Ventilatory, Electromyography, Muscle and Cerebral Thresholds During Incremental Cycling

Nathan Townsend , David Nichols, Martin Buchheit, Olivier Girard, Sebastian Racinais

Athlete Health and Performance Centre, Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

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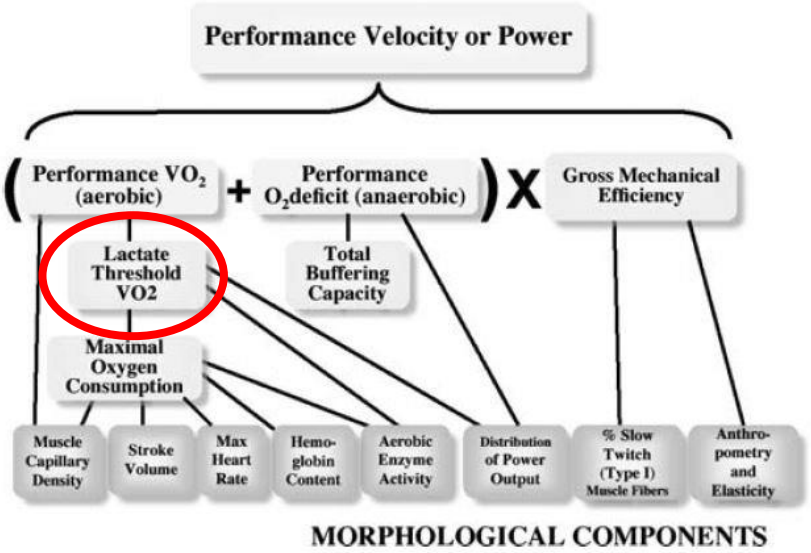
The “Threshold” Phenomenon

J Physiol 586.1 (2008) pp 35–44

TOPICAL REVIEW

Endurance exercise performance: the physiology of champions

Michael J. Joyner[1] and Edward F. Coyle[2]



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Lactate and Ventilatory Thresholds (incremental test)

Blood Lactate Diagnostics in Exercise Testing and Training

Ralph Beneke, Renate M. Leithäuser, and Oliver Ochentel

International Journal of Sports Physiology and Performance, 2011, 6, 8-24

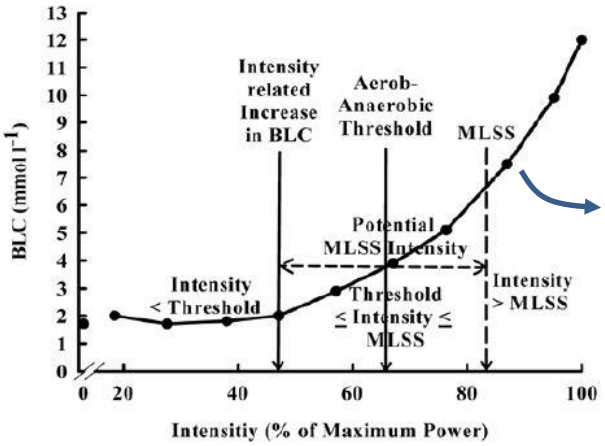


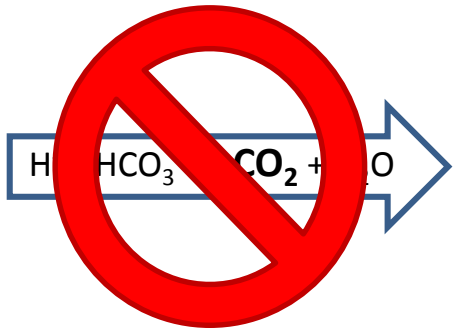
Figure 1 — Example of BLC during INCP; the BLC does not increase during increasing power up to an intensity of 48%; at 4 mmol·L⁻¹ exercise intensity is 66%, which is lower than the MLSS intensity of 83% of maximum power at test termination.

Lactate Threshold Concepts
How Valid are They?

Oliver Faude,[1,2] *Wilfried Kindermann*[2] and *Tim Meyer*[1,2]

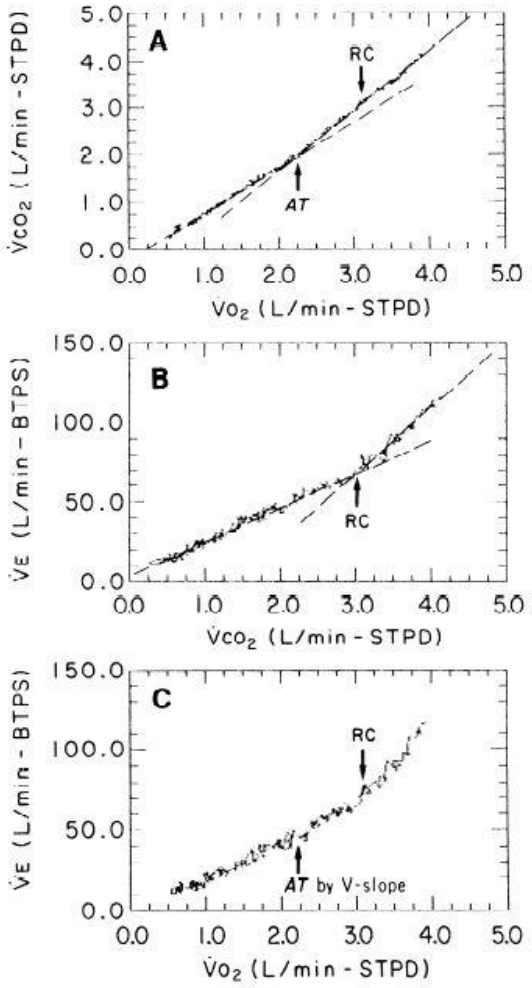
Sports Med 2009; 39 (6): 469-490
0112-1642/09/0006-0469/$49.95/0

"A total of 25 LT concepts were located"



