

Exercise & Training Convention | 16.-17.05.2025 | Universität Bayreuth

Wearables - Wie neue Technologien den Trainingsprozess transformieren und wo sie versagen.

Billy Sperlich

Lehrstuhl für
Integrative & Experimentelle Trainings- & Bewegungswissenschaft
Universität Würzburg



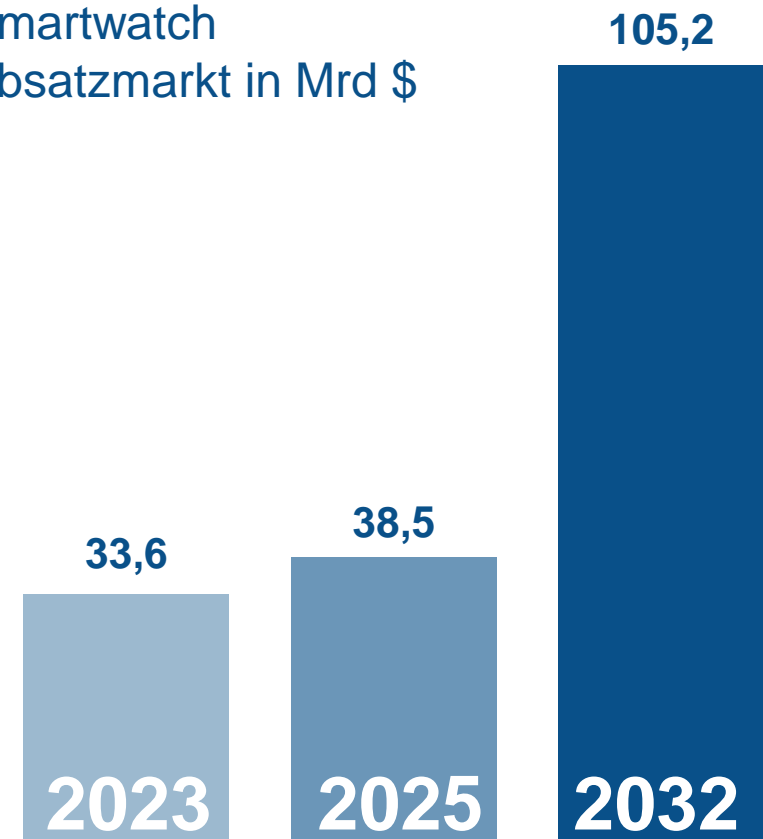
@sportsandscience



Wer besitzt eine Smartwatch?



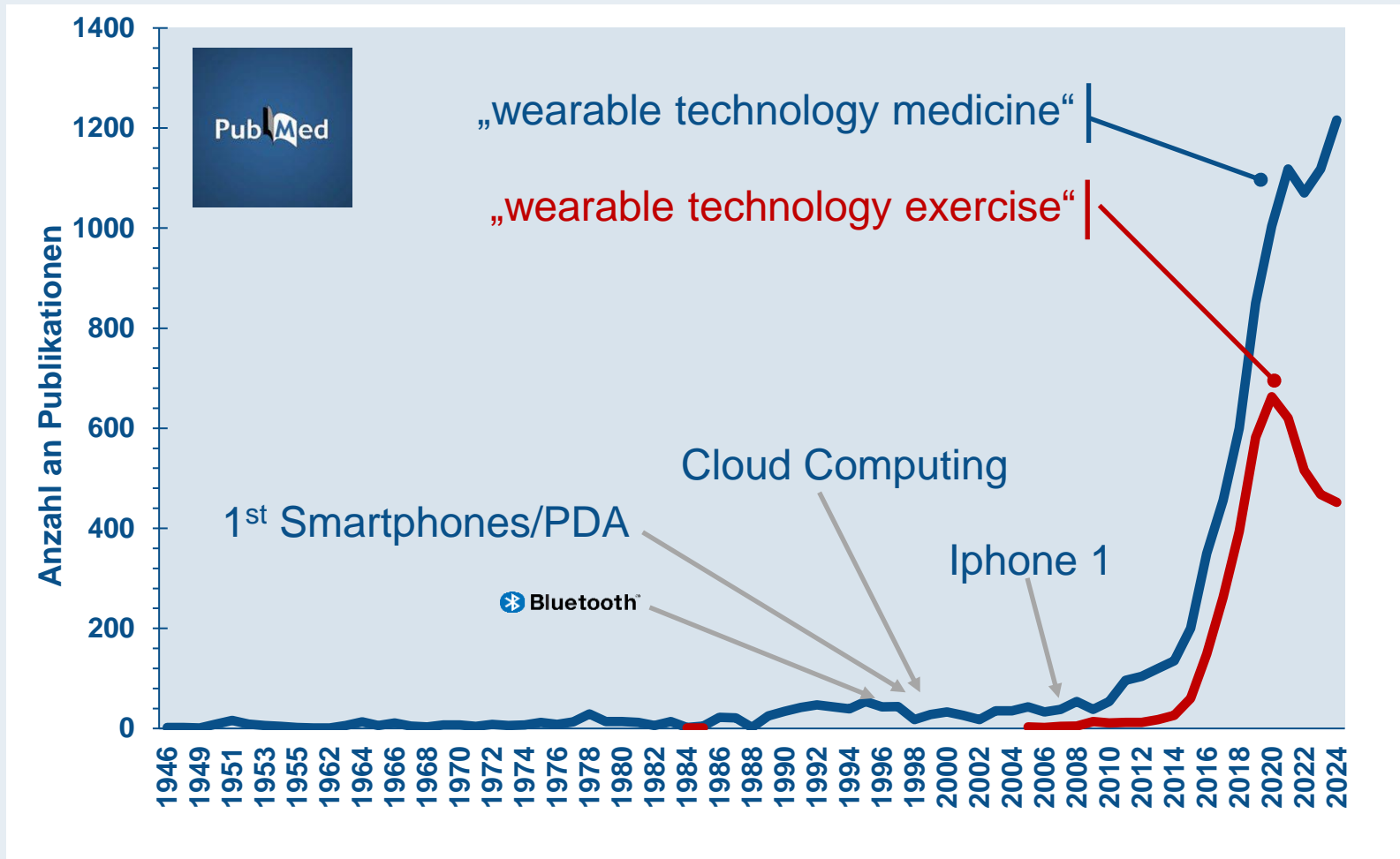
Smartwatch
Absatzmarkt in Mrd \$



Quelle:

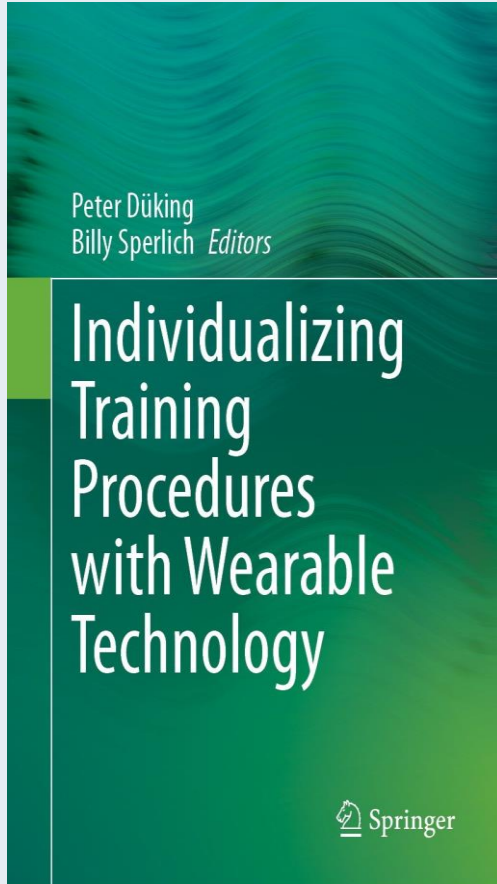
<https://www.fortunebusinessinsights.com/de/smartwatch-markt-106625>

Wearables: Anzahl an Publikationen & Bedeutung



Global Fitness Trend 2025

- 1 Wearable technology
- 2 Mobile exercise apps
- 3 Fitness programs for older adults
- 4 Exercise for weight loss
- 5 Traditional strength training



1

Warm-Up

2

Warum Wearables wichtig sind

3

Aktuelle Beispiele

4

Überlegungen & Konsequenzen

Tragbare Sensorik: "Wearables" / "Wearable Technology"

- Sensoren, die **Nahe, auf oder unter der Hautoberfläche** getragen werden.
- **Erkennen, analysieren und übermitteln** Informationen von Körpersignalen und/oder Umgebungsdaten
- geben (zeitnah) **Biofeedback**.

O₂-Kinetik
Atemfrequenz
Substrate

Beschleunigungssensor
GPS
Herzfrequenz
Belastungsempfinden

Körperkerntemperatur
HRV
Schweiß

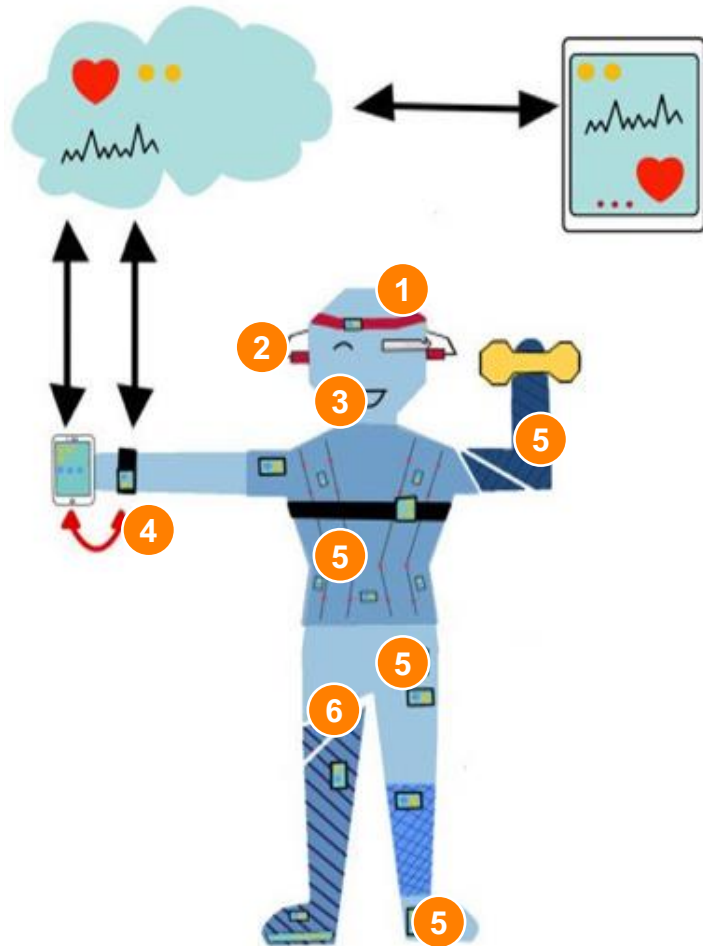
EMG
(Muskelaktivierung)

Nahinfrarotspektroskopie
(Oxygenierung)

Sensorsohle
(Drücke, Frequenz...)

