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Exercise physiology and sports performance

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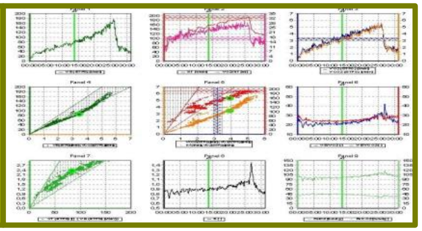
Factors influencing sports performance

Sports performance

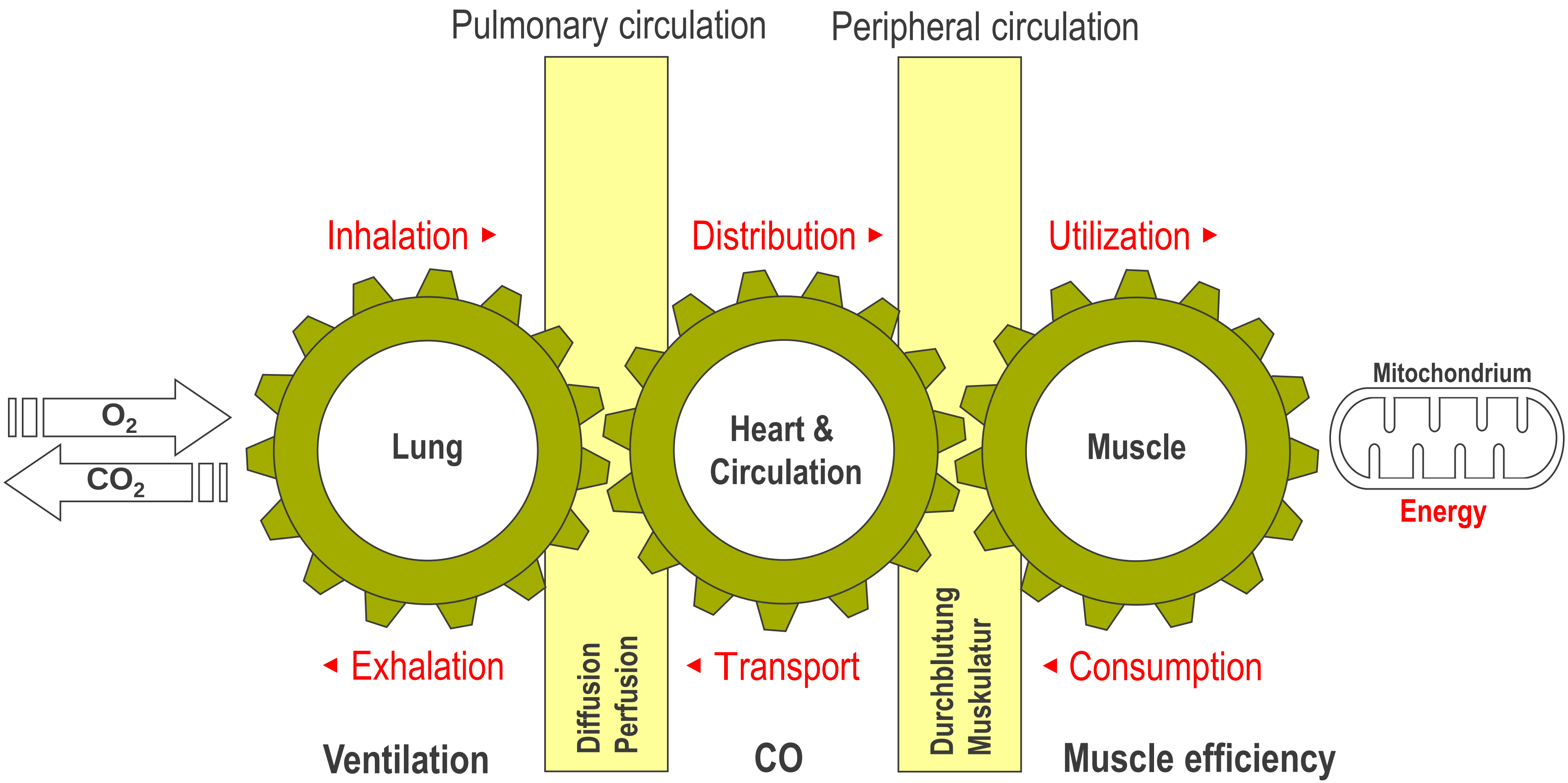
- **Flexibility**
- **Strength**
- **Endurance**
- **Agility**
- **Balance**

