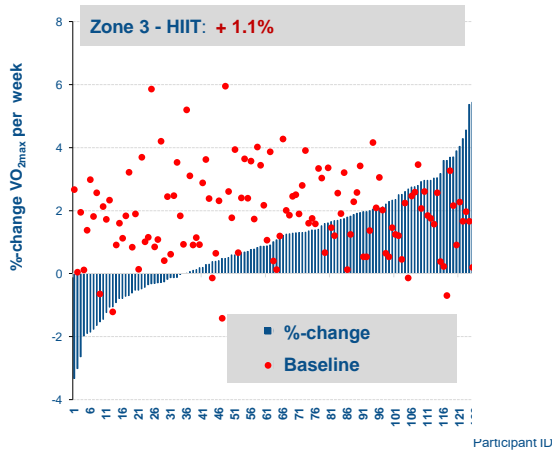
$$\text{Fick'sche Equation: } VO_2 = HF \times SV \times \Delta(aO_2 - vO_2)$$

Cardiac output (Q)  
„O<sub>2</sub>-transport“

Arteriovenous Oxygen Difference  
„O<sub>2</sub>-utilization“

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### Pre-post VO<sub>2max</sub> (3-9 weeks; 2-5 sessions/week, n=265)

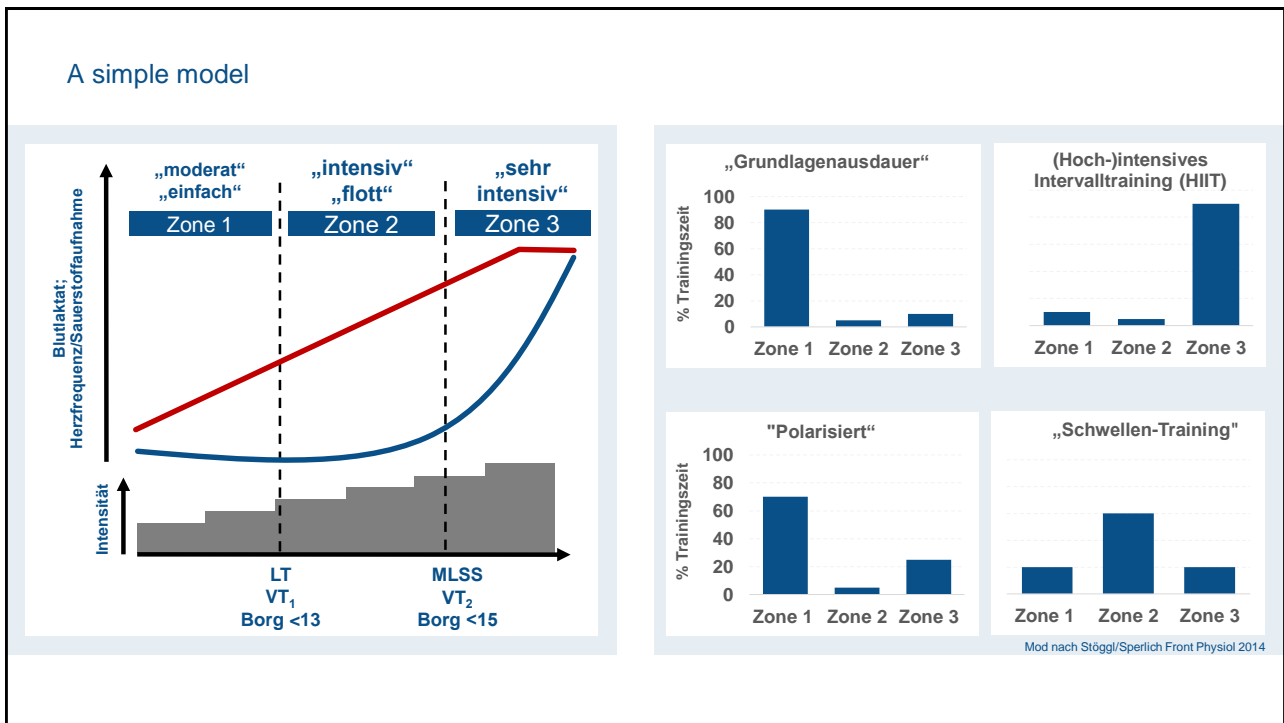


Düking et al. JAP submitted  
Zinner et al. MSSE 2018;  
Born et al. Front Physiol 2017  
Sperlich et al. Front Physiol 2017  
Messler et al. J Atten Disord 2016  
Schmitt et al. Physiol Rep 2016  
Stoggl/Sperlich Front Physiol 2014  
Sperlich et al. J Strength Cond Res 2011  
Sperlich et al. Eur J Appl Physiol 2010

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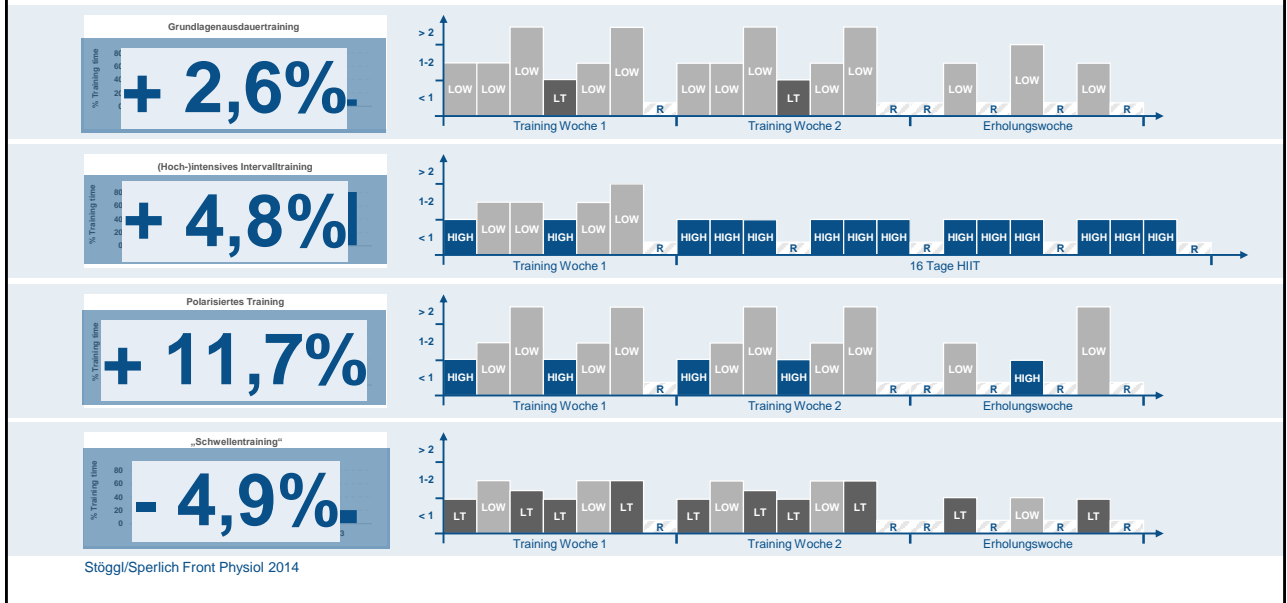
# Intensity distribution

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9-wk experiment (n=48, VO2max: 63±7 mL/min/kg)



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Intensity distribution in endurance sport

**The training intensity distribution among well-trained and elite endurance athletes**

Legend: Zone 1 (black), Zone 2 (grey), Zone 3 (white)

**A Preparation Period**

- Explos et al. 2007 - cycling - elite
- Stögl et al. 2011 - cross-country skiing - 18 months
- Louis et al. 2000 - cycling - transition phase
- Hartmann et al. 1980 - rowing
- Trommsdorff et al. 2014 - cross-country skiing - general preparation
- Mohrman et al. 1981 - rowing - 18 weeks build-up
- Quodt et al. 2009 - rowing
- MS-AT