A new method for detecting anaerobic threshold by gas exchange

WILLIAM L. BEAVER, KARLMAN WASSERMAN, AND BRIAN J. WHIPP



Electromyography threshold

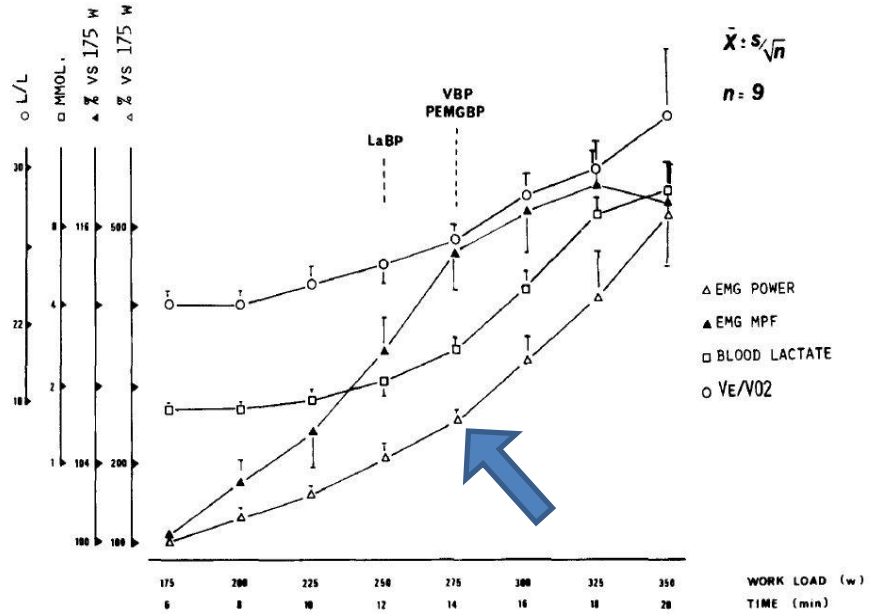


Fig. 1. Mean evolution of myoelectrical and metabolic parameters during incremental exercise. Vertical bars indicate standard deviations

The aerobic-anaerobic transition: re-examination of the threshold concept including an electromyographic approach

J. N. Helal[1], C. Y. Guezennec[2], and F. Goubel[1]

Eur J Appl Physiol (1987) 56:643—649

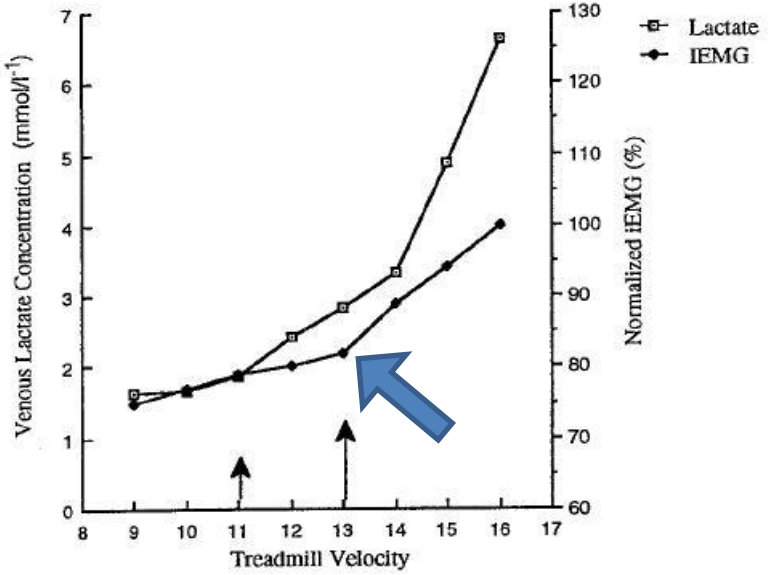


Fig. 6. Overlay graph of *iEMG* and venous lactate concentration vs treadmill velocity (km·h^{-1}) for subject 1

Electromyographic correlates of the transition from aerobic to anaerobic metabolism in treadmill running

A. D. Taylor, R. Bronks

Eur J Appl Physiol (1994) 69:508–515

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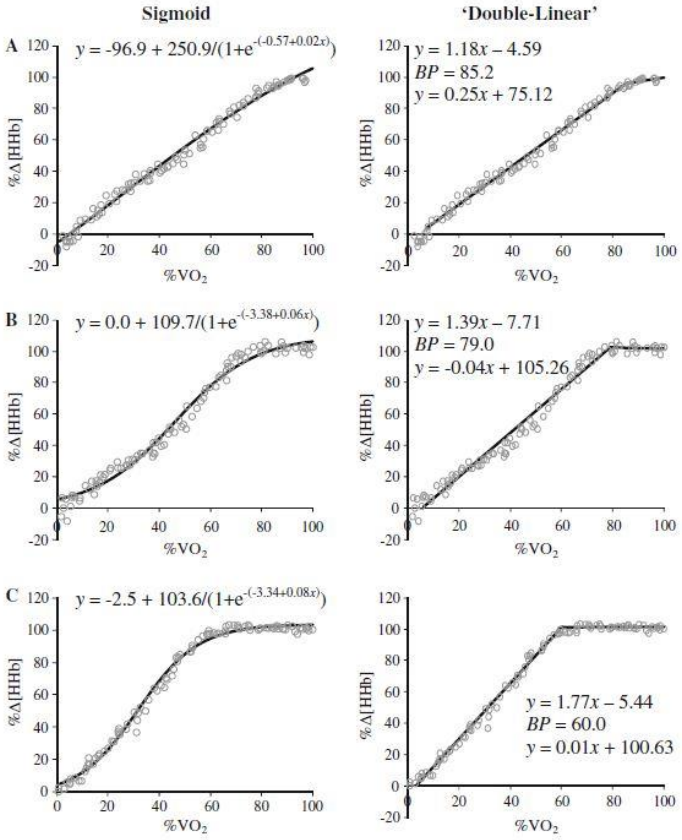
Near Infrared Spectroscopy (NIRS) Threshold

De-oxyhaemoglobin + myoglobin [HHb] signal represents balance between O_2 extraction/utilisation and convective O_2 delivery



Characterizing the profile of muscle deoxygenation during ramp incremental exercise in young men

Matthew D. Spencer · Juan M. Murias · Donald H. Paterson

Eur J Appl Physiol (2012) 112:3349–3360

Dynamics of noninvasively estimated microvascular O_2 extraction during ramp exercise

Leonardo F. Ferreira,[1] Shunsaku Koga,[2] and Thomas J. Barstow[1]

J Appl Physiol 103: 1999–2004, 2007.