Peak oxygen consumption / uptake

Cardiopulmonary exercise testing



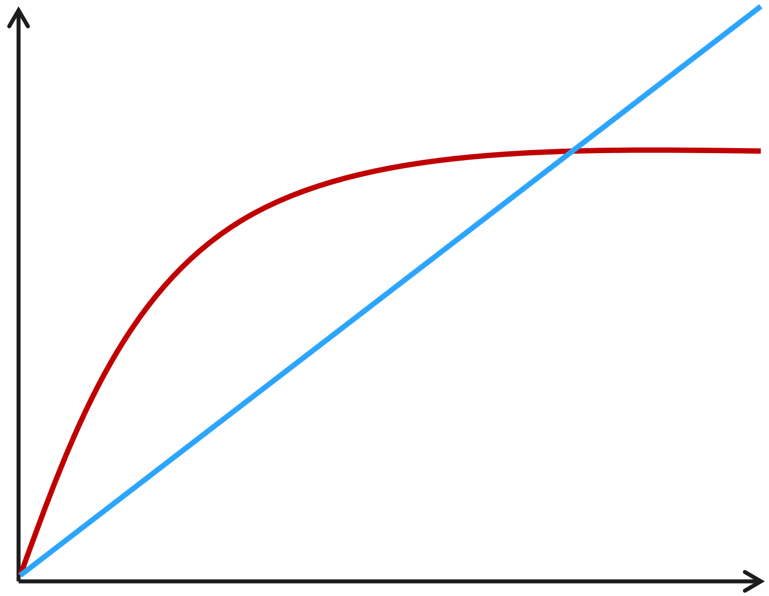
Determinants of sports performance

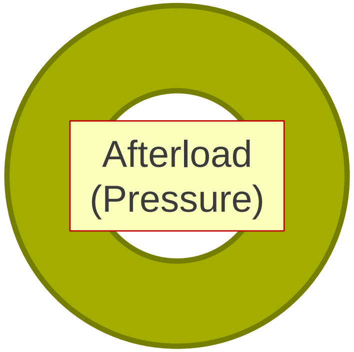


Cardiac output in athletes

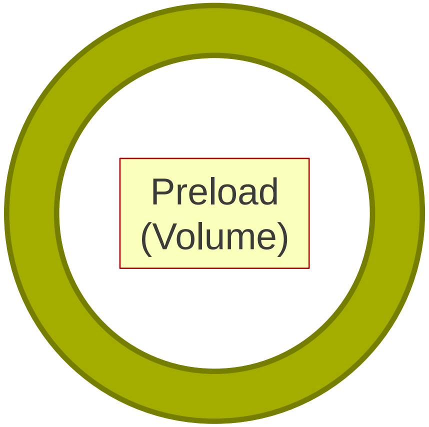
VO_2 = Cardiac output (CO) x a-vO_2Diff

CO = Stroke volume (SV) x Heart rate (HR)





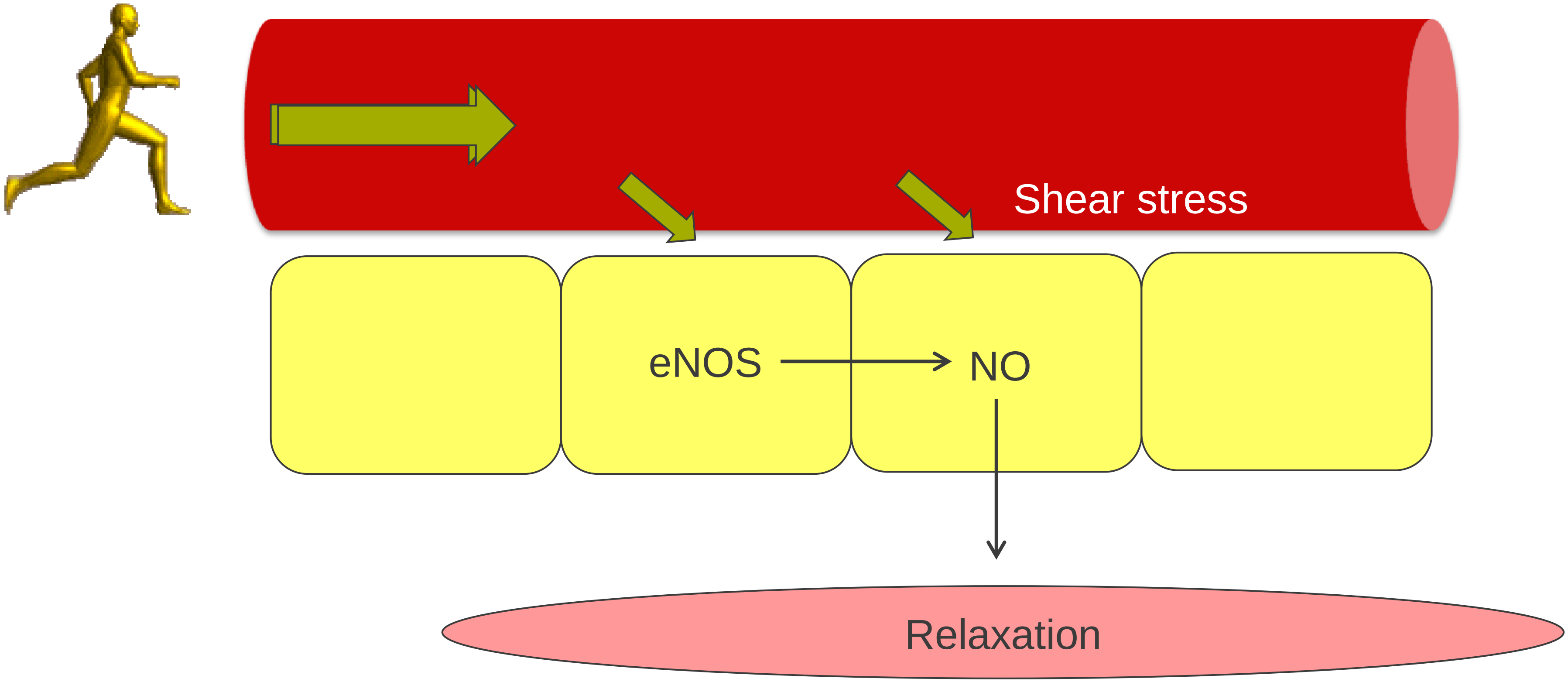
Picture of strength athlete



Picture of endurance athlete

Morganroth J, Maron BJ, Ann NY Acad Sci 1977;301:931

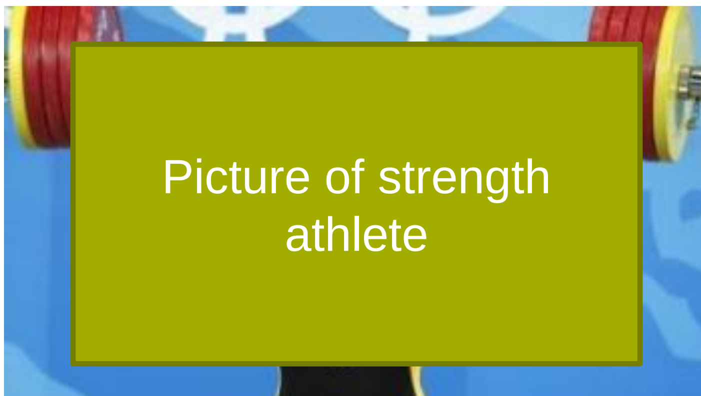
Circulation in endurance athletes



Increased capillary density- and surface → maintains oxygen utilization (a-vO_2Diff)