**B Pre-competition Period**

- Explos et al. 2007 - cycling - elite
- Hartmann et al. 1980 - rowing
- Saller and Hoptmann 2008 - cross-country skiing - 12 weeks
- Phares et al. 2014 - rowing - 28 weeks
- Louis et al. 2000 - cycling
- Blair et al. 2001 - rowing - 8 weeks before Olympic
- Strommer et al. 2000 - rowing - 14 weeks
- Trommsdorff et al. 2014 - cross-country skiing - specific preparation
- Quodt et al. 2009 - rowing
- MS-AT

**C Competition Period**

- Louis et al. 2000 - cycling
- Trommsdorff et al. 2014 - cross-country skiing
- MS-AT

Research Topic

**Training intensity, volume and recovery distribution among elite and recreational endurance athletes**

frontiers in Physiology

Overview | 18 Articles | 79 Authors

Topic Editors

**Thomas Leonhard Stögl**  
University of Salzburg  
Salzburg, Austria  
75 publications

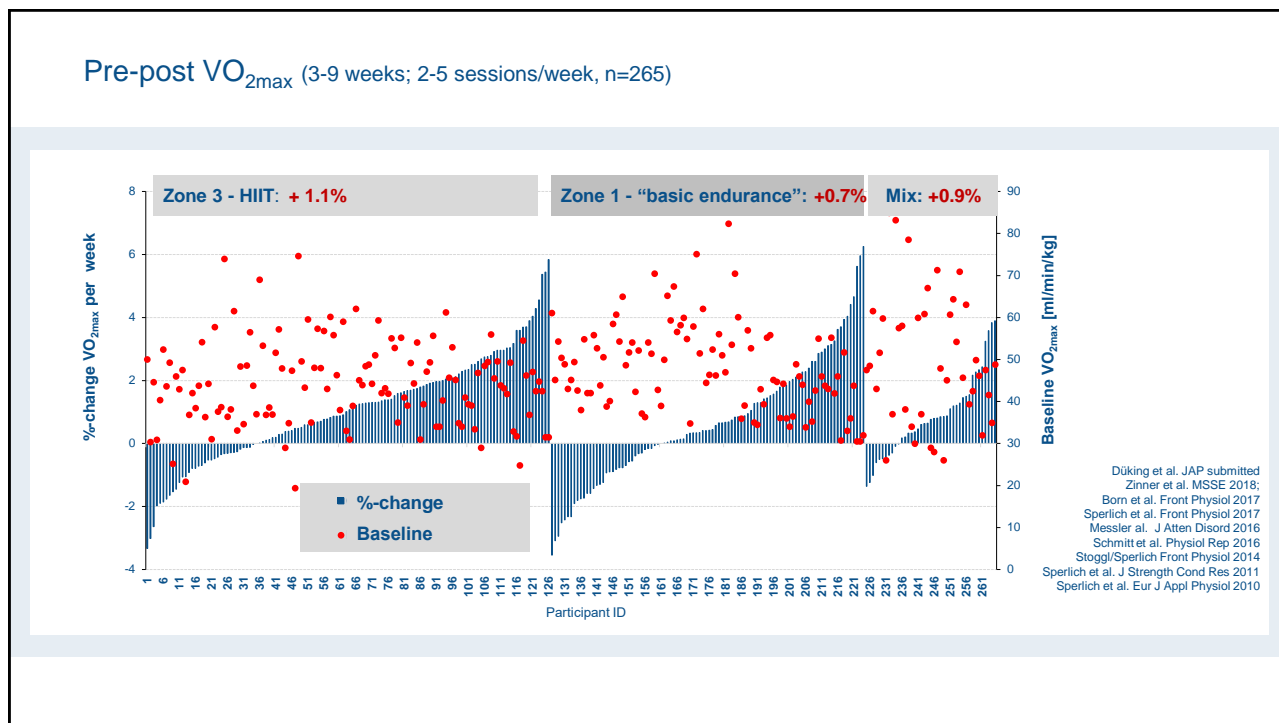
**Billy Sperlich**  
University of Würzburg  
Würzburg, Germany  
119 publications