Fig. 2. Increase in deoxygenated hemoglobin + myoglobin (HHb) during incremental ramp exercise. ○, Deoxygenated hemoglobin and myoglobin [deoxy-(Hb+Mb)] data averaged every 10 s. Solid line, best regression fit from sigmoidal function (see METHODS). The deoxy-(Hb+Mb) data are normalized to the amplitude of response from baseline to peak exercise.

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Cerebral Oxygenation Threshold

Effects of acute hypoxia on cerebral and muscle oxygenation during incremental exercise

Andrew W. Subudhi, Andrew C. Dimmen, and Robert C. Roach

J Appl Physiol 103: 177–183, 2007.

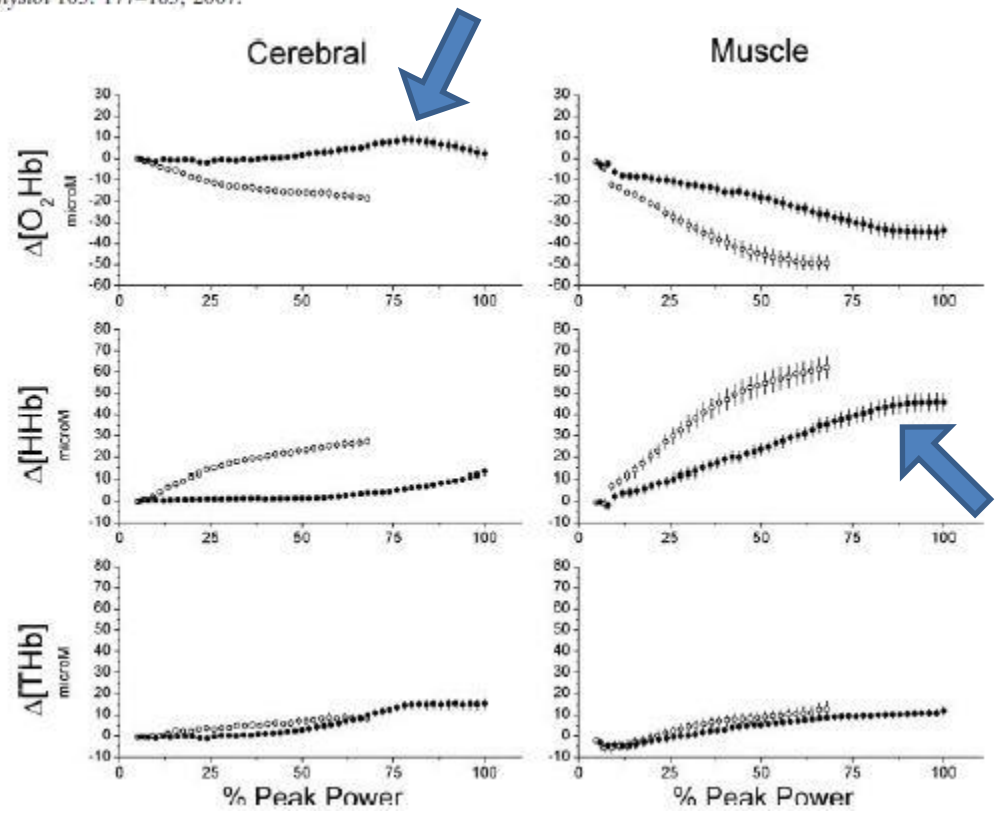

Fig. 1. Near-infrared spectroscopy (NIRS) concentration changes (means ± SE) during incremental exercise in normoxia (●) and hypoxia (○). All values are expressed relative to the peak power output achieved in normoxia.

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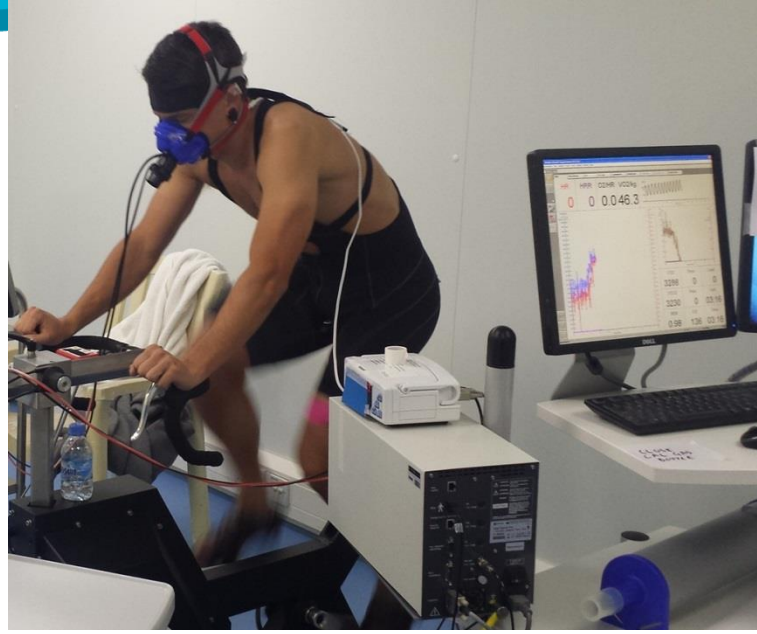
Statement of Problem

- No previous literature examines *simultaneously* the ventilatory, EMG, muscle and cerebral oxygenation thresholds during ramp incremental testing

Aim

- Examine simultaneously the ventilatory, EMG, muscle and cerebral oxygenation thresholds during ramp incremental testing

Methods



- Subjects
  - 25 recreational cyclists
    - Age: 37 ± 8 yr
    - Weight: 78 ± 13 kg
    - VO_{2max}: 53 ± 8 ml/min/kg

- Procedures
  - 25 W/min ramp incremental test to volitional exhaustion (Excalibur, Lode)