Schuler G et al, Eur Heart J 2013;34:1790-9

Circulation in strength athletes



Dynamic / concentric
(muscle contracts and shortens)

Eccentric
(muscle contracts but lengthens)

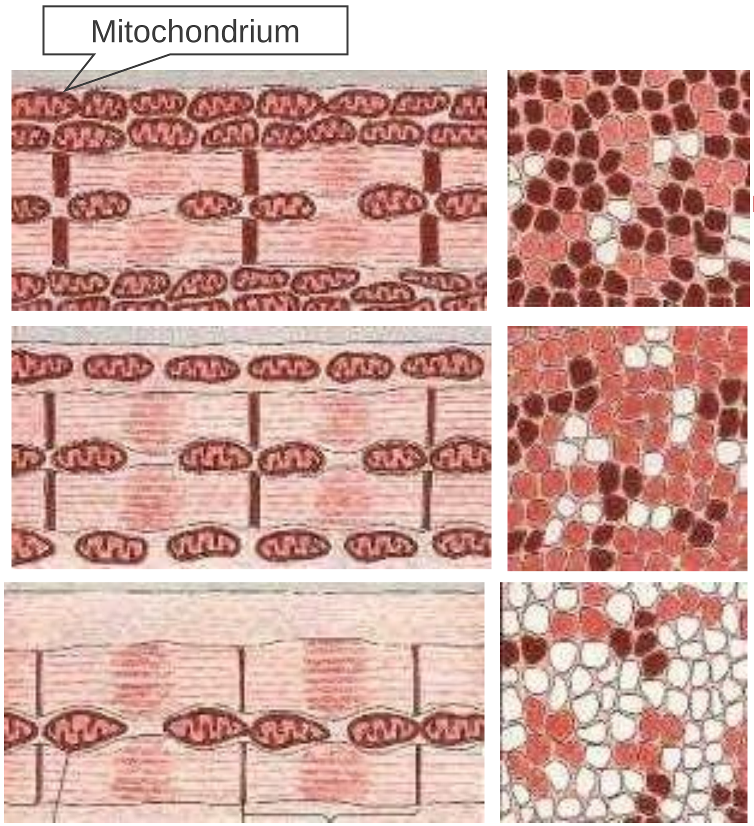
Isometric
(muscle contracts, no change in length)

Initial vasodilatation and slight increase in cardiac output

Muscle contraction compresses vessels with reduced blood flow

Increase in peripheral resistance and blood pressure

Types of muscle fibers



Type I: S(low) fibers
Predominantly aerobic, „slowly twitching“,
High density of mitochondria, high activity of aerobic enzymes, fatigue-resistant
→ „red muscle“

Type IIa: F(ast resistant) fibers
Mainly anaerobic, „fast twitching“
Less mitochondria, rapid fatiguing, but good response to exercise!
→ „white muscle“

Type IIb: F(ast fatigue) fibers
Anaerobic, „fast twitching“
Few mitochondra, strong, agile, but very rapid fatigue
→ „white muscle“

Determinants and limits of VO_2max

Ethnicity

Age

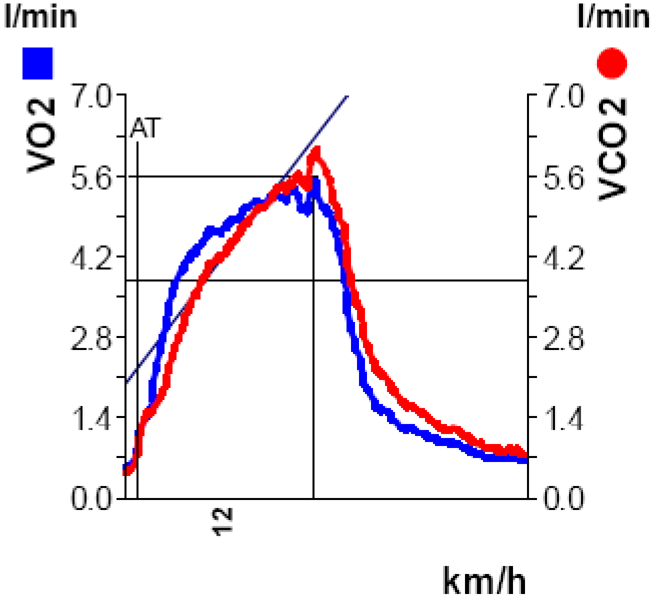
Training status

Gender

Capacity of energy-delivering systems

Genetic disposition

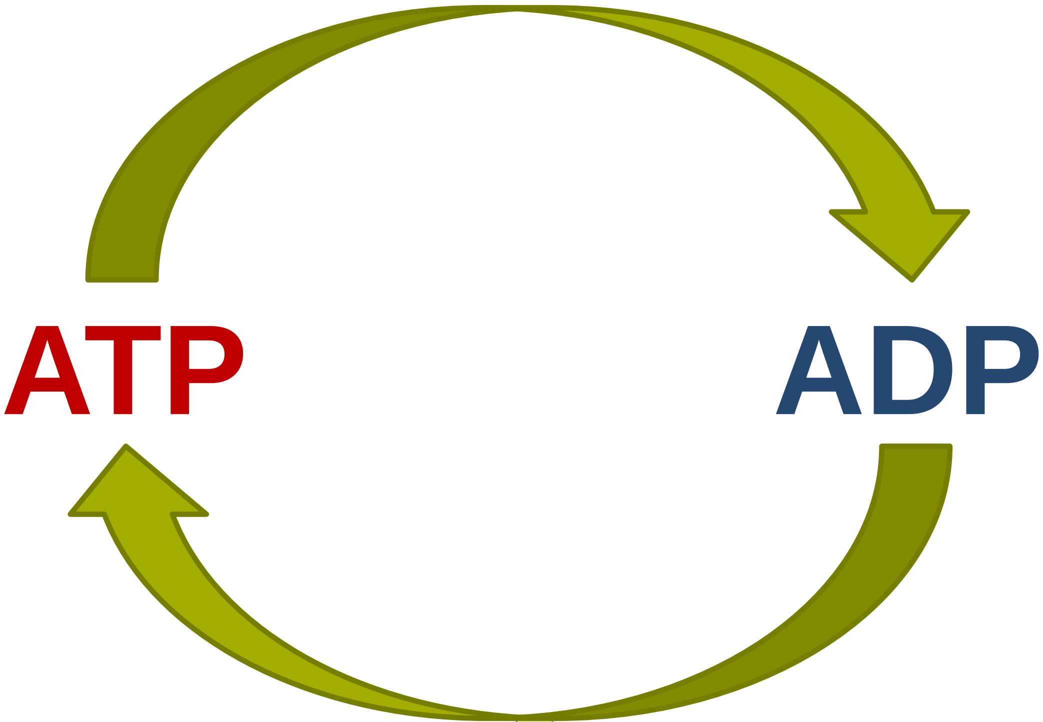
Upper physiological limits of cardiac adaptation