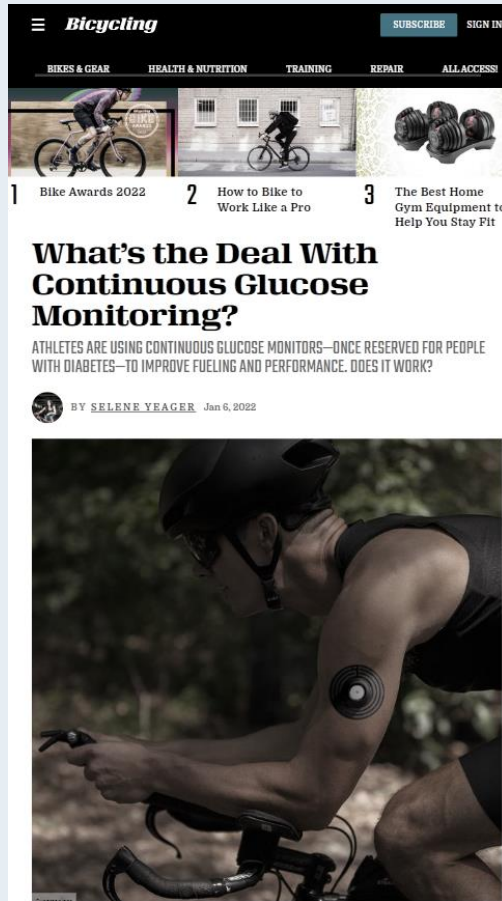


Wearables: Sensorik & Lokalisation



		1	2	3	4	5	6
	Sensor/Technologie	Stirnband/ Mütze/Brille/ Schuh	In-Ear	„Ingestible“	Smart- watches/ -phone	Integriert in Kleidung/ Sportgerät	Klebe- elektroden
	Akzelerometer/ Inklinometer	X	X		X	X	X
	Enzymatik			X			X
	Kamera			X	X		
	Optischer Sensor		X		X	X	X
	Elektromyographie						X
	Elektroenzephalogramm	X					
	Elektrodermographie				X	X	X
	GPS				X	X	
	Mikrofon		X	X	X		
	(Puls)Oximeter	X	X		X	X	X
	Barometer			X	X	X	X
	Thermometer	X	X	X			X
	UV-Strahlung	X			X	X	X
	Psychometrie				X		

Adhesives, Patches, Klebeelektroden



Bicycling SUBSCRIBE SIGN IN

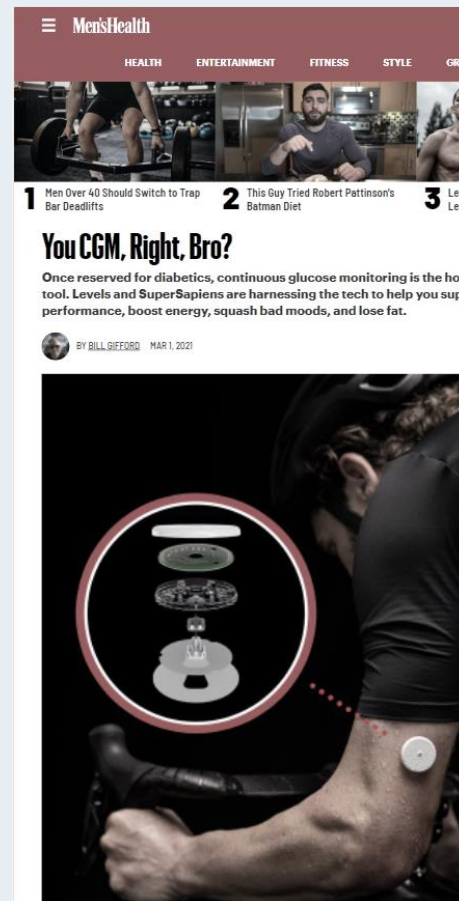

BIKES & GEAR HEALTH & NUTRITION TRAINING REPAIR ALL ACCESS

1 Bike Awards 2022 2 How to Bike to Work Like a Pro 3 The Best Home Gym Equipment to Help You Stay Fit

What's the Deal With Continuous Glucose Monitoring?

ATHLETES ARE USING CONTINUOUS GLUCOSE MONITORS—ONCE RESERVED FOR PEOPLE WITH DIABETES—TO IMPROVE FUELING AND PERFORMANCE. DOES IT WORK?

BY SELENE YEAGER Jan 6, 2022



Men's Health


HEALTH ENTERTAINMENT FITNESS STYLE GROOMING

1 Men Over 40 Should Switch to Trap Bar Deadlifts 2 This Guy Tried Robert Pattinson's Batman Diet 3 Learn Leg

You CGM, Right, Bro?

Once reserved for diabetics, continuous glucose monitoring is the hot tool. Levels and SuperSapiens are harnessing the tech to help you super performance, boost energy, squash bad moods, and lose fat.

BY BILL GIFFORD MAR 1, 2021




RUNNER'S WORLD SUBSCRIBE UK

Libre Sense: What is the biosensor used by Eliud Kipchoge?

Kipchoge has been using the glucose monitoring technology to train for the NN Mission Marathon this weekend

BY JACOB MORETON 16/04/2021




IRONMAN

Never Bonk Again: How Glucose Data Can Change Your Training, Your Racing, and Your Life


Take control of your nutrition like you never have before with Supersapiens.

Implantables

 **frontiers**
in Physiology

published: 05 September 2017
doi: 10.3389/fphys.2017.00629

OPINION



A SWOT Analysis of the Use and Potential Misuse of Implantable Monitoring Devices by Athletes

Billy Sperlich^{1*}, Peter Dürking^{1,2} and Hans-Christer Holmberg^{2,3,4}

¹Integrative and Experimental Exercise Science, Institute for Sport Sciences, University of Würzburg, Würzburg, Germany, ²Swedish Winter Sports Research Centre, Mid Sweden University, Östersund, Sweden, ³School of Sport Sciences, UiT The Arctic University of Norway, Tromsø, Norway, ⁴School of Kinesiology, University of British Columbia, Vancouver, BC, Canada

 **techworld**
FROM IBC

Features Technology Innovation Jobs Follow: 

Home > Features > Apps & wearables Features >

Implantables will be a thing in three years says Greenwave systems' Jim Hunter

Implantables will be a big thing in three years according to IoT and M2M firm Greenwave Systems

Implantables are the future, not wearables says Greenwave Systems' chief scientist

 By Christina Mercer | Nov 10, 2016

Share    

Wearable technology will soon be surpassed by smart devices people can implant into their bodies, according to Greenwave Systems' chief scientist Jim Hunter.

"I think implantables will be a big thing in three years," Hunter tells *Techworld* at Web Summit in Lisbon.



 **TAGESSPIEGEL**

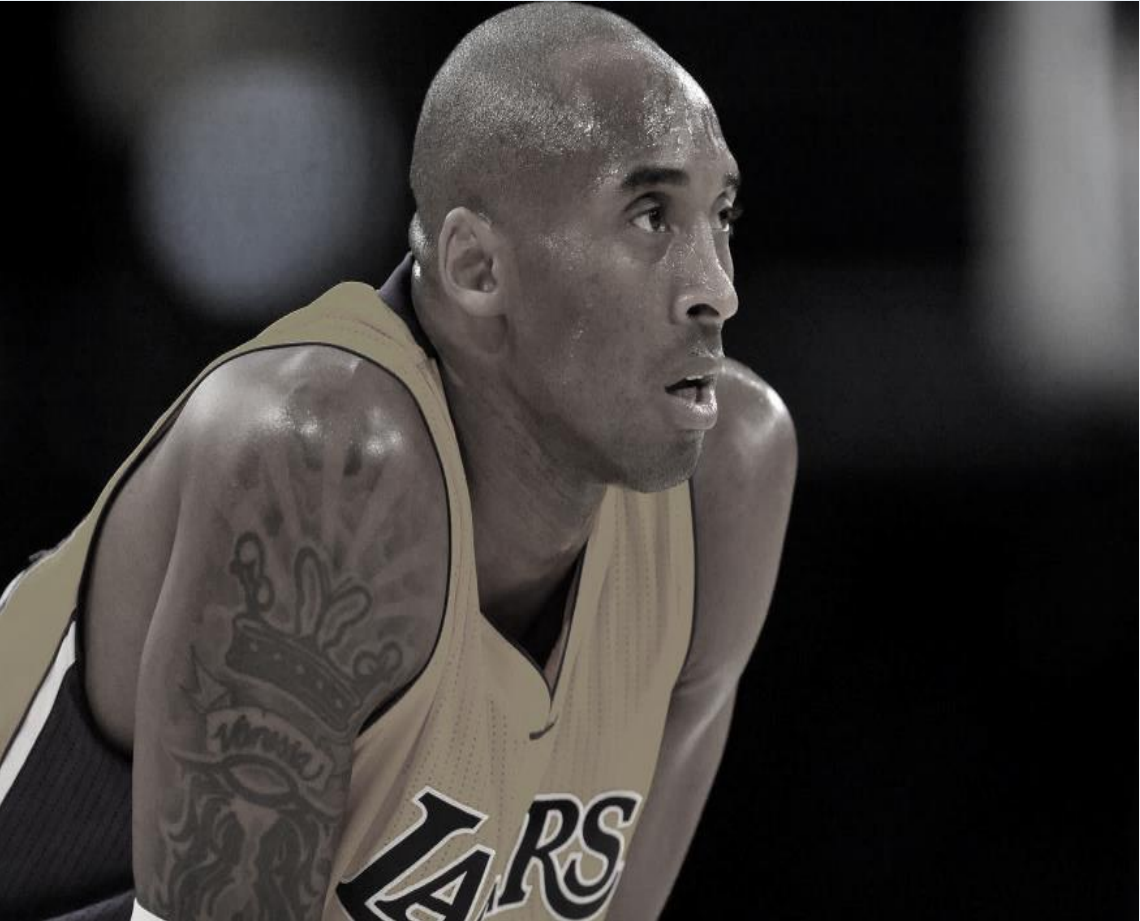


Trend in Schweden Warum Tui seinen Mitarbeitern Mikrochips unter die Haut pflanzt

115 der Tui-Mitarbeiter in Schweden stimmten dem Angebot zu. Sie nutzen den Chip als Schlüssel und Datenspeicher. In Deutschland überwiegt die Skepsis.

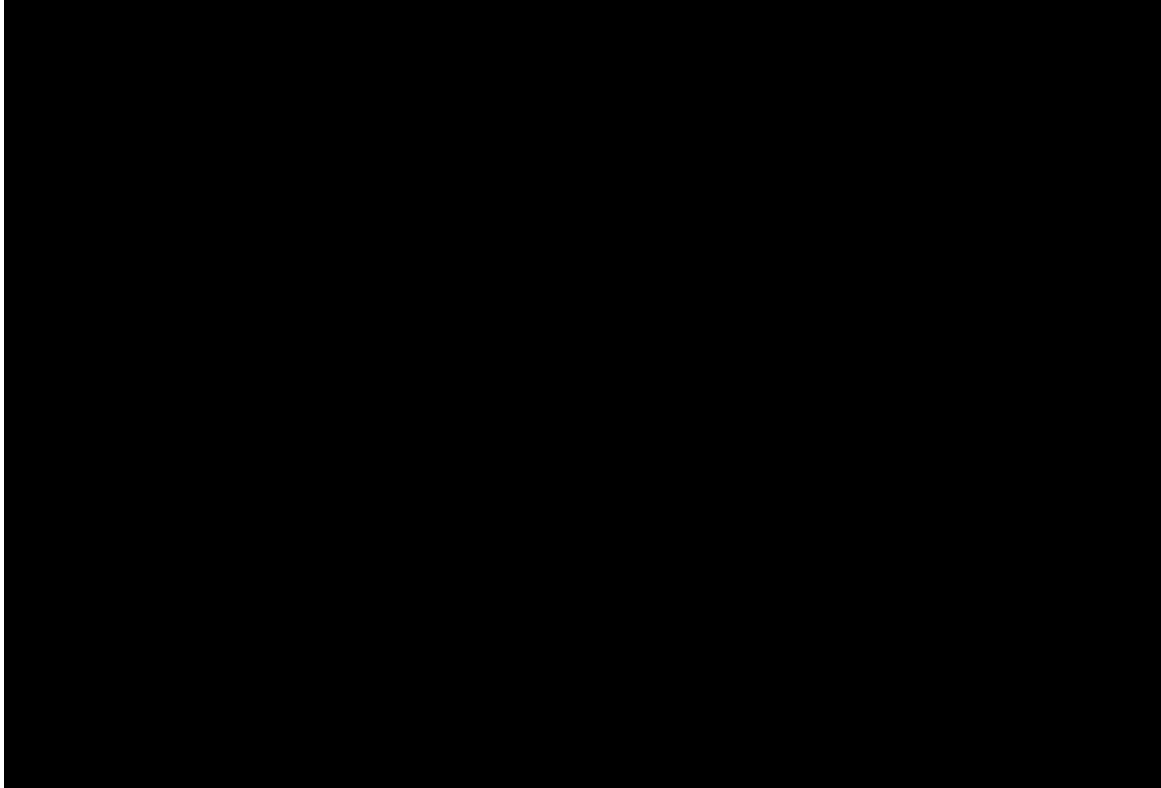
01.11.2019, 18:16 Uhr

Neue Anwendung



YouTube ^{DE}

<https://www.youtube.com/watch?v=9iFuTaqD4fM>



“Neue” Sensoren



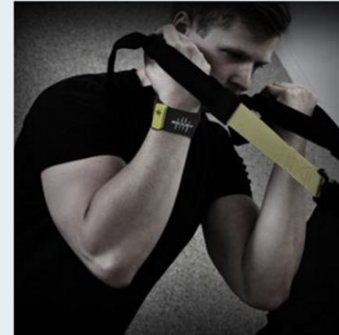
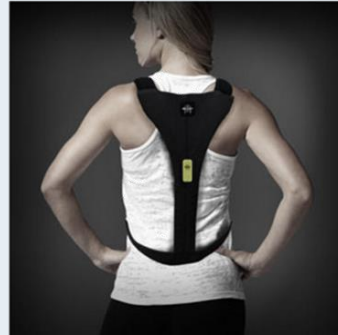
24-h Blutdruckmessung früher & heute



OMRON

**FDA
CLEARED**

Bekannte/andere Beispiele



Traumatic sports injuries tracked, prevented with high-tech mouthguard

by DEVIN COLDEWEY



1

Warm-Up

2

Warum sind Wearables in der Wissenschaft & Praxis wichtig?