162,910 VIEWS

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### Adaptation to „free-living & exercising-biology“

**The Responses of Elite Athletes to Exercise: An All-Day, 24-h Integrative View Is Required!**

Billy Sperlich<sup>1</sup> and Hans-Christer Holmberg<sup>1,2,3,4</sup>

<sup>1</sup>Integrative and Experimental Exercise Science, Institute for Sport Sciences, University of Würzburg, Würzburg, Germany  
<sup>2</sup>Risö Research Center, Swedish Institute of Sport Research, Örebro, Sweden  
<sup>3</sup>School of Sport Sciences, UiT The Arctic University of Norway, Tromsø, Norway  
<sup>4</sup>School of Kinesiology, University of British Columbia, Vancouver, BC, Canada

24h

0.5 – 4h

Max. waking time: 20%

**a) Activities of daily living**

**b) Sleep**

**c) Recovery procedures e.g.:**

- Massage & Stretching & Foam Rolling
- Active/passiv recovery
- Compression clothing
- Cold water immersion

**d) Nutrition Pre-, intra-, post Training**

**e) Environment (UV, Heat, Altitude, Cold, Ozone, particulate matter, noise...)**

**f) Circadian Rhythm**

**g) Psycho-social aspects (work, family, friends, sponsors, finance, media, travel)**

**h) Alcohol, drugs...**

**i) Doping**

**j) Factor x, y, z**

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## Wearable sensors

**BMJ Journals**  
British Journal of Sports Medicine  
Billy Sperlich<sup>1</sup>, Hans-Christer Holmberg<sup>2,3,4</sup>

**Wearable, yes, but able...?: it is time for evidence-based marketing claims!**

Düking, Sperlich *Curr Sports Med Rep* 2018  
 Düking, Sperlich *Sensors* 2018  
 Düking, Sperlich *JMIR Mhealth Uhealth* 2018  
 Düking, Sperlich *Front Physiol* 2018

Sperlich et al. *Front Physiol* 2017  
 Sperlich/Holmberg *Front Physiol* 2017  
 Düking, Sperlich *Front Physiol* 2017  
 Düking, Sperlich *Front Physiol* 2016

- Technology not (often) validated
- Some variable (not yet) to measure
- Urgent need for evaluation

Research Topic  
**Wearable Sensor Technology for Monitoring Training Load and Health in the Athletic Population**