85-90 ml/min/kg

Lavie CJ et al, Circ Res 2015;117:207-219

ATP-Resynthesis: Energy supply



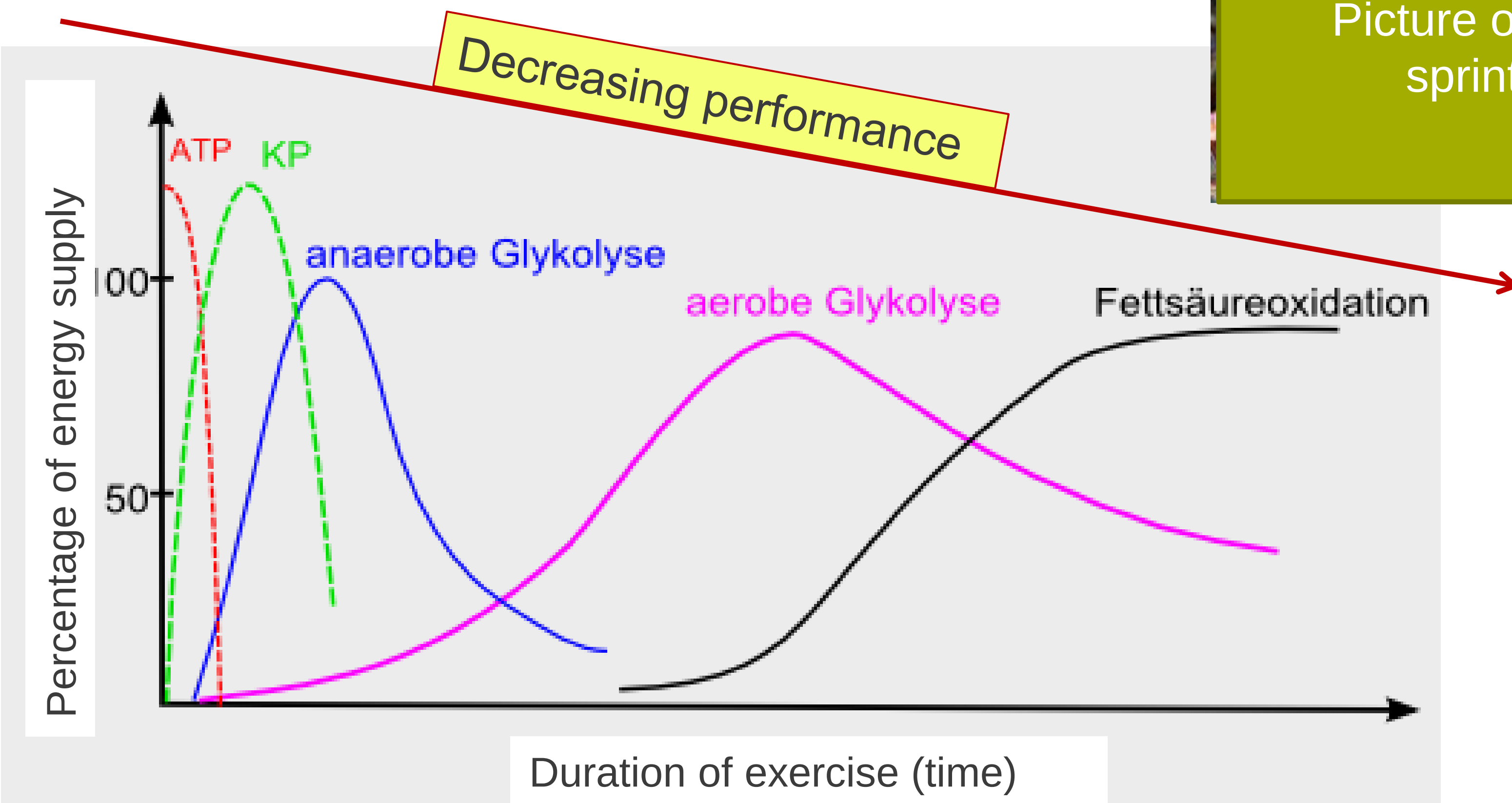
Aerobic
(O_2-Consumption)

Anaerobic-lactacid
(anaerobic glycolysis)