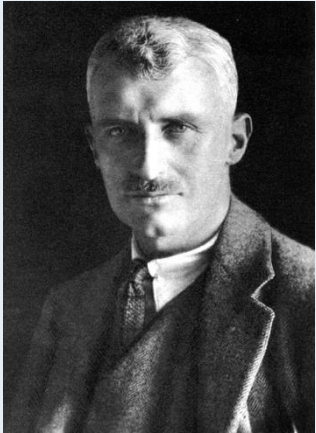
3

Aktuelle Beispiele

4

Überlegungen & Konsequenzen

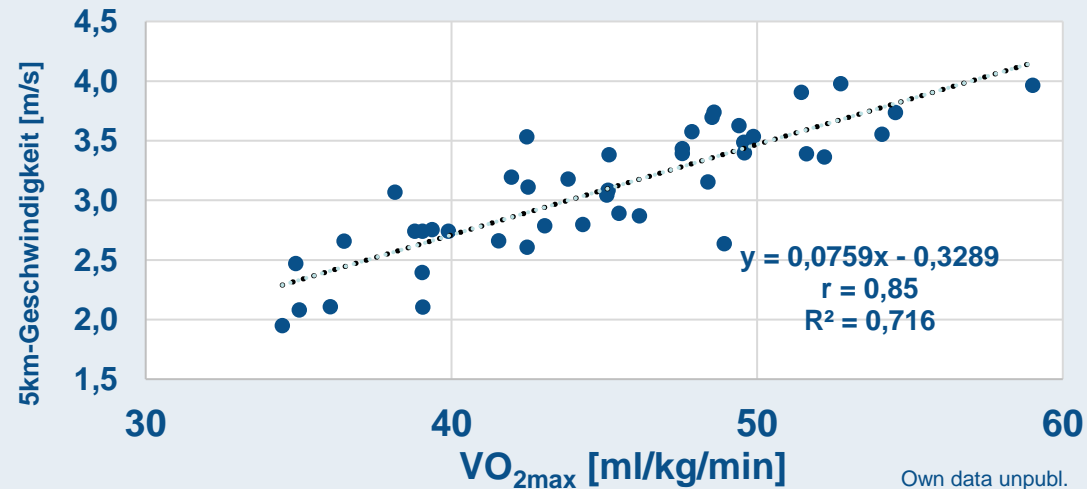
Maximale Sauerstoffaufnahme



“Maximum oxygen uptake (VO_{2max}) [...] sets the upper limit for endurance performance.”

Archibald Vivian Hill
Nobel Prize 1922

Basset JAP 2002



JAMA Network | **Open**

Original Investigation | Cardiology

Association of Cardiorespiratory Fitness With Long-term Mortality Among Adults Undergoing Exercise Treadmill Testing

Kyle Mandsager, MD; Serge Harb, MD; Paul Cremer, MD; Dermot Phelan, MD, PhD; Steven E. Nissen, MD; Wael Jaber, MD

Review

Mortality trends in the general population: the importance of cardiorespiratory fitness

Duck-chul Lee¹, Enrique G Artero², Xuemei Sui¹ and Steven N Blair³

Abstract



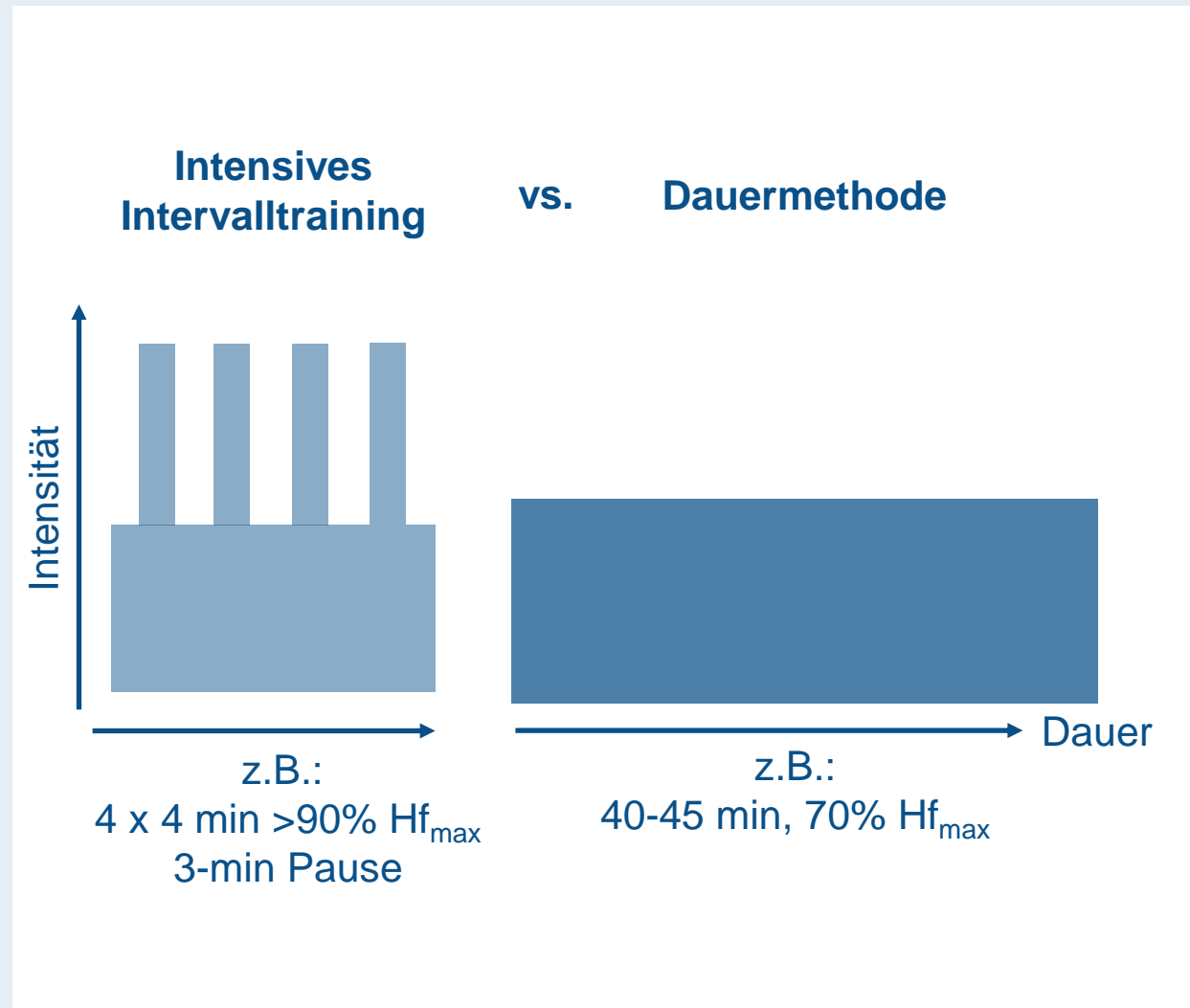
Journal of Psychopharmacology
24(11) Supplement 4, 27-35
© The Author(s) 2010
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/1359786810382057
jop.sagepub.com