- Measures
  - Breath x breath gas analysis (Cosmed Quark b^2)
  - 2000 Hz vastus lateralis, rectus femoris, biceps femoris EMG (BSL Pro, Biopac)
  - 10 Hz vastus lateralis and pre-frontal cortex NIRS (Oxymon MkIII, Artinis)
    - [HHb] = deoxy-hemoglobin + myoglobin; [O_2Hb] = oxygenated hemoglobin + myoglobin
    - Bandpass filter: 30-500 Hz

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Data Analysis

- Ventilatory thresholds
  1. VT1: non-linear increase in VE/VO_2 without increase in VE/VCO_2
  2. VT2: second non-linear increase in VE/VO_2 with corresponding non-linear increase in VE/VCO_2
  3. Visual inspection

- NIRS and EMG
  1. Normalized to 100 points (1 point = 1% of exercise duration)
  2. Individual muscle EMG root mean square (RMS) normalized to maximal activity during incremental test
  3. Iterative double linear regression analysis solved for least sum of squares error: intersection of regression lines denotes threshold

- Statistics
  - Shapiro-Wilk test for normality
  - Mixed linear modeling (to accommodate missing data)
  - Effect sizes using Cohen's *d*

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Results

EMG threshold (EMG-t)

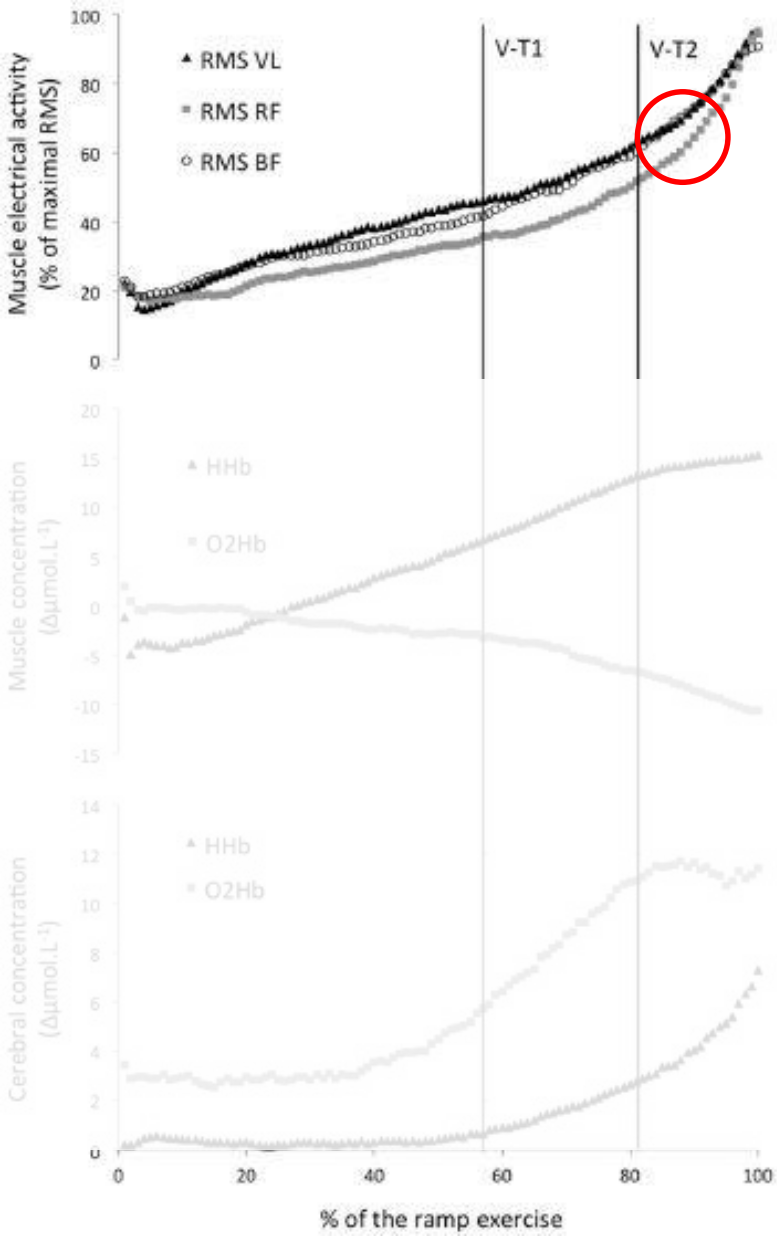
- Only one threshold identified (60-88% of measures)

Muscle de-oxygenation threshold (HHb-t)

- Only one threshold identified (64% of measures)

Cerebral oxygenation threshold (HHb-t)