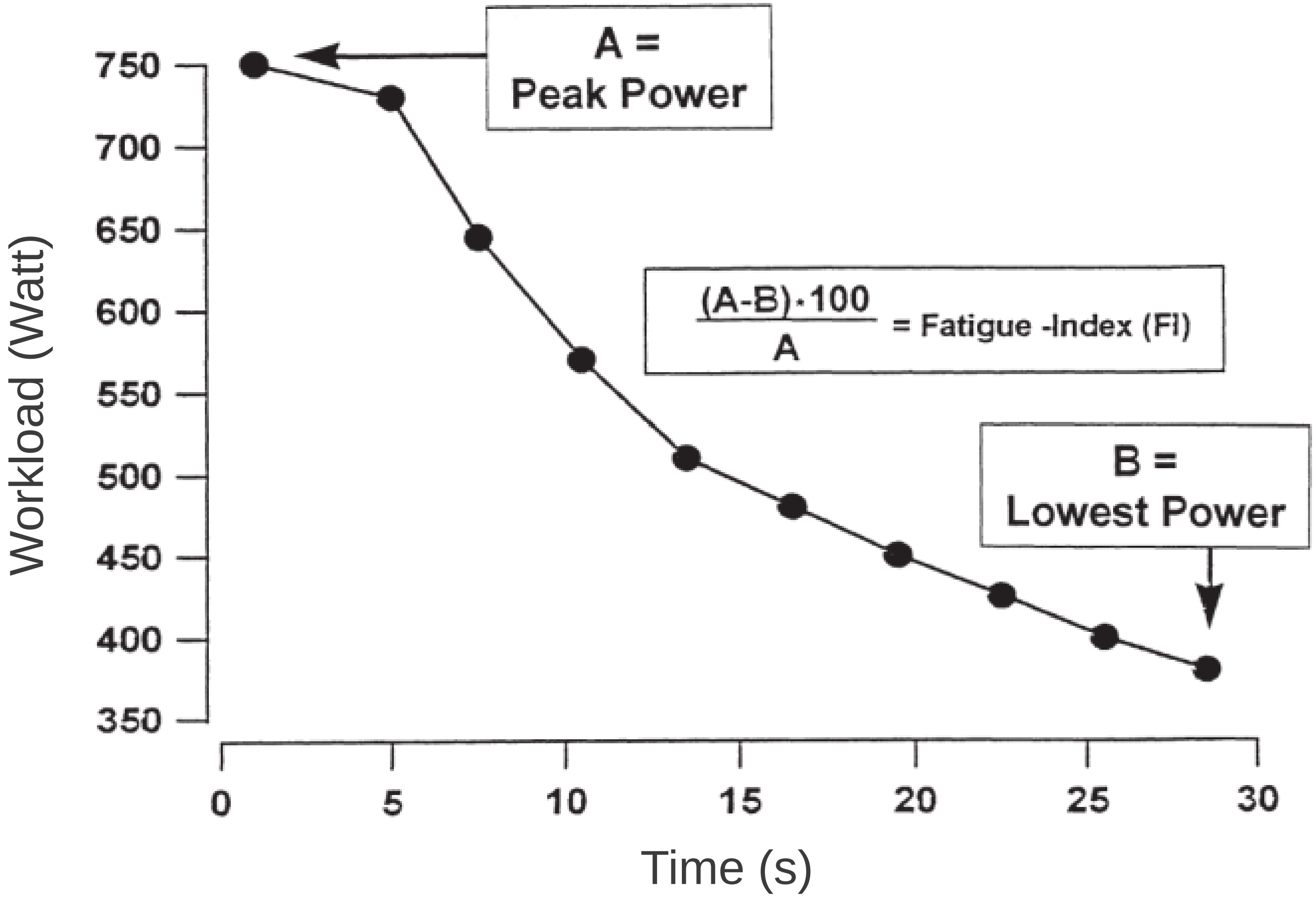
Anaerobic-alactacid
(creatine phosphate)