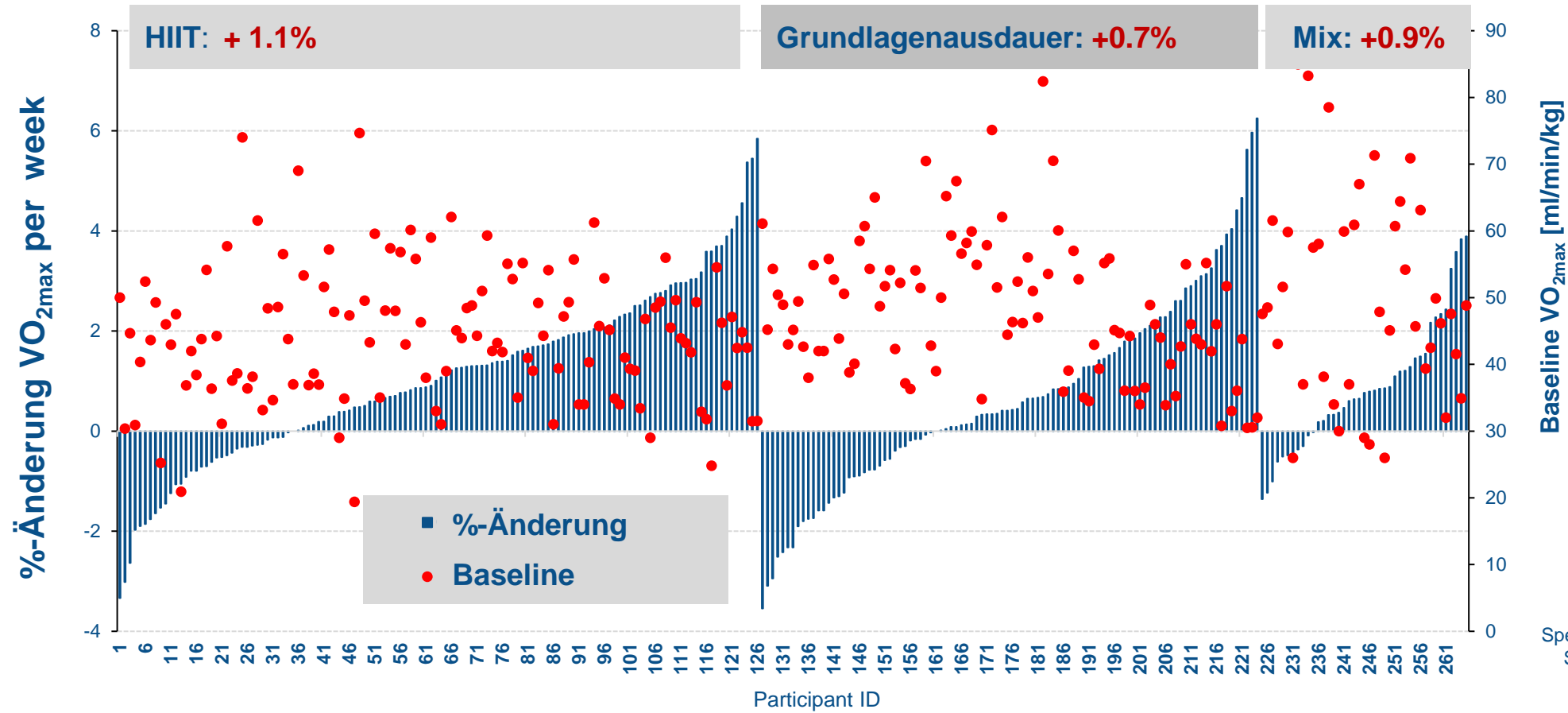
Deutliche Risikominderung für

Koronare Herzkrankheit, Diabetes, Bluthochdruck,
Schlaganfall, Krebsarten

Trainingsmethoden & maximale Sauerstoffaufnahme

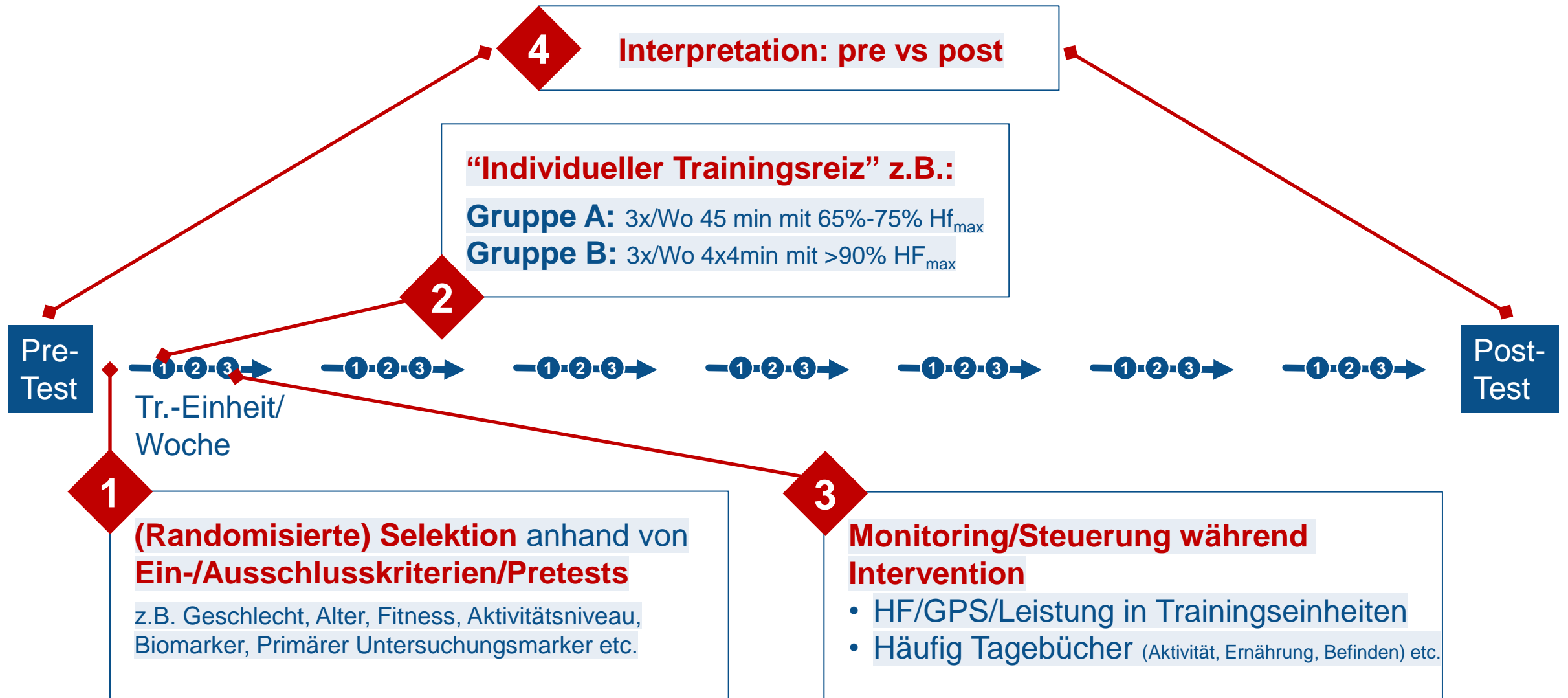


Pre-post VO_{2max} (3-9 Wochen; 2-5 Trainingseinheiten/Woche, n=265)



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

Häufiges Interventionsdesign in der Trainingswissenschaft

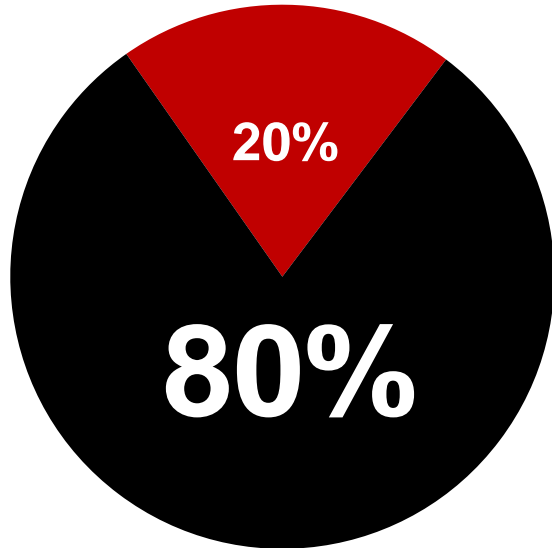


Blackbox: Training vs. „Off-Training“



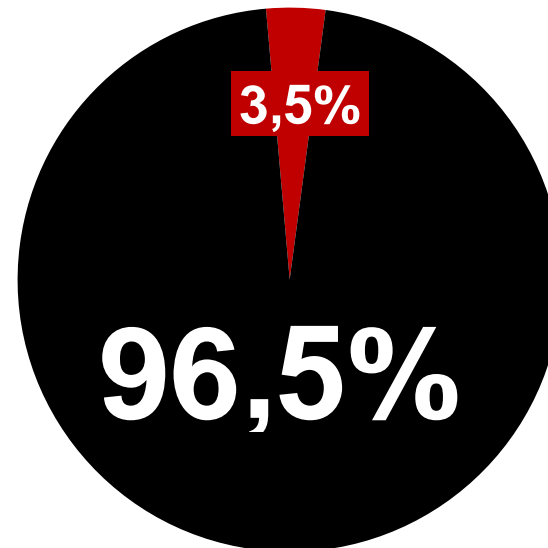
Leistungssport
>20h/Woche

Wachzeit/Woche



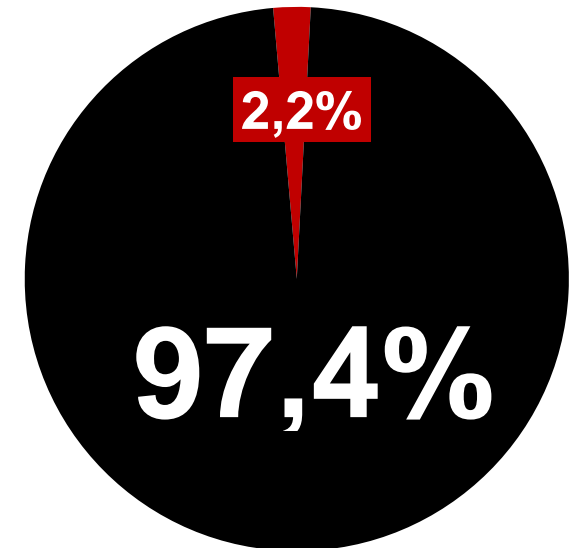
„Sportstudierenden-Studie“
z.B. 4x1h Training/Woche

Wachzeit/Woche



WHO
2.5h/Woche Aktivitätszeit

Wachzeit/Woche



Anpassung „free-living athlete“

 **frontiers**
in Physiology

Exercise Physiology

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

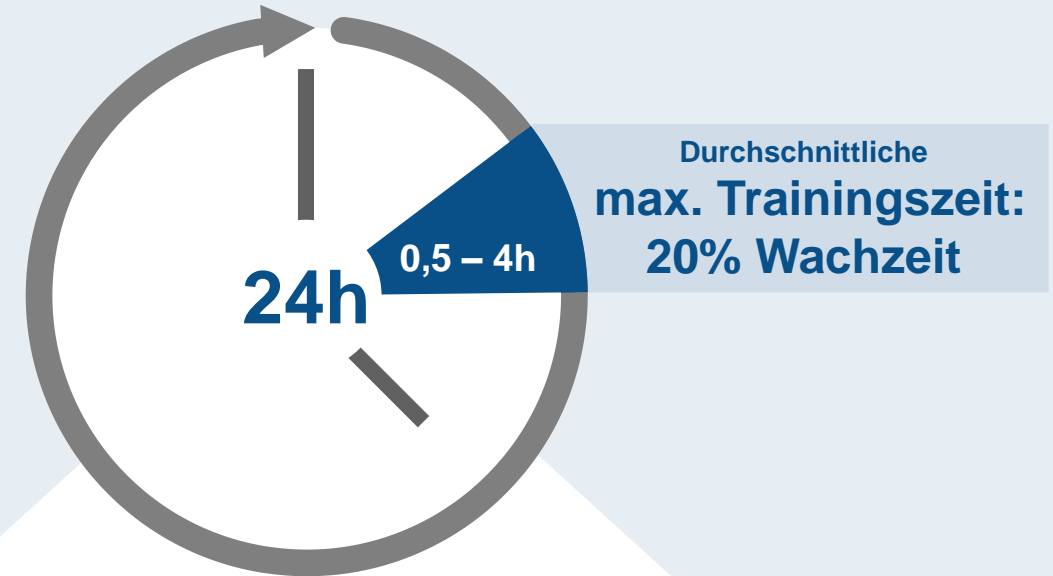
 **Billy Sperlich^{1*} and Hans-Christer Holmberg^{2,3,4}**

¹Integrative and Experimental Exercise Science, Institute for Sport Sciences, University of Würzburg, Würzburg, Germany

²Swedish Winter Sports Research Centre, Mid Sweden University, Östersund, Sweden

³School of Sport Sciences, UiT The Arctic University of Norway, Tromsø, Norway

⁴School of Kinesiology, University of British Columbia, Vancouver, BC, Canada



a) Alltagsaktivität (z.B. aktiv/passiv)

b) Schlaf/Naps

c) Regenerationsmanagement z.B:

- Massage & Stretching & Foam Rolling
- Aktive/passive Regeneration
- Kompressionsbekleidung
- Kaltwasserimmersion, u.v.m.

d) Ernährung/Trinken/Fasten Prä-, intra-, post Training

e) Umwelt (UV, Hitze, Höhe, Kälte, Ozon, Feinstaub, Lärm...)

f) Zirkadiane Rhythmik (z.B. Reisen, Wettkampfzeiten)

g) Psycho-soziale Faktoren (Arbeit, Familie, Freunde, Sponsoren, Finanzen, Medien, Reisen)