- 80% of cases two cerebral thresholds were determined



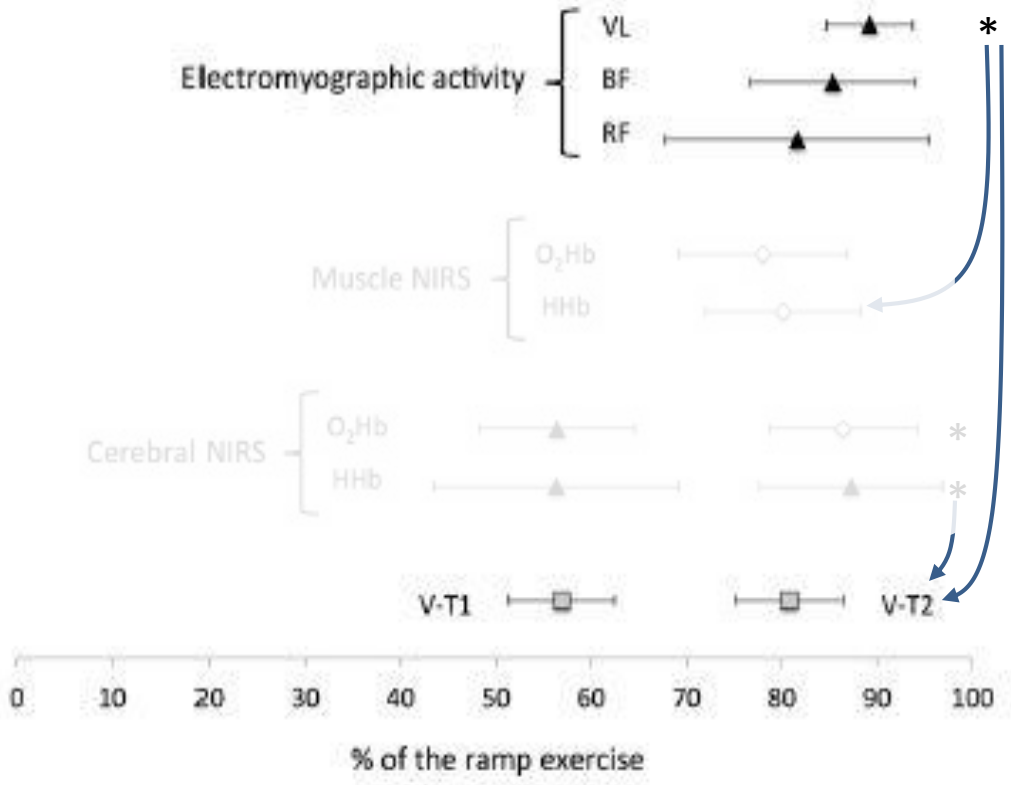
Results

EMG threshold (EMG-t)

- EMG-t for **RF** and **BF** not significantly diff to VT2
- EMG-t for **VL** occurred after VT2 (p=0.004, d = 1.7) and also muscle HHb-t (p=0.006; d=1.7)

Muscle de-oxygenation threshold (HHb-t)

HHb-t and O_2Hb-t not sig diff to VT2 (p>0.15; d<0.4)



Cerebral oxygenation threshold (HHb-t)

- 1st threshold for [HHb] and [O_2Hb] not different from VT1 (p > 0.86, d < 0.1)
- 2nd threshold for [HHb] and [O_2Hb] occurred later than VT2 (p < 0.02, d > 0.8)

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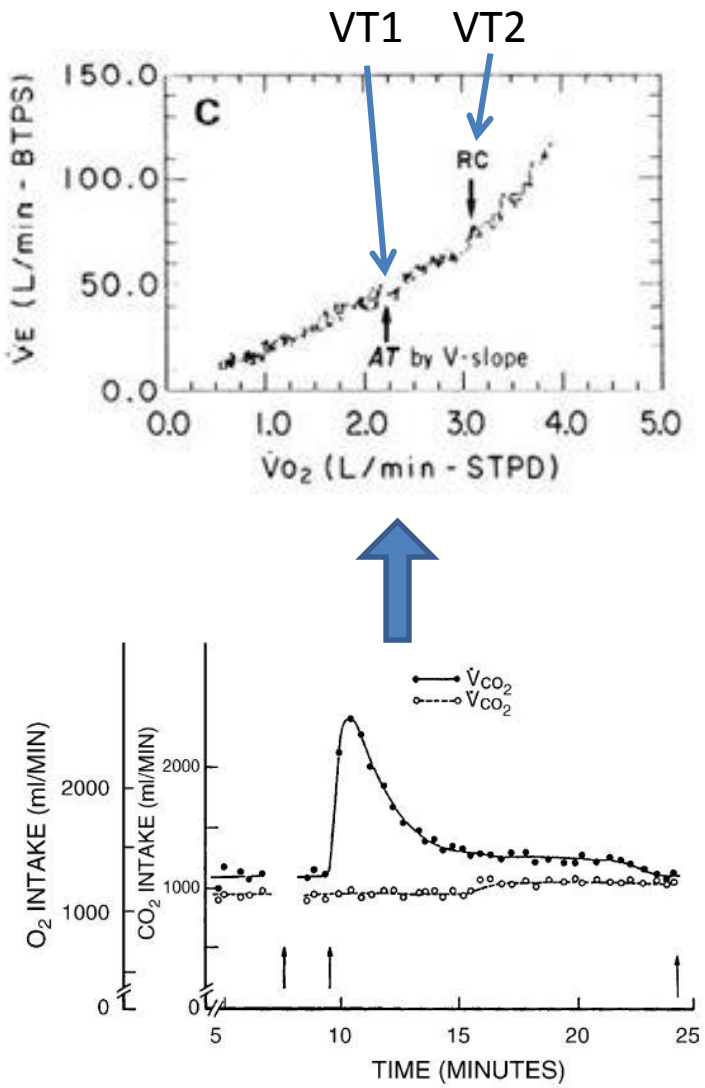
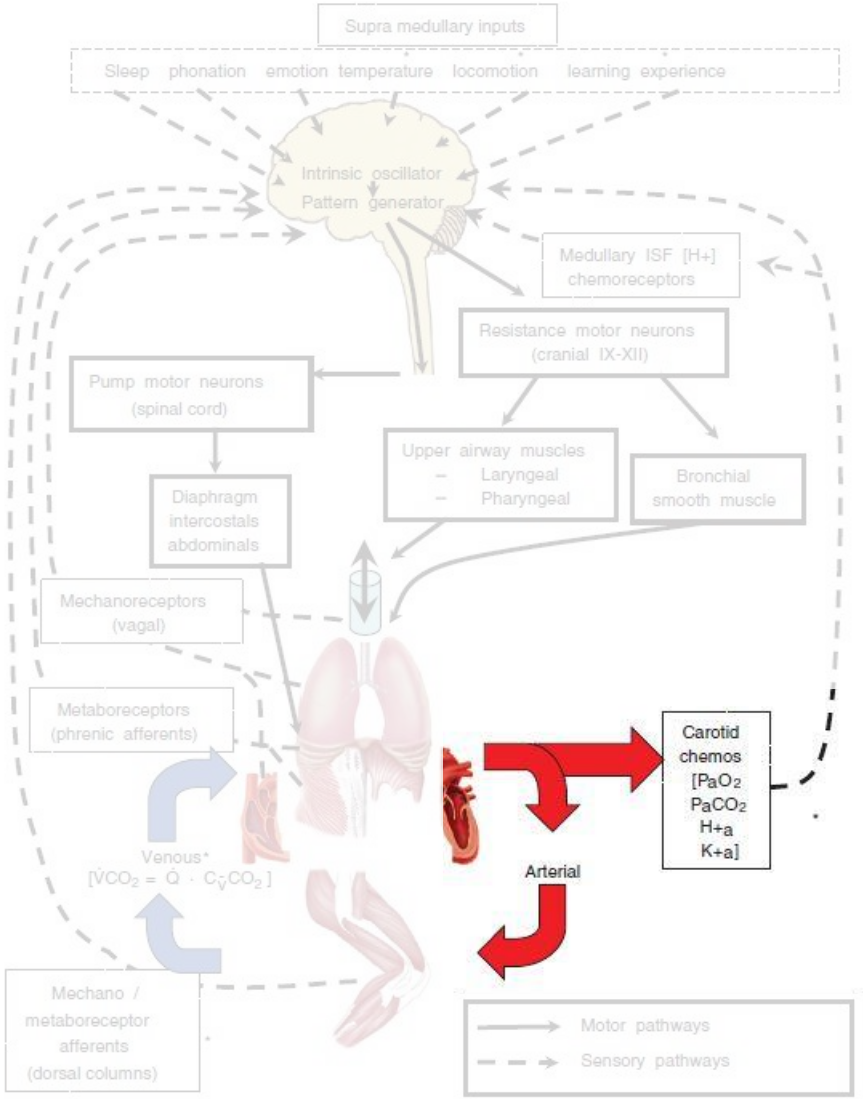
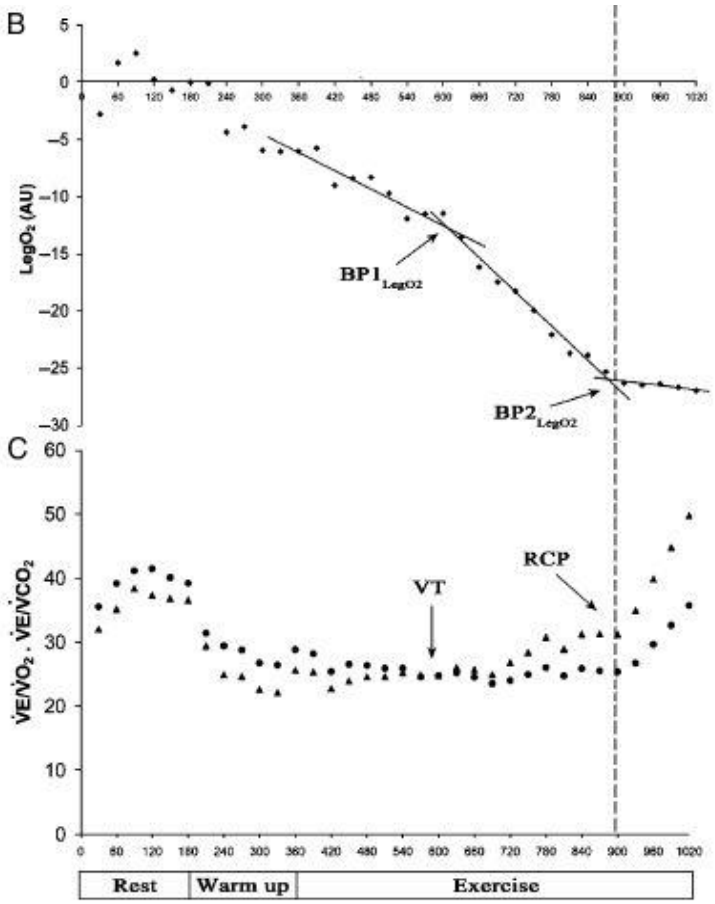
Discussion: Ventilatory Threshold