Energy supply during maximal exercise

Picture of 100m sprinters

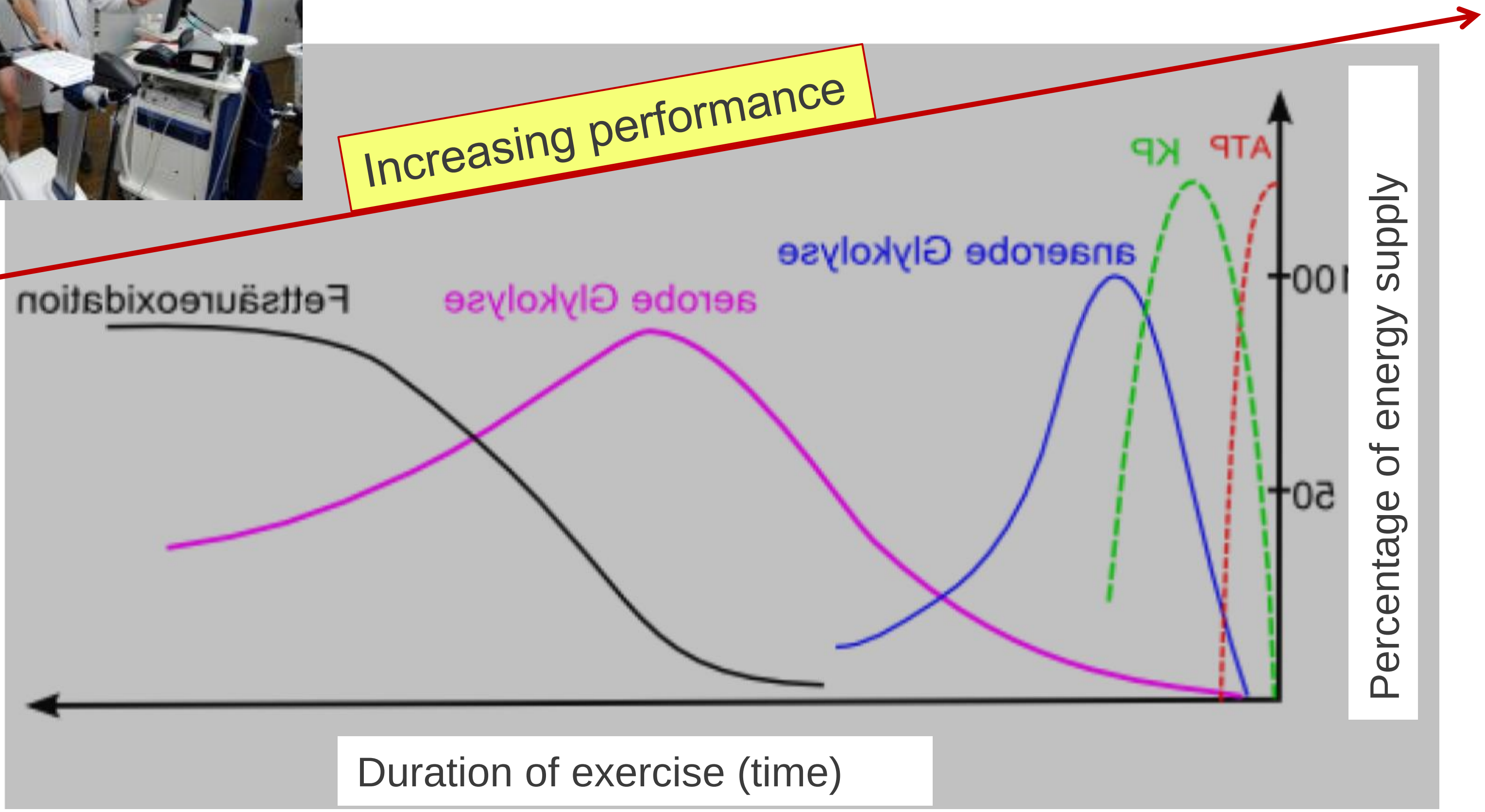


Testing anaerobic capacity

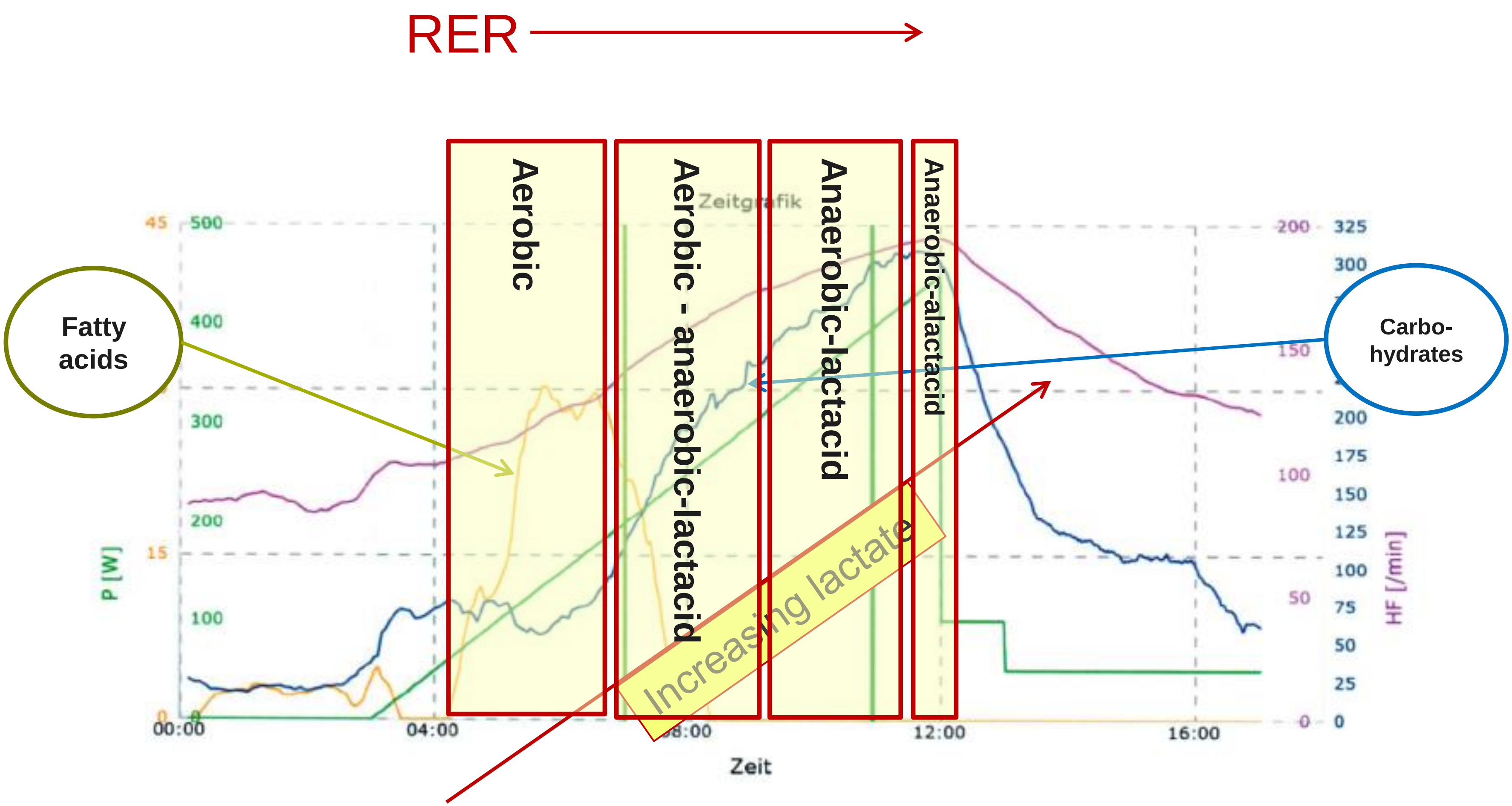


Heck H, Schulz H, Dtsch Z Sportmed 2002;53:202-12