h) Alkohol, Medikamente

i) Doping

j) Faktor x, y, z

Biomarker-Analyse mittels tragbarer Technologie



Article

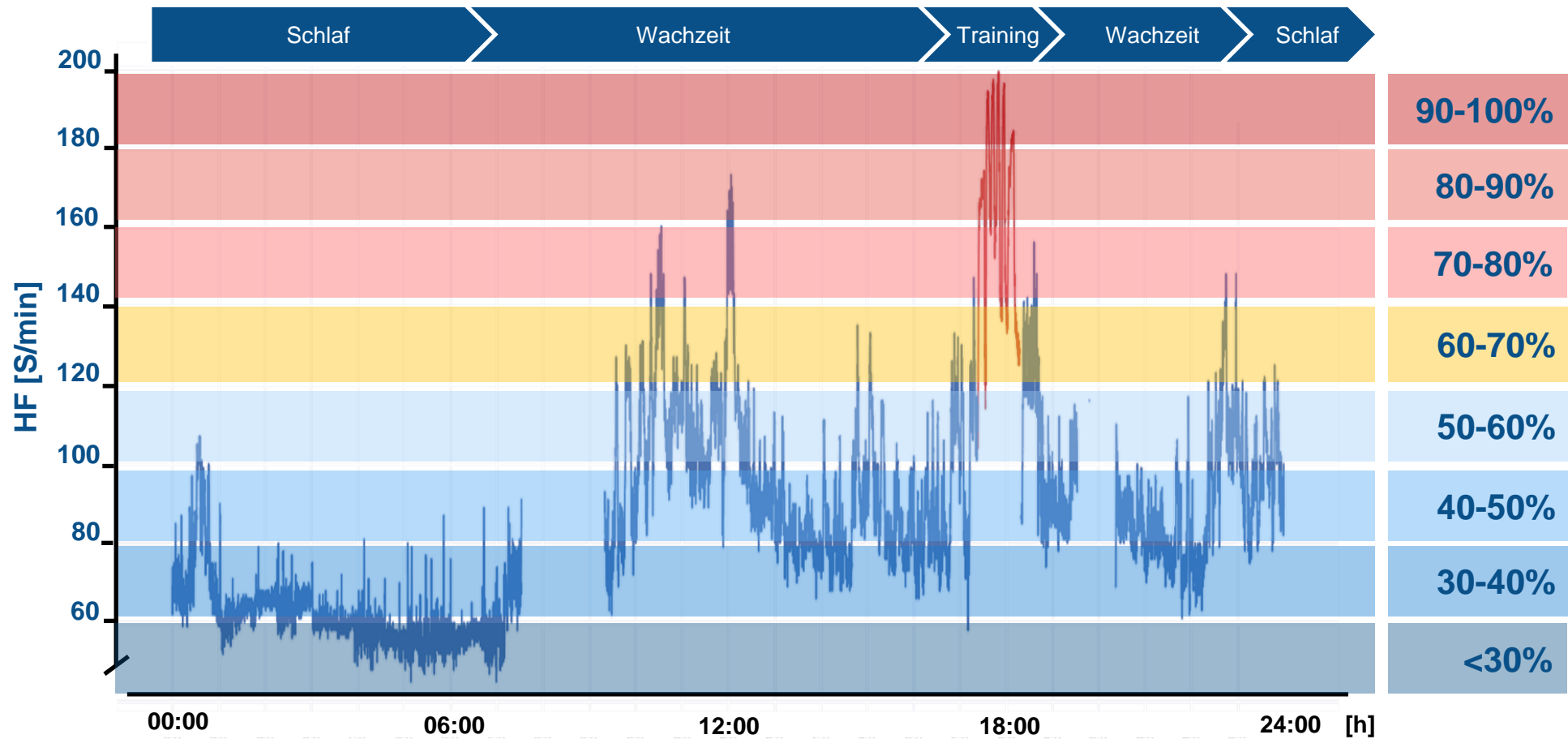
Integrated Framework of Load Monitoring by a Combination of Smartphone Applications, Wearables and Point-of-Care Testing Provides Feedback that Allows Individual Responsive Adjustments to Activities of Daily Living

Peter Dürking ^{1,*}, Silvia Achtzehn ^{2,3}, Hans-Christer Holmberg ^{4,5} and Billy Sperlich ¹

Biomarker	Wearable	Smartphone	POCT*
Heart rate, HR variability, HR recovery	X	X	
Energy expenditure	X	X	
Lactate-RPE Ratio	(X)		
Oxygenation	X	X	X
Hydration	(X)		X
Metabolites (Chol/Trig/Cr, Urea, etc)			X
Blood lactate & glucose	(X)		X
Blood gases (pH, pCO2, PO2)			X
Electrolytes (Na, K, Ca, Cl)			X
Haematology (Hb, Hk, Ery, Leuc, Thromb)			X
Enzyme (AST, ALT, Y-GT, Amylase)			X
Cardiac markers (CK, CK-MB, cTnl, Myo, BNP/NT-pro BNP..)			X
Acute Phase Protein (CRP, hsCRP)			X
Temperature (skin, body, core)	X	X	X
Subjective ratings (RPE, Session RPE)	(X)	X	
Training Impulse (TRIMP)	(X)	X	
Diaries	(X)	X	
Questionnaires (sleep; POMS; fatigue; readiness, stress...)	(X)	X	

*Point-of-Care-Testing: Athletennahe Sofortdiagnostik

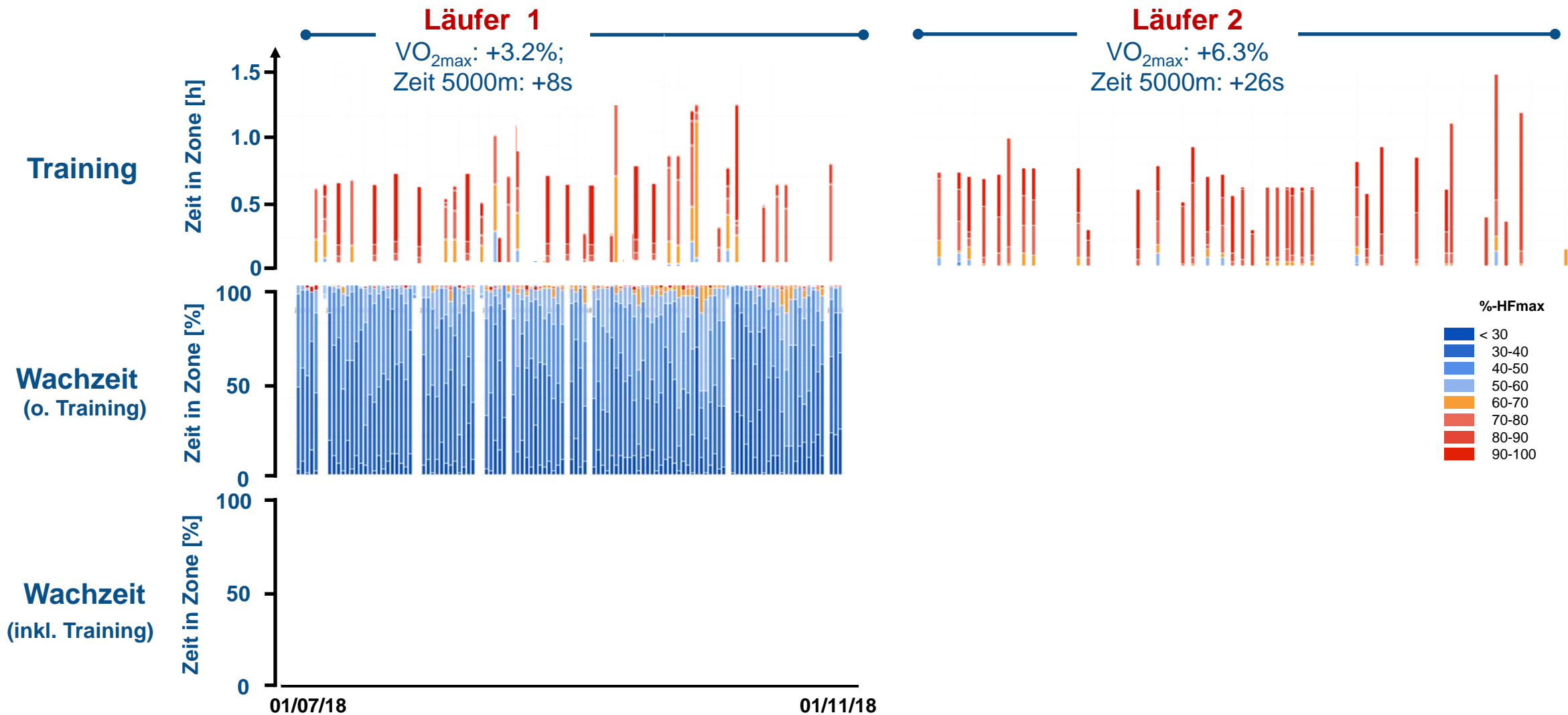
24h-Kontinuum & Intensitätszonen



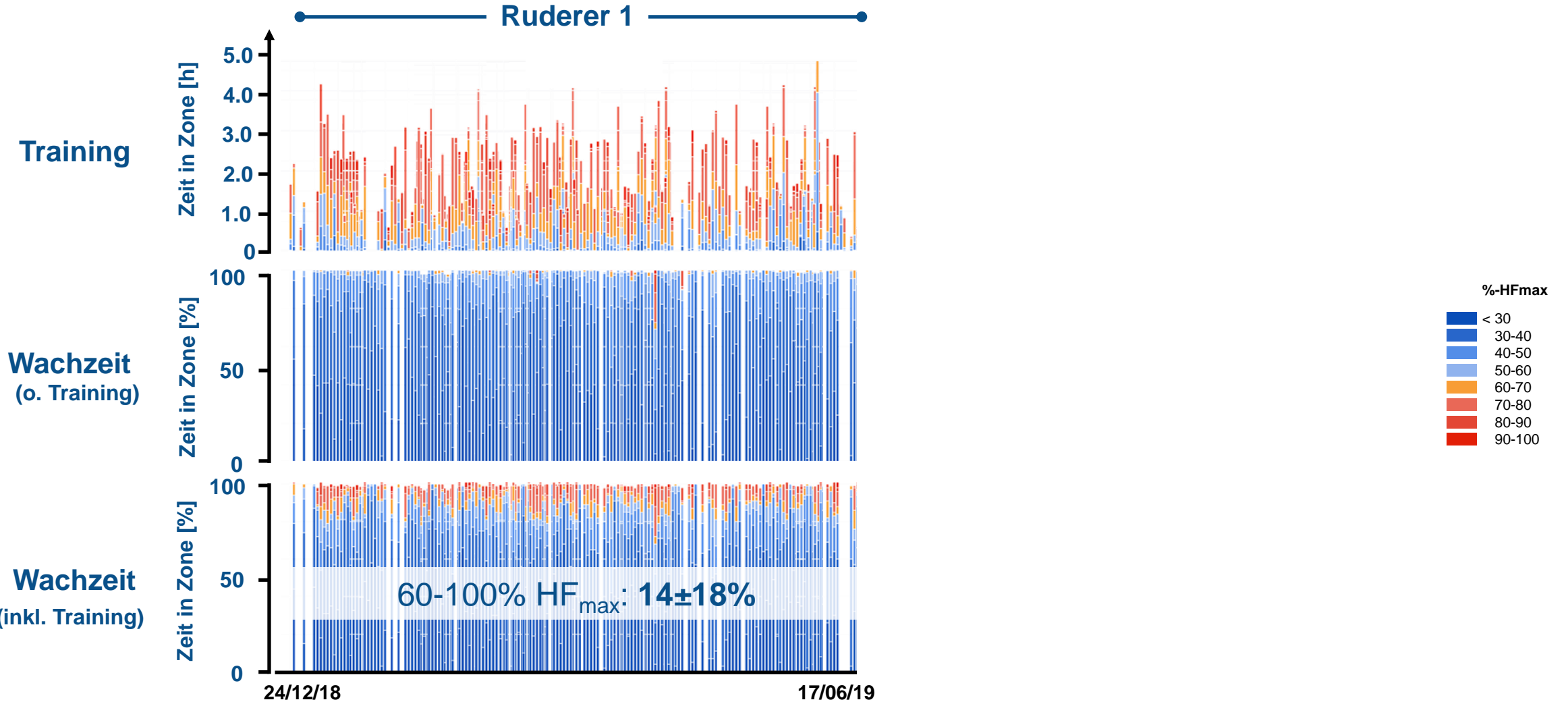
Polar M600; Kempele, FIN

- programmierbar
- Multisensor
- 1Hz HF-Aufzeichnung
- ca. 36-48h Batterielaufzeit
- Wasserdicht
- Bluetooth & WLAN

Langzeit 24h-Monitoring – Beispiel Langstreckenlauf



Beispiel 24h Monitoring - Rudern



Treff et al. Sci Rep 2021

1

Warm-Up

2

Warum sind Wearables in der Wissenschaft & Praxis wichtig?