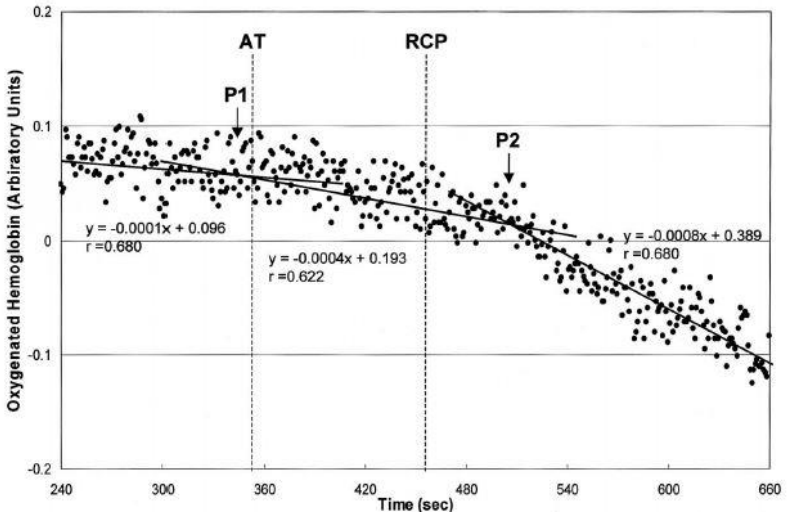




Discussion: Muscle Oxygenation Threshold

- Muscle HHb and O_2Hb breakpoints coincident with VT2





Takeshi Miura, MD; Toru Takeuchi, MD; Hiroshi Sato, MD; Naoko Nishioka, MD;
Jpn Circ J 1998; **62**: 649–657

No sig diff between muscle O_2Hb breakpoint and VT2

LEGRAND, R., A. MARLES, F. PRIEUR, S. LAZZARI, N. BLONDEL, and P. MUCCI. Related Trends in Locomotor and Respiratory Muscle Oxygenation during Exercise. *Med. Sci. Sports Exerc.*, Vol. 39, No. 1, pp. 91–100, 2007.