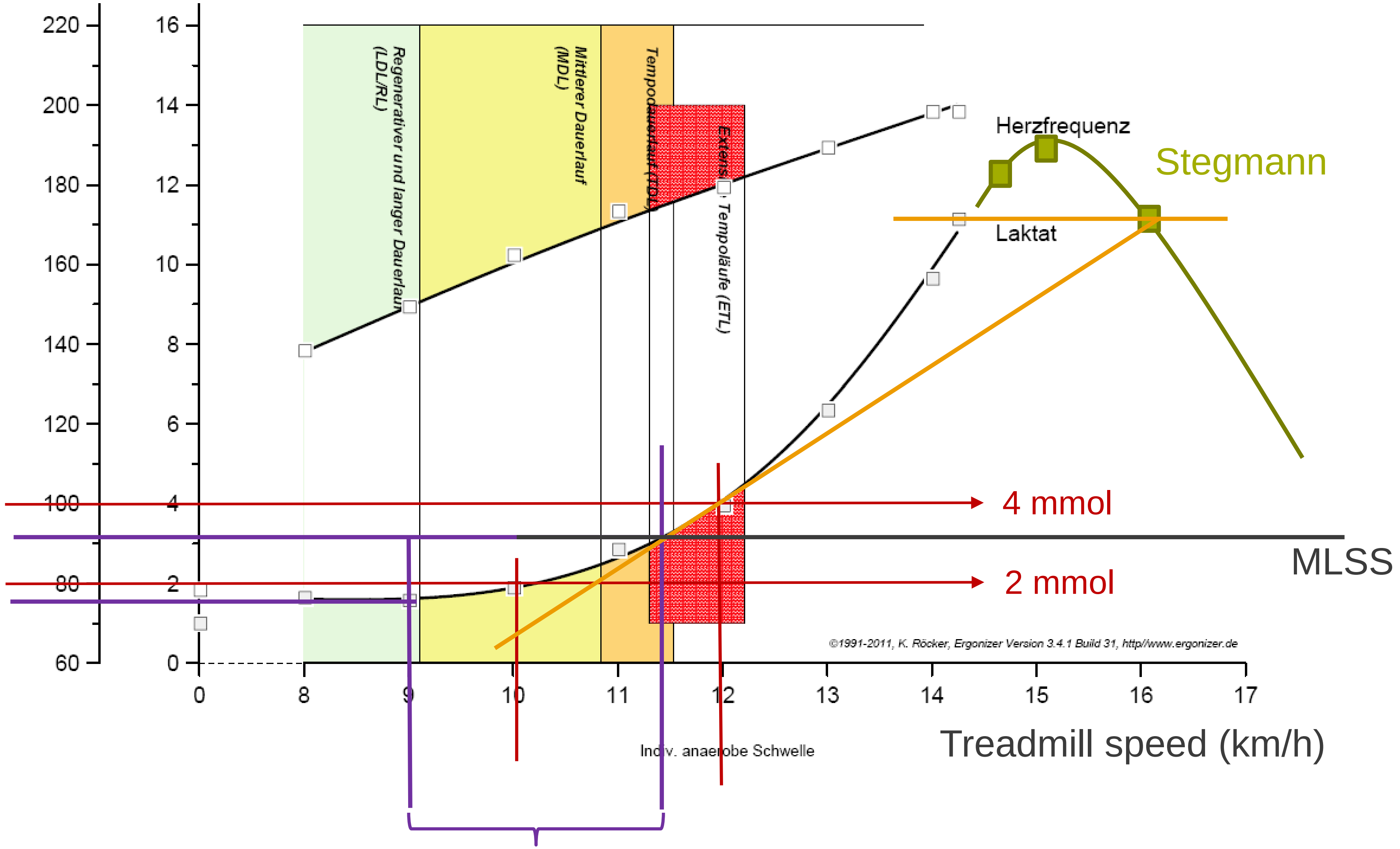
Energy supply during incremental exercise



Indirect Calorimetry

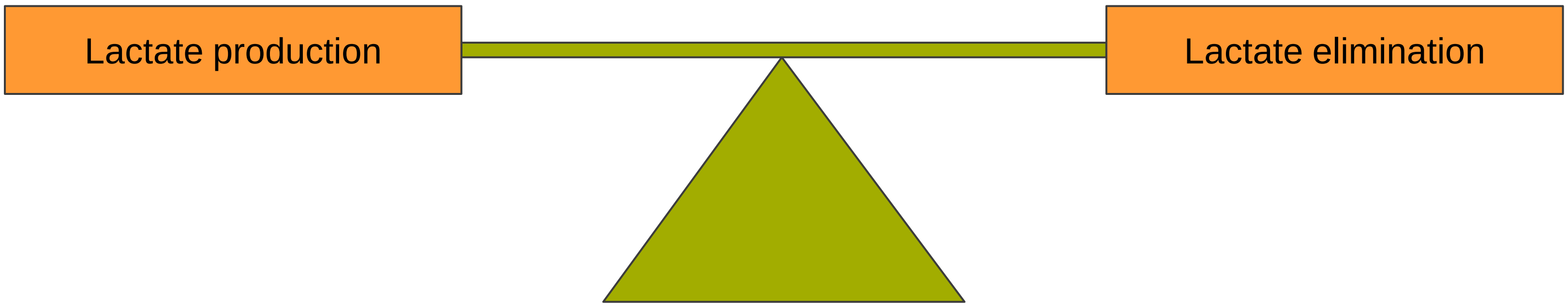


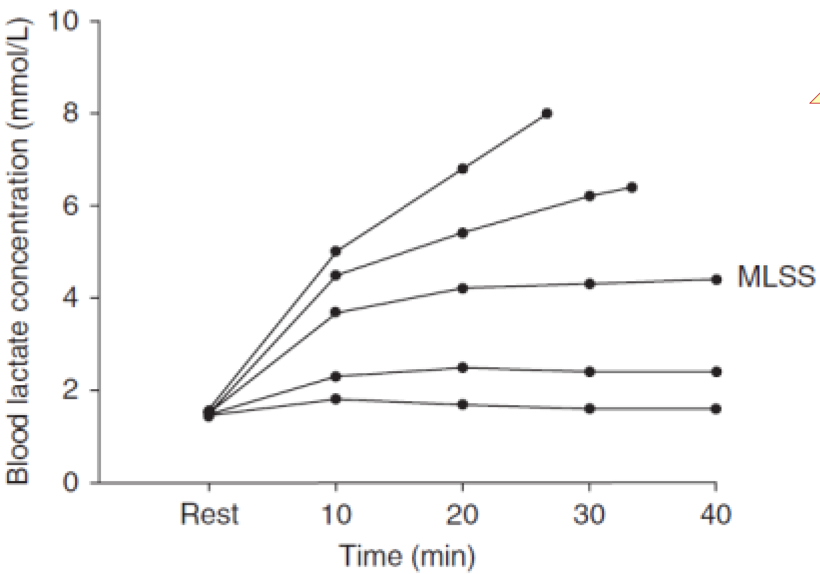
Lactate curve: Selected threshold concepts