frontiers in Physiology

Overview Articles 28 Authors 115

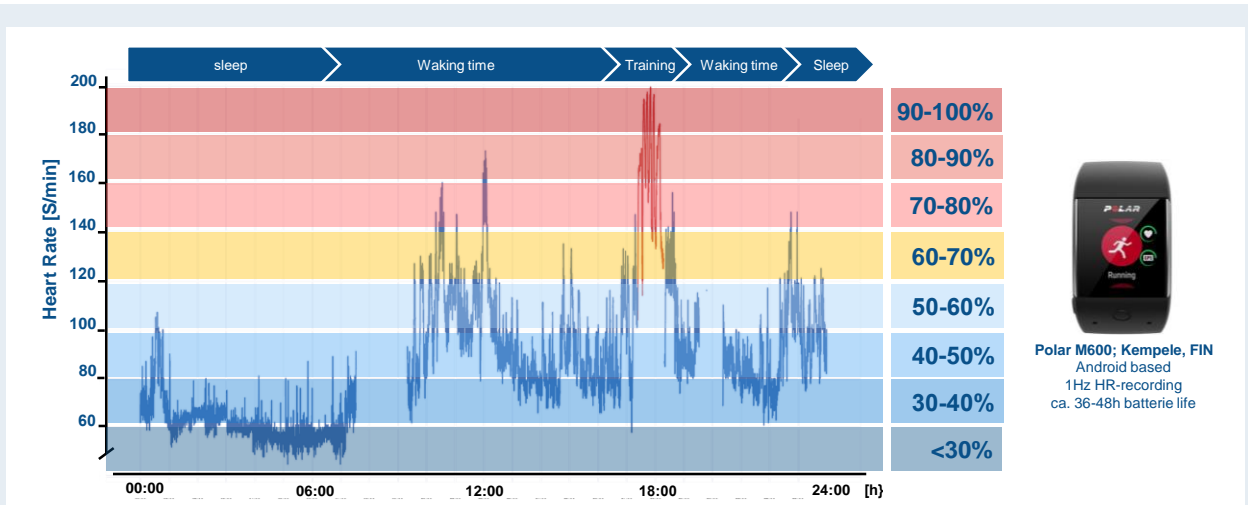
Topic Editors

- Billy Sperlich**  
University of Würzburg, Würzburg, Germany  
117 publications
- H-C Holmberg**  
Häl Söders University, Sundsvall, Sweden  
199 publications
- Kamran Aminian**  
École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Views: **139,740**

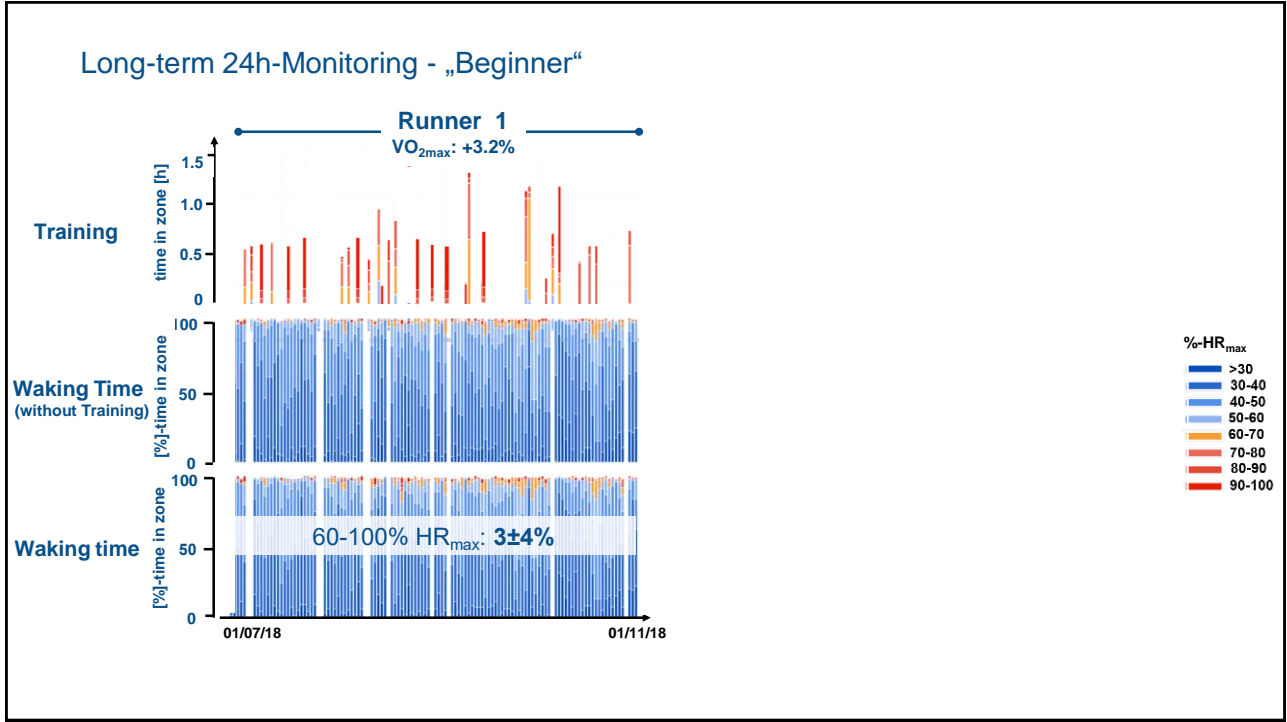
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## 24h-continuum & intensity zones