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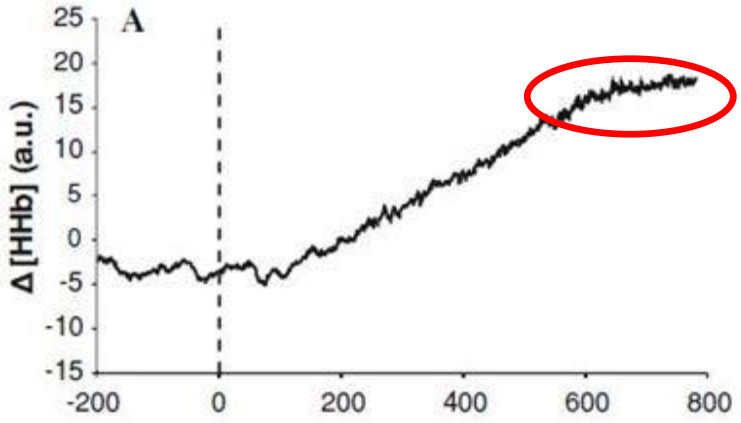
Discussion: Muscle De-Oxy Threshold

De-oxyhaemoglobin + myoglobin [HHb] signal represents balance between O_2 extraction/utilisation and convective O_2 delivery



Characterizing the profile of muscle deoxygenation during ramp incremental exercise in young men

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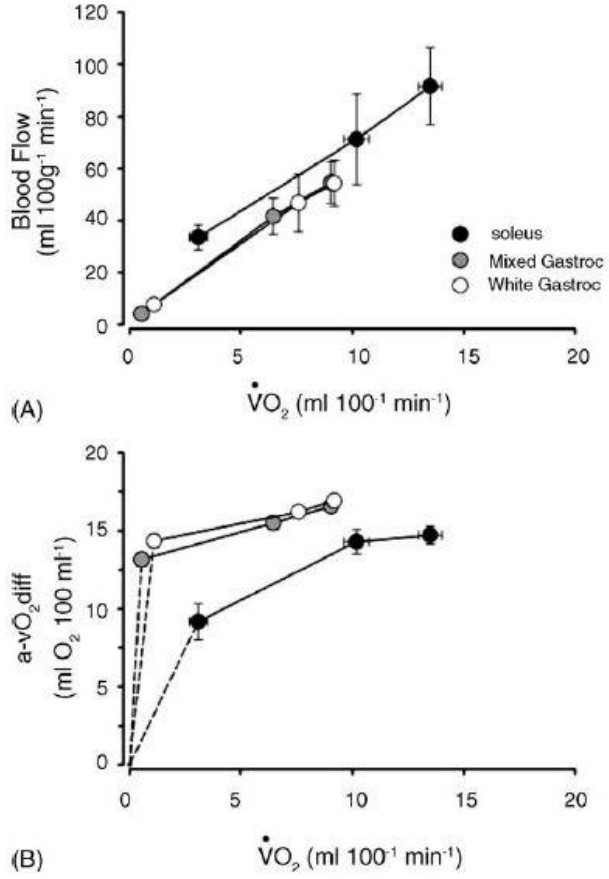


Blood flow and O_2 extraction as a function of O_2 uptake in muscles composed of different fiber types

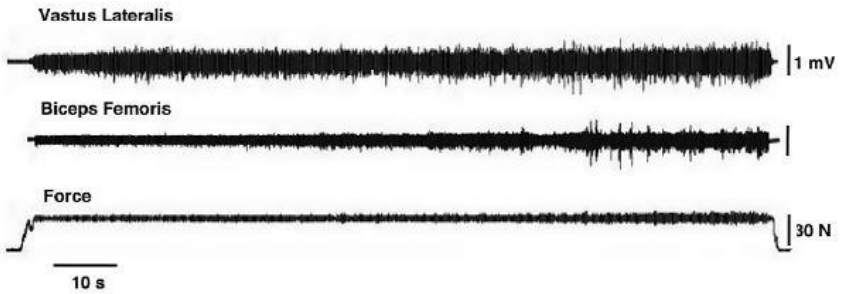
Leonardo F. Ferreira[a,b], Paul McDonough[c], Brad J. Behnke[d], Timothy I. Musch[a,b], David C. Poole[a,b,*]

Respiratory Physiology & Neurobiology 153 (2006) 237–249

Discussion: EMG Threshold

- BF and RF EMG-t coincident with VT2
- VL EMG-t occurred *after* VT2

Fatigue → additional MU recruitment
Henneman size principle → type II MU recruitment



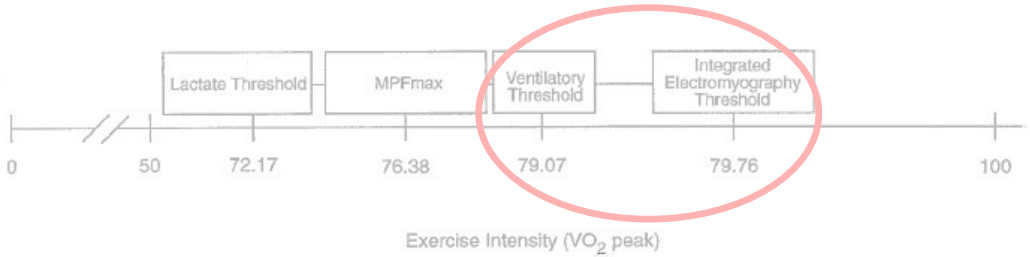
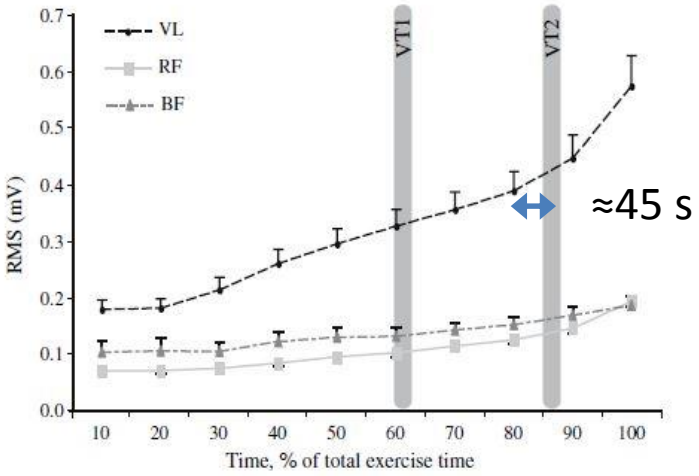


Fig. 7. Flow chart of the order of physiological events on an exercise intensity continuum. Mean data for subjects 1–10

Electromyographic correlates of the transition from aerobic to anaerobic metabolism in treadmill running