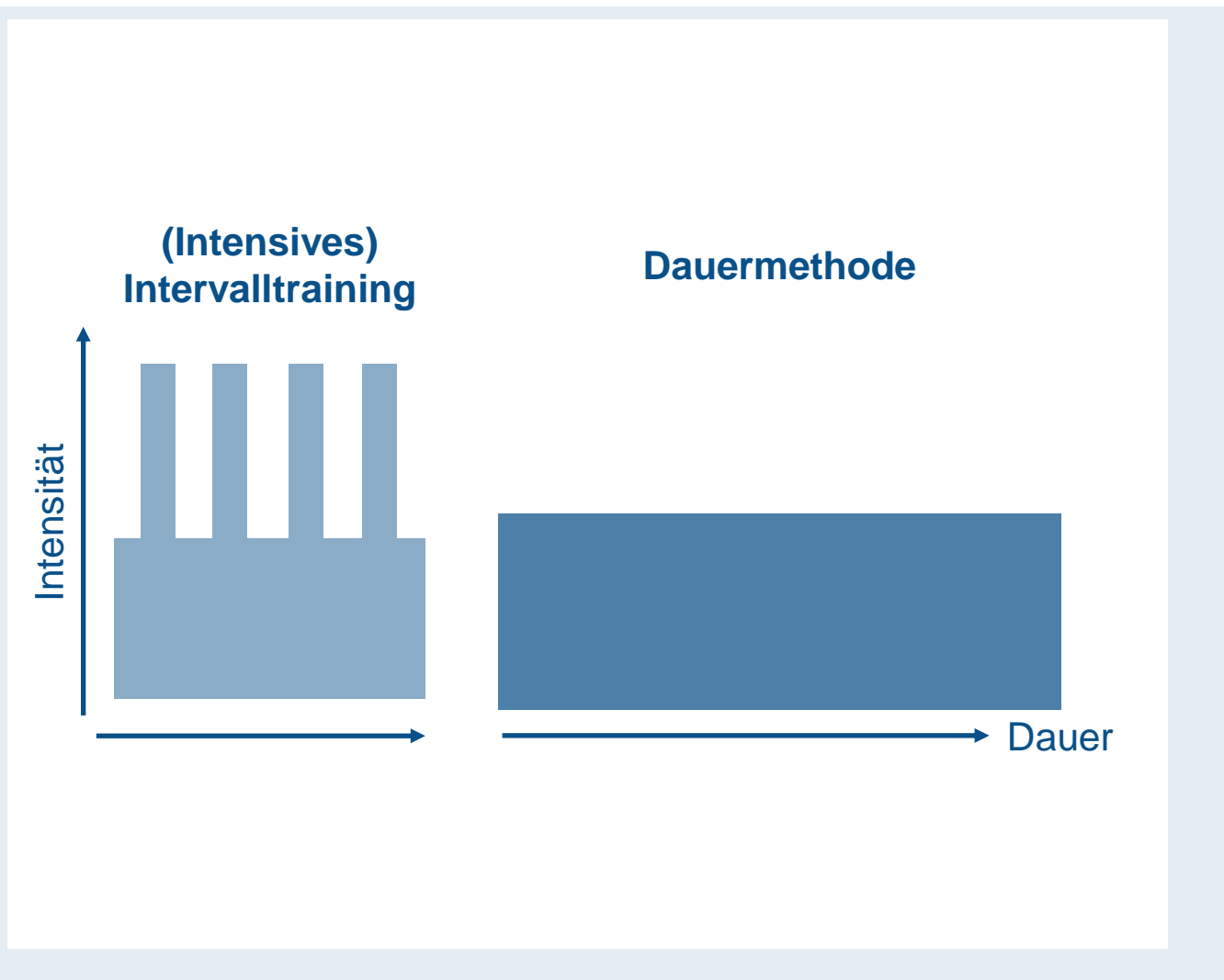
3

Aktuelle Beispiele

4

Überlegungen & Konsequenzen

Steuerung der Intensität



Aerobic Exercise Intensity

Substantial health benefits are gained when adults achieve 150-300 minutes per week of moderate intensity exercise, or 75-150 minutes of vigorous intensity exercise per week. Several tools and methods are used to monitor exercise intensity. Utilizing these methods help adults achieve physical activity goals.

Talk test is a way to gauge exercise intensity based on ability to carry on a conversation.

Steady conversation is associated with moderate intensity aerobic exercise.

Vigorous intensity is an exercise intensity where only a few words are sustainable.

Heart rate can be monitored by a wrist worn device.

- A percentage of maximal heart rate indicates intensity (%HRmax)
- Moderate intensity exercise is at 65-75 %HRmax
- Vigorous intensity exercise is 76-96 %HRmax
- Formula: $(220 - \text{age}) \times \%HR_{max}$

Empfehlung ACSM:

- Geschwindigkeit/Leistung
- % HF_{max} oder %VO_{2max}
- “Laufen ohne zu schnaufen”
- Borg Skala
- Schrittfrequenz
- Blutlaktat

Perceived effort is a subjective method to monitor exercise intensity.

- Commonly reported as a rating of perceived exertion (RPE)
- Based on RPE of 3-4

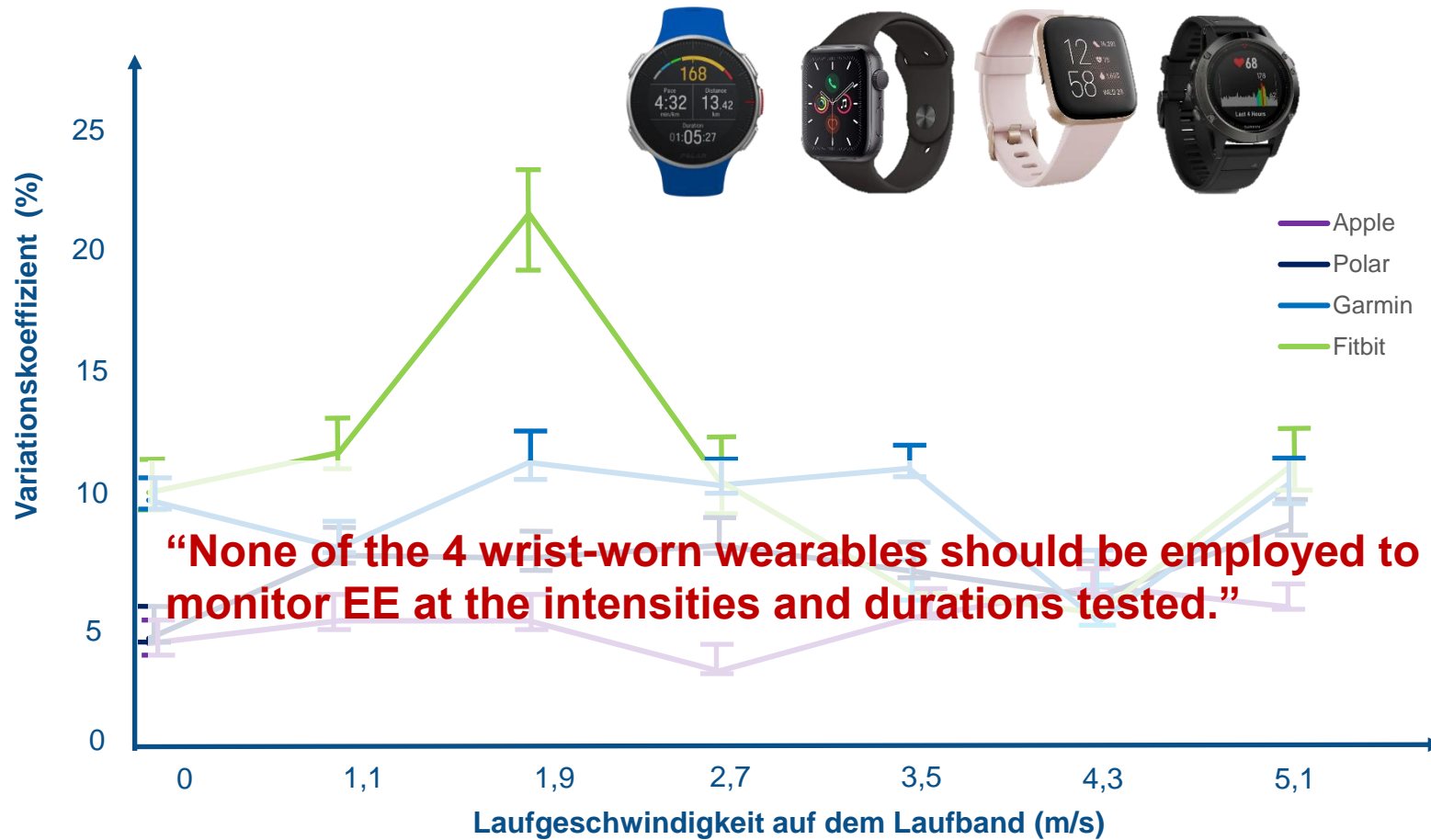
Rating Descriptor

1	2	3	4	5	6	7	8	9	10
Very light	Light	Light to moderate	Moderate	Moderate to hard	Hard	Very hard	Very hard	Very hard	Maximal effort

Moderate intensity exercise is a step rate of 100 steps per minute, or 1,000 per 10 minutes.

- A common recommendation is to achieve 3,000 steps in 30 minutes.
- Vigorous intensity is > 100 steps per minute.