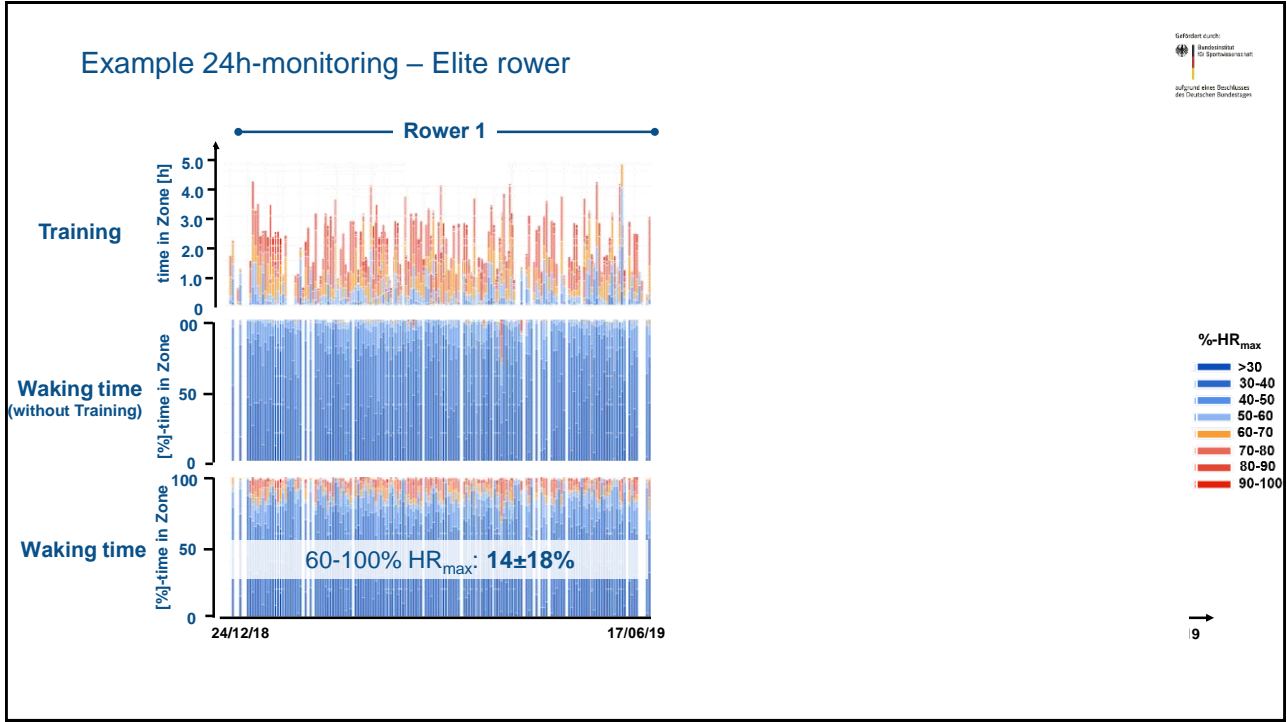


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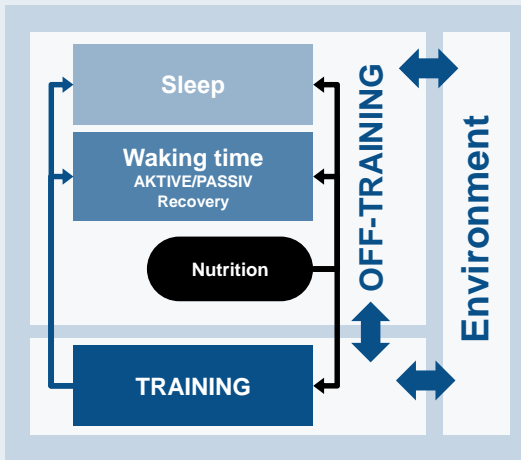