A. D. Taylor, R. Bronks

Eur J Appl Physiol (1994) 69:508–515



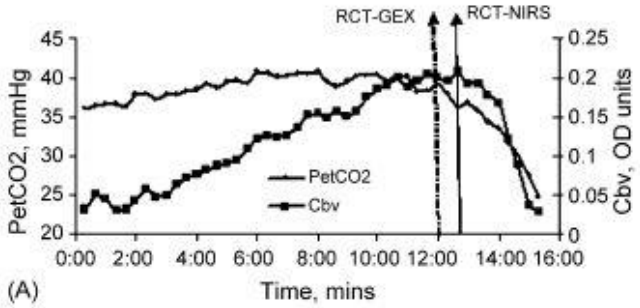
Prefrontal cortex oxygenation and neuromuscular responses to exhaustive exercise

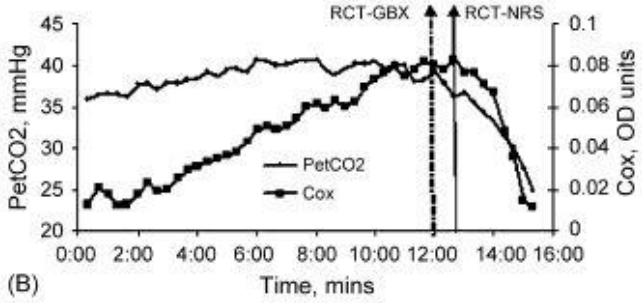
Rupp Thomas · Perrey Stephane

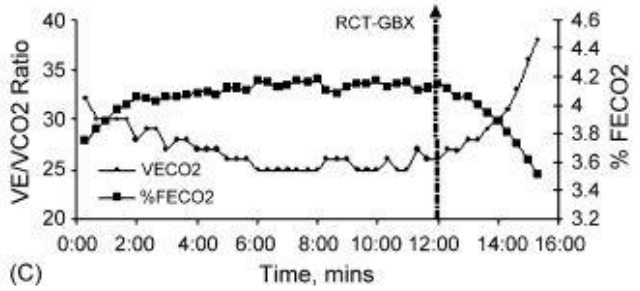
Eur J Appl Physiol (2008) 102:153–163

Discussion: Cerebral Oxygenation

- Cerebral O_2Hb threshold occurs *after* VT2



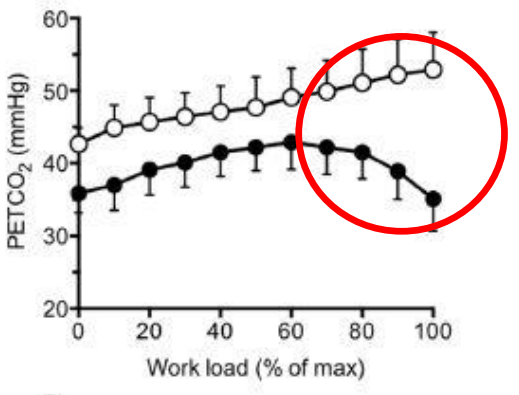


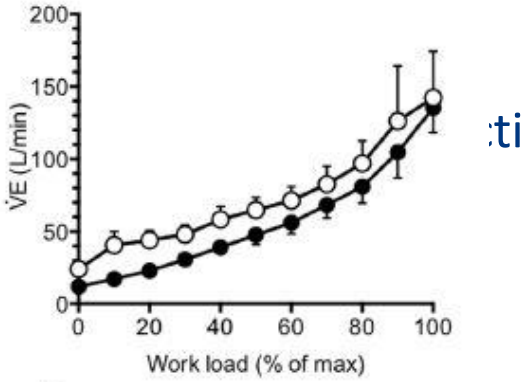


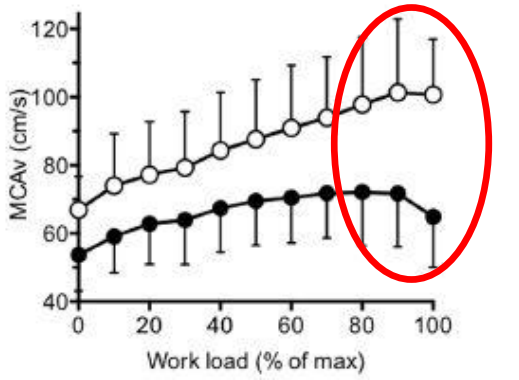
Cerebral

- $PaCO_2$
- Perfus

:tion)







Y. Bhambhani et al. / Respiratory Physiology & Neurobiology 156 (2007) 196–202

Summary and Conclusions

Threshold behaviour during incremental ramp exercise reflects central feed-forward and rapid neural feedback mechanisms to increase V_E

Reduced O_2 extraction and plateauing of HHb signal coincident with type II MU recruitment

↓

Type II MU recruitment and subsequent rapid onset fatigue reflected by t-EMG

Decreasing $PaCO_2$ → cerebral vasoconstriction and ↓CBF

↓

↓ cerebral O_2Hb signal

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Practical application = non-invasive monitoring

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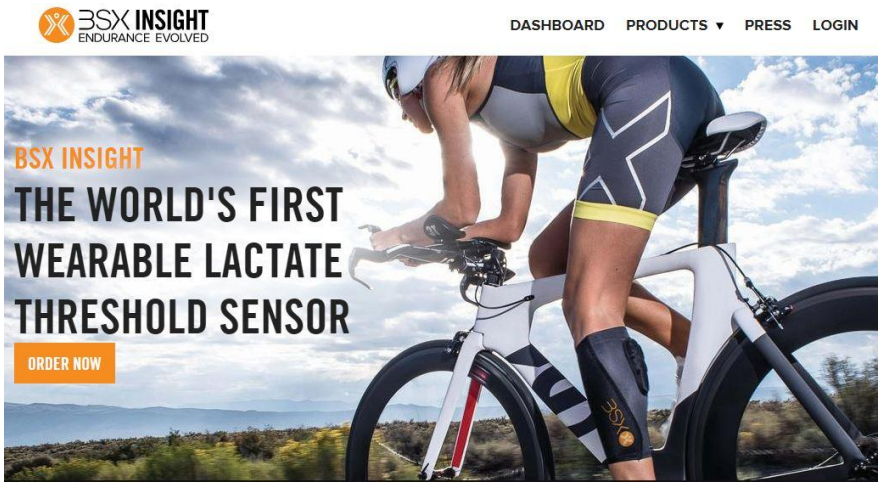

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