Herzfrequenz gemessen am Handgelenk



Apple Watch Series 4

± 2.3 S/min

Polar Vantage V

± 5.9 S/min

Fitbit Versa

± 13.3 S/min

Garmin Fenix 5

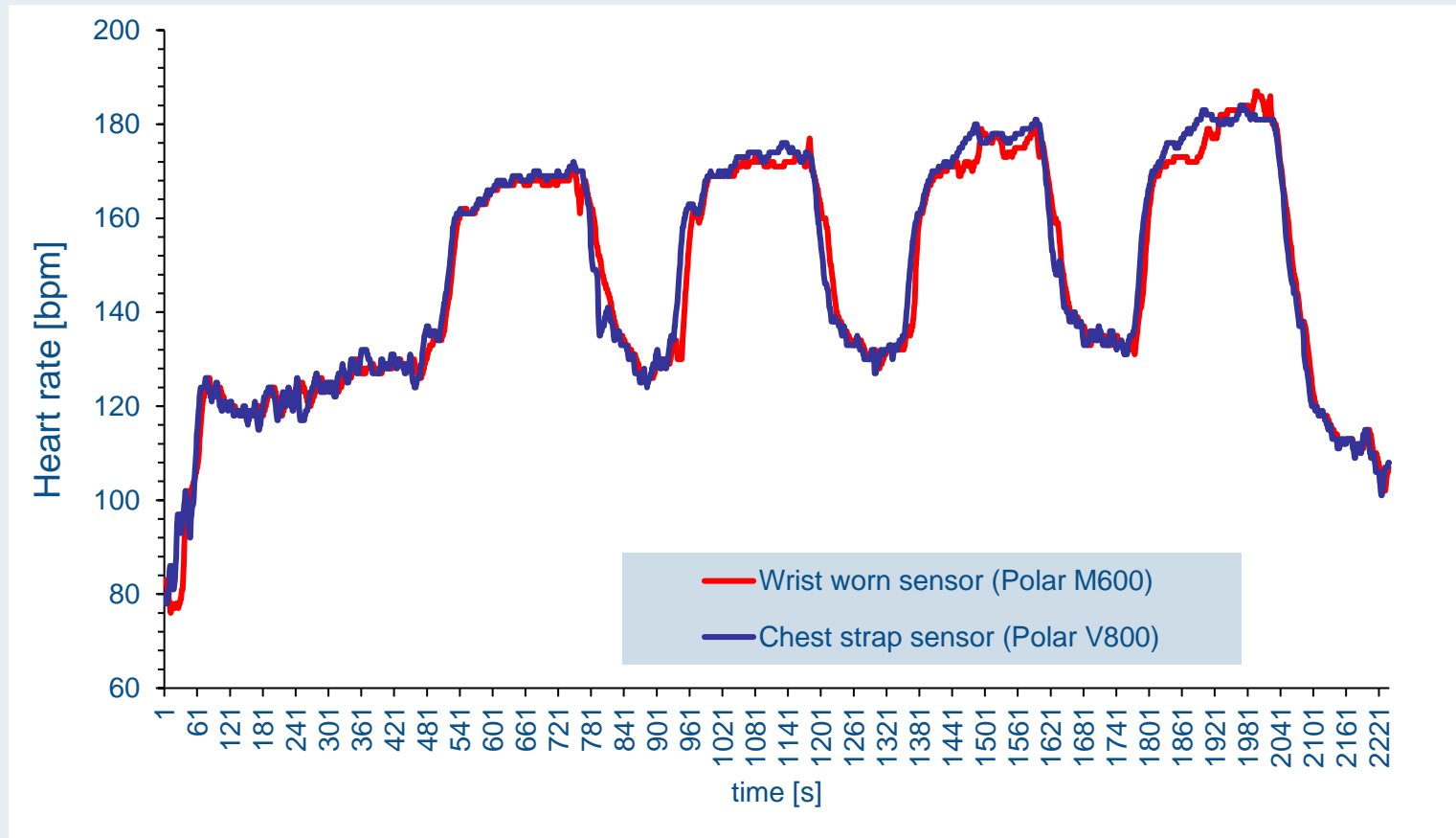
± 9.1 S/min



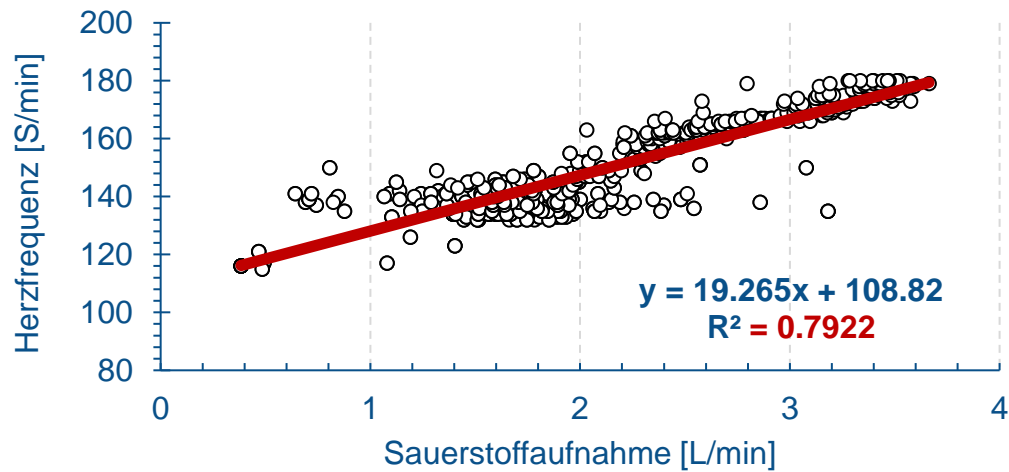
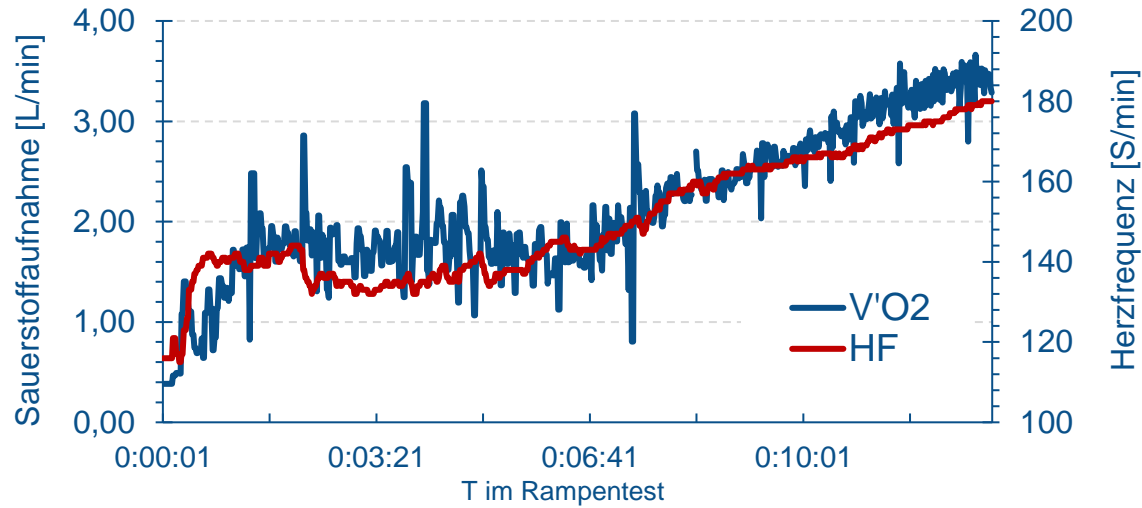
Wrist-Worn Wearables for Monitoring Heart Rate and Energy Expenditure While Sitting or Performing Light-to-Vigorous Physical Activity: Validation Study

Peter Dürking¹, MSc ; Laura Giessing², MSc ; Marie Ottilie Frenkel², PhD ; Karsten Koehler³, PhD ; Hans-Christer Holmberg^{4, 5}, PhD ; Billy Sperlich¹, PhD

Beispiel



VO_{2max} Approximation mittels Smartwatch



Labor-VO_{2max}
Metamax 3B

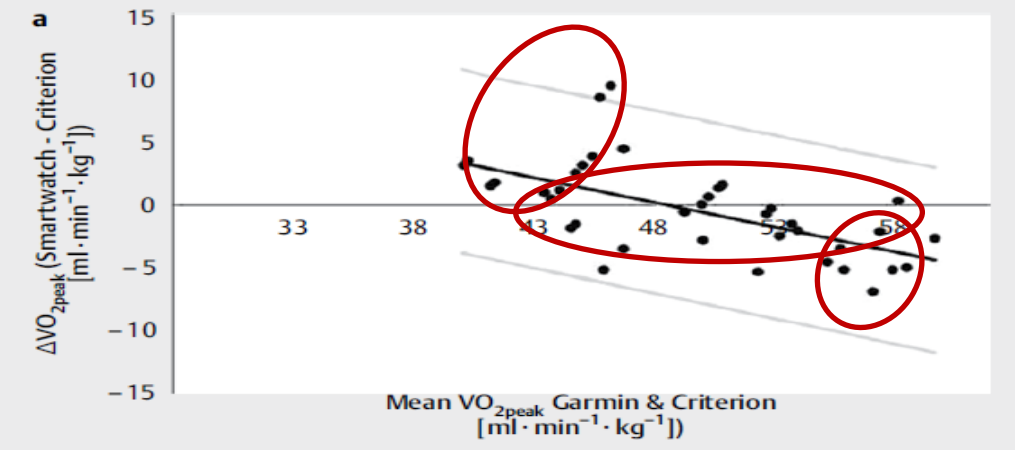


VS

Smartwatch VO_{2max}
Garmin Forerunner 245

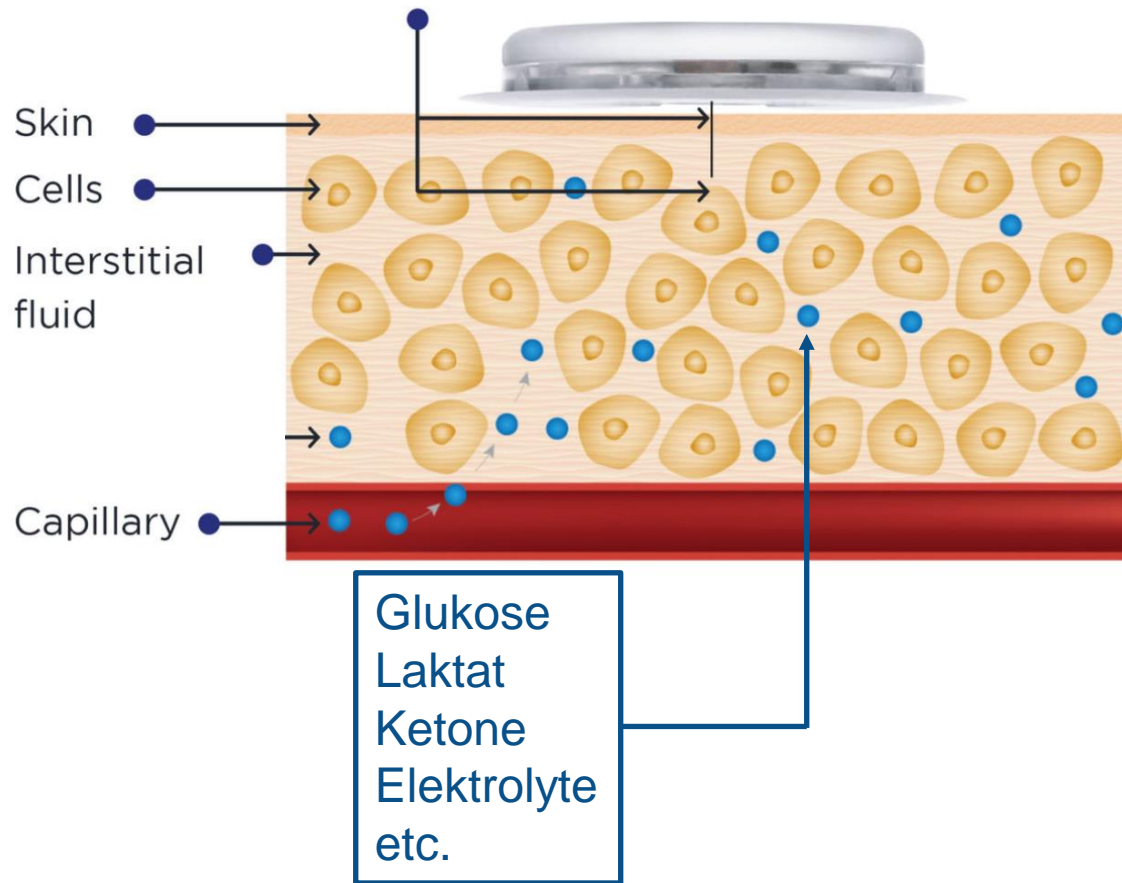


5.7%
(~2.80 ml/min/kg)



Düking et al. Int J Sports Med 2021

Klebelektroden: Interstitielle Diagnostik, z.B. Blutzuckermessung



Typische Motive

- Kontinuierliche Echtzeit-Überwachung
- Früherkennung Therapieanpassung
- Komfort
- Langzeitkontrolle



Kontinuierliche Blutzuckermessung vor, während und nach Krafttraining mit/ohne KH-Frühstück

European Journal of Applied Physiology (2024) 124:3557–3569
<https://doi.org/10.1007/s00421-024-05557-5>

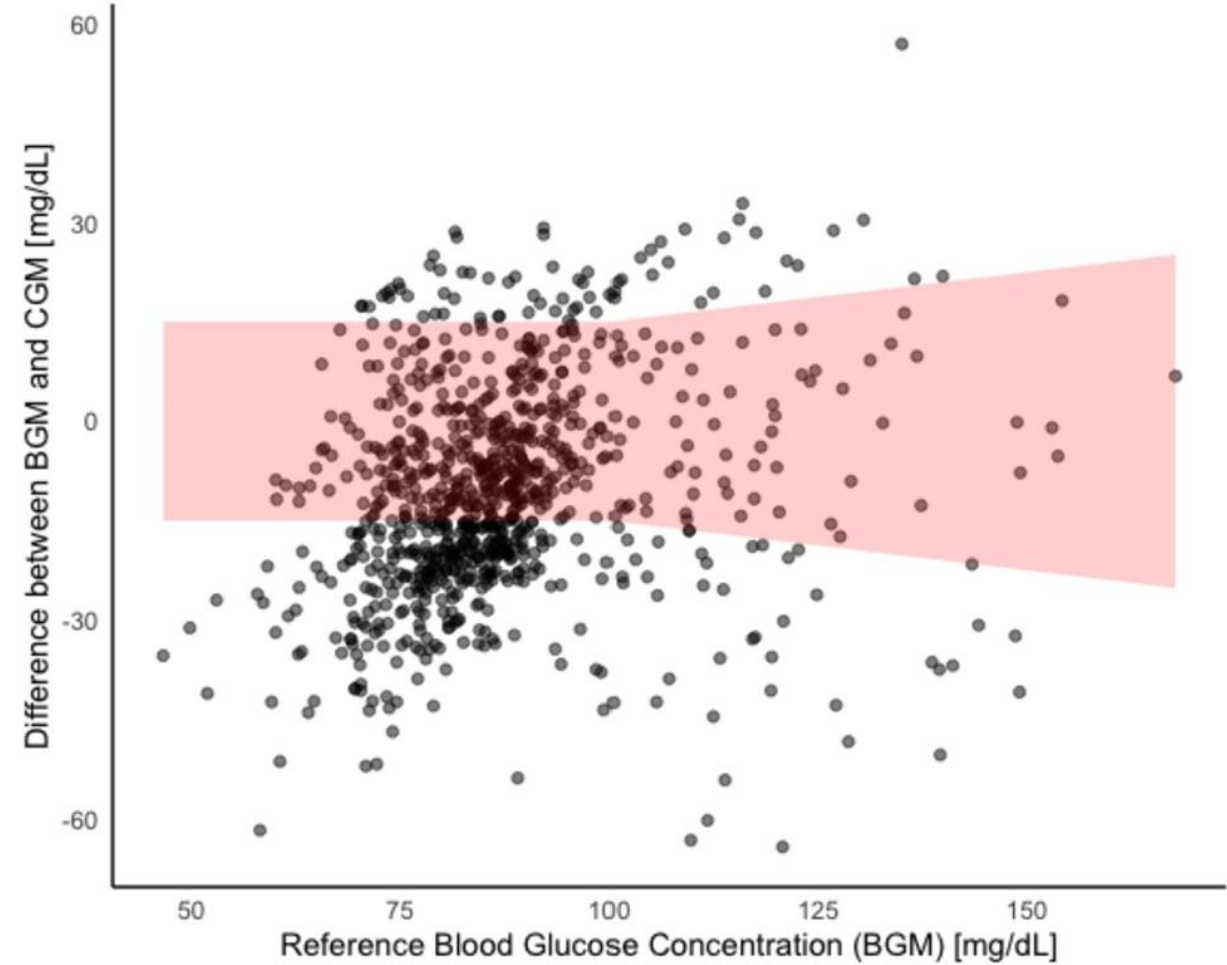
ORIGINAL ARTICLE



Accuracy of a continuous glucose monitoring system applied before, during, and after an intense leg-squat session with low- and high-carbohydrate availability in young adults without diabetes

Manuel Matzka¹ · Niels Ørtenblad² · Mascha Lenk¹ · Billy Sperlich¹

“CGM [...] varied substantially between individuals compared to BGM and fails in meeting clinical criteria for diabetic monitoring.”