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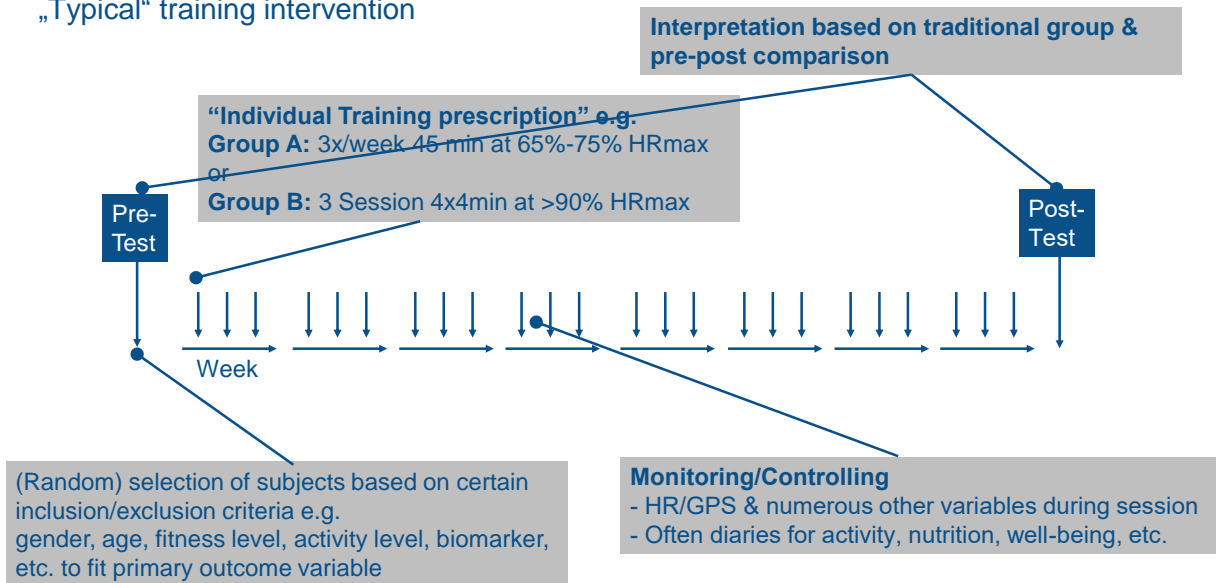
Perspectives: 24-h continuum



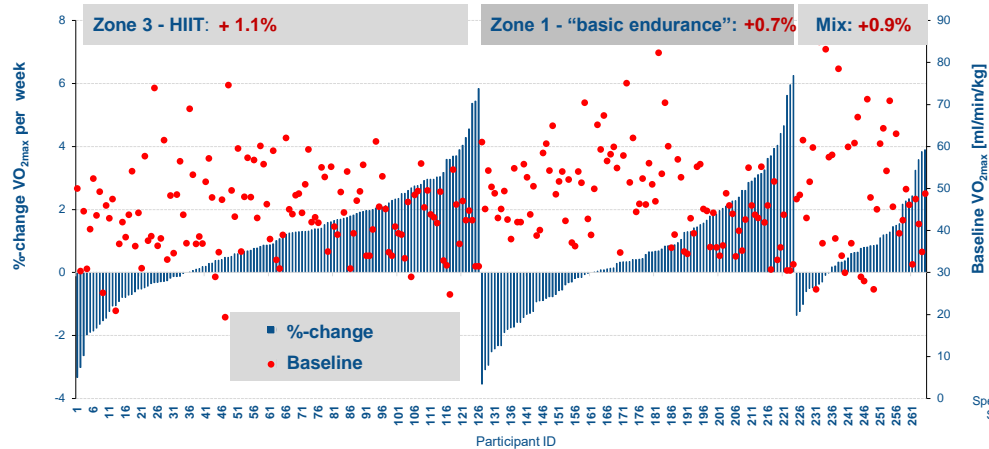
- Interactions
- Scalable
- Integration of novel (24h-) technology (blood pressure, near-infrared spectroscopy, pulse rate variability etc.)
- Long-term studies
- Multi-center designs
- Pattern recognition
- Prediction of changes
- Recommendations for course of action
- Situation-adapted adjustability of training stimuli