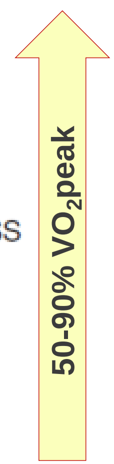


Dickhuth: Increase of lactate over baseline + 1,5 mmol

Maximal lactate steady state







- Production and elimination of lactate are in equilibrium
- Determined by several constant load trials at increasing intensities with a maximum increase of 1 mmol/l
- Respiratory parameters remain constant, but respiratory and heart rate increase

Faude O et al, Sports Med 2009;39:469-90

Lactate thresholds and performance

Threshold	Short distance		Middle distance		Long-distance	
	Velocity	VO_2	Velocity	VO_2	Velocity	VO_2
LT_{FIX}	0.85 (0.68-0.93)	0.73 (0.51-0.79)	0.91 (0.81-0.95)	0.89 (0.74-0.93)	0.92 (0.68-0.98)	0.92 (0.68-0.98)
LT_{AER}	0.74 (0.43-0.93)	0.66 (0.58-0.85)	0.84 (0.73-0.97)	0.79 (0.45-0.92)	0.86 (0.76-0.98)	0.68 (0.42-0.91)
LT_{AN}	0.88		0.91 (0.83-0.94)	0.76 (0.66-0.83)	0.91 (0.89-0.93)	0.71 (0.67-0.83)

Above: Correlation coefficients between different thresholds and running performance

Below: Mean bias for different threshold concepts as compared to MLSS

Lactate threshold concept	Treadmill ergometry 3 min stages, +0.4 m/s			Treadmill ergometry 5 min stages, +0.4 m/s			Cycle ergometry 2 min stages, +25 W		
	mean bias (m/s)	LoA (m/s)	LoA (%)	mean bias (m/s)	LoA (m/s)	LoA (%)	mean bias (W)	LoA (W)	LoA (%)
LT4	−0.13	±0.35	±8	0.02	±0.39	±9	−19.8	±28.4	±14
IAT (Keul et al.[96])	−0.20	±0.39	±9	0.06	±0.35	±8	−21.0	±22.4	±11
IAT (Stegmann et al.[88])	−0.03	±0.51	±12	−0.03	±0.37	±9	−15.0	±35.0	±18
IAT (Bunc et al.[143])	−0.33	±0.33	±8	−0.14	±0.37	±9	−71.4	±52.8	±27

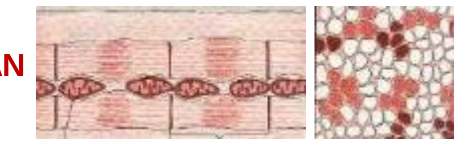
IAT = individual anaerobic threshold; **LT4** = 4 mmol/L threshold.

Faude O et al, Sports Med 2009;39:469-90

Training zones

LT_{AER}

LT_{AN}



aerobic | aerobic - anaerobic | anaerobic

Regeneration / compensation:

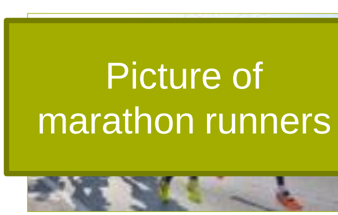
- Exercise for „recovery“ or long-distance training
- Stabilizing rather than increasing performance
- No threshold shift
- Continuous exercise
- Stabilizing mitochondrial density and capillary flow

Aerobic performance I & II:

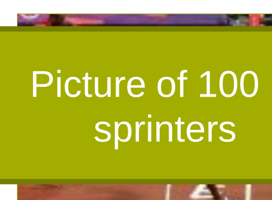
- Exercise for improving basic aerobic fitness
- Shift of thresholds to higher intensities
- Either as continuous (I) or interval-based exercise
- Increasing capillary flow and mitochondrial density

Anaerobic, maximal capacity:

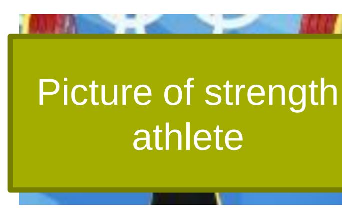
- Exercise for improving peak performance
- Usually no relevant threshold shift
- Maximal consumption of all energy sources
- Increasing „lactate tolerance“



Picture of marathon runners

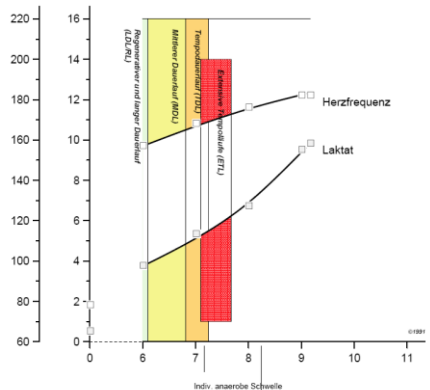


Picture of 100 m sprinters

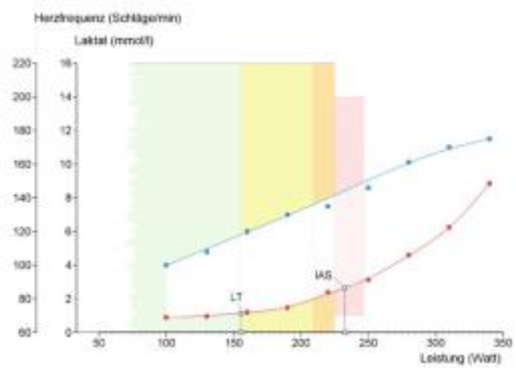


Picture of strength athlete