1

Warm-Up

2

Warum sind Wearables in der Wissenschaft & Praxis wichtig?

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Aktuelle Beispiele

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Überlegungen & Konsequenzen

Was ist jetzt brauchbar?

British Journal of
Sports Medicine

Br J Sports Med 2017

Billy Sperlich¹, Hans-Christer Holmberg^{2, 3, 4}

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

- (Massenmarkttaugliche) Technologie meist nicht validiert
- Häufig Surrogat-Marker
(Ersatzmarker für ein Phänomen z.B. Akzelerometrie => „Schlaf“)
- Viele leistungsphysiologische und trainingspraktische Parameter (noch) nicht (direkt) messbar
- Indirekte Abschätzung mittels künstlicher Intelligenz
- Dringender Evaluierungsbedarf mit bestehenden Referenzmethoden

Bedeutungsvolles/nutzbares Feedback

[Int J Sports Physiol Perform](#). 2018 Jun 28:1-21. doi: 10.1123/ijsp.2018-0098. [Epub ahead of print]

Training Monitoring Engagement: An Evidence-Based Approach in Elite Sport.

[Neupert EC](#)¹, [Cotterill ST](#)¹, [Jobson SA](#)¹.

Author information

¹ Department of Sport, Exercise and Health, University of Winchester, Hampshire, United Kingdom.



“[...] analysis showed that athletes reported their main reason for poor buy-in to training monitoring systems **was a lack of feedback on their monitoring data from key staff**. Further, training modifications made in response to meaningful changes in monitoring data were sometimes **perceived to be disproportionate**, resulting in **dishonest** reporting practices”

“I don't trust some of the proprietary metrics established by vendors”

“Stopped providing me information I didn't already know.”

“Phantasie Marker”

POLAR PRODUKTE INSPIRATION HÄNDLER FINDEN KUNDENSERVICE BLOG FLOW DE - POLAR DEUTSCHLAND

NIGHTLY RECHARGE™

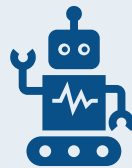
DIE NACHT MACHT DEN TAG

Nightly Recharge™ ist eine nächtliche Messung und zeigt an, wie gut du dich nachts von Stress und vom Training erholst. Sie hilft dir dabei, tagsüber die richtigen Entscheidungen zu treffen, um so dein allgemeines Wohlbefinden aufrechtzuerhalten und deine Trainingsziele zu erreichen.

Für was ist ein Produkt entwickelt worden?

Häufig

Neue Technologie



Identifizieren eines Problems im Zusammenhang mit dem Produkt



ggfls. Lösung



Besser

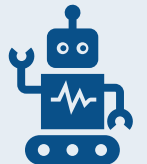
Identifizieren des Problems
Marktrecherche



Lösung



Tech/Konzept



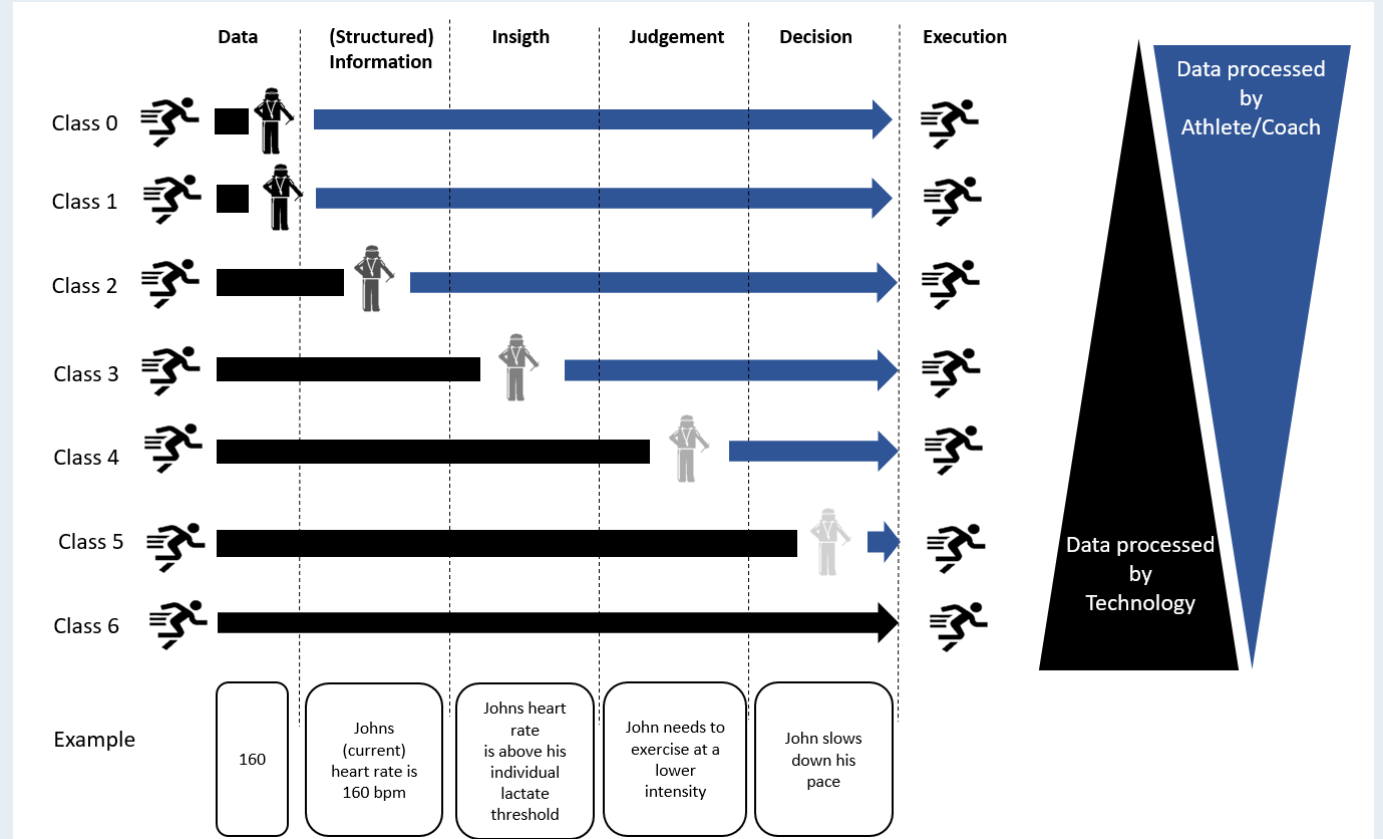
Wer oder was entscheidet wann?

frontiers

Front. Sports Act. Living, 29 January 2025
 Sec. Elite Sports and Performance Enhancement
 Volume 6 - 2024 | <https://doi.org/10.3389/fspor.2024.1500563>

Classification system for Ai-enabled consumer-grade wearable technologies aiming to automatize decision-making about individualization of exercise procedures

Peter Düking^{1*} Sam Robertson²
 Hans-Christer Holmberg^{3,4} Klaus-Hendrik Wolf⁵
 Billy Sperlich⁶

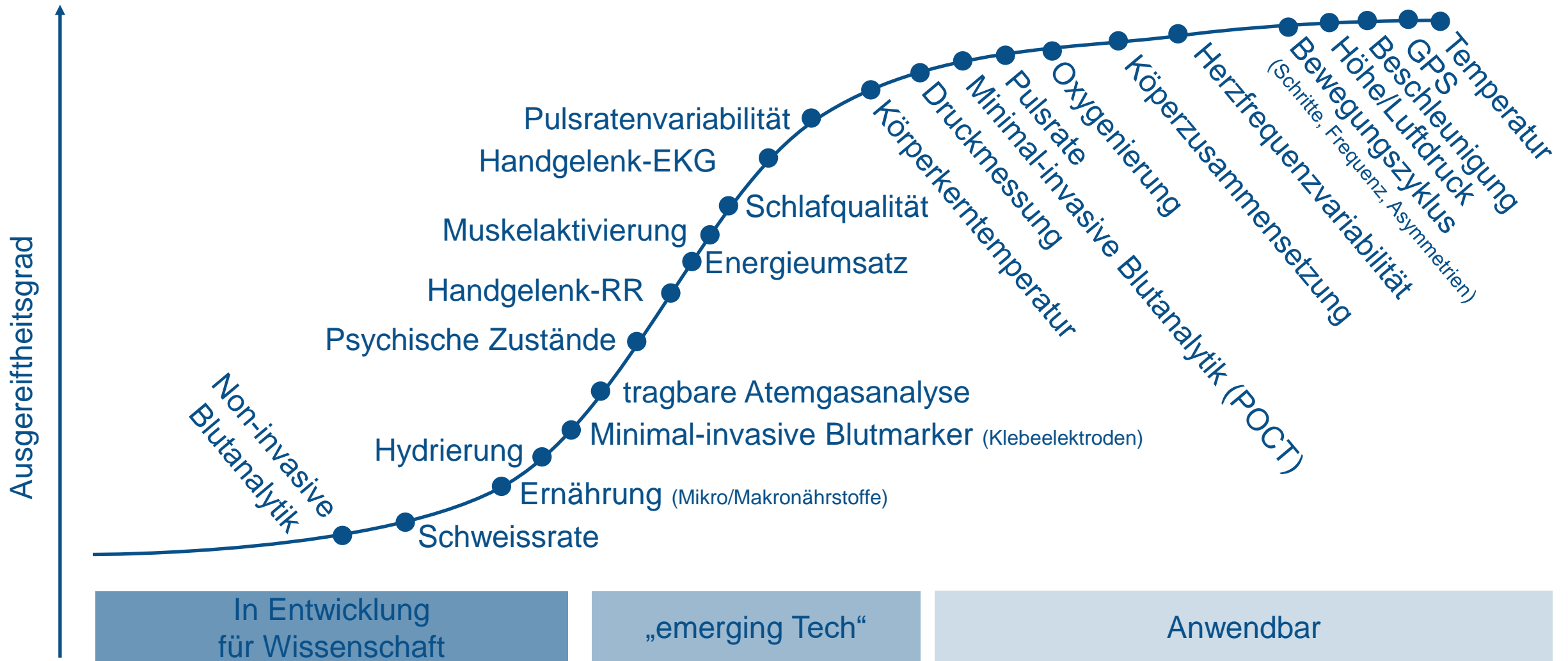




[...] numerous studies in the field of human information processing demonstrate that human decision making can actually be deteriorated by information overload.

Baker 2020 J Science Engineering Ethics

Ausgereiftheitsgrad/Anwendbarkeit von Biosensorik/-marker für Langzeitmonitoring



Vielen Dank!

Univ-Prof. Dr. Billy Sperlich

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