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„Typical“ training intervention



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Pre-post  $\text{VO}_{2\text{max}}$  (3-9 weeks; 2-5 sessions/week, n=265)

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Merci beaucoup!!!



/billysperlich



billy.sperlich@uni-wuerzburg.de

HOLMBERG HC, ZINNER C, BORN DP, MESTER J, ACHTZEHN S, SCHIFFER T, DUKING P, ENGEL FA, KRUEGER M, WALLMANN-SPERLICH B, DE MAREES M, FREIWALD J, HAEGELE M, HOPPE MW, WAHL P, BAUMGART C, STRUDER HK, SCHULTE S, WINTER R, HAUSER A, REED JL, STEINACKER JM, LINVILLE J, WEGRZYK J, SAREBAN M, WINKERT K, MICHELS G, HARTEL S, KILIAN Y, WEISE K, TREFF G, KOHL-BAREIS M, KLEINODER H, WALDMANN H, STRAHLER J, CHTOUROU H, WEHRLIN JP, WILLIS SJ, LINDNER N, MILLET GP, KOEHLER K, PODLOG LW, KNICKER A, STOGGL T, KRUGER M, FRICKE H, BECKER M, FUSS FK, FAISS R, HOTH O, MEYER T, ZELLE S, ENGEL F, KUNZ P, BOS K, VON STAUFFENBERG V, OSMAN-REINKENS S, SCHAFFER-OLSTAD D, HEBERT-LOSIER K, KERAMITSOGLU I, MUNIZ-PARDOS B, REUSS-BORST M, KALLIOKOSKI KK, NIKOLAIDIS PT, PITSILADIS YP, HELMPROBST J, AL-AYOUBI S, STOCKINGER C, LAAKSONEN MS, SCHUMACHER F, HECKSTEDEN A, DE MAREES M, LINVILLE JW, DE CLERCK I, SPERLICH PF, STRUEDER HK, KJENDLIE PL, HEILEMANN I, ACKERMANN A, MOLLINGER A, ANDERSSON E, KASKINORO K, VON PAPAN H, BORNEFELD J, WEHMEIER UF, CALBET JAL, PFEIFFER M, FERRAUTI A, HOFFMANN U, FROBOESE I, ZAGATTO AM, KNECHTLE B, GEESMANN B, HOLLMANN W, BAESSLER B, LOCHMANN M, NIEBAUER J, FAKHFAKH H, GOERNERT F, SANDBAKK O, HAMMOUDA O, SUTEHALL S, TRABELSI K, MESSLER CF, DITTMAR KH, BESENIUS E, CALBET JA, LEPPICH R, BOUSHEL R, THISSEN A, SULADZE S, STOGGL TL, KONDRIC M, PFISTER R, WAGNER MO, PIGOZZI F, STOCKER U, GARIVET G, SCHOFFL V, KILDUFF L, RICHTER K, HERLITZ B, STAMMEL C, SOUISSI N, MEMMERT D, SCHMITT J, GEISLER S, BERGER MM, LEFTER MD, IBRAHIM H, HILBERG T, JANSSEN M, KAPOOR S, MATHES S, ZHANG SY, LOSERT H, DONATH L, WILLIS SJ, VESIN JM, HAMMES D, JANSEN C, SWAREN M, FOCKE T, HAHN LS, CINAR S, BLOCH W, TRENK D, WEISS K, PELKA M, ERWIN N, SUPEJ M, AMMAR A, FAUDE O, KAMP CF, BEHR T, EDEL A, WOLF P, LIMA G, BUHR M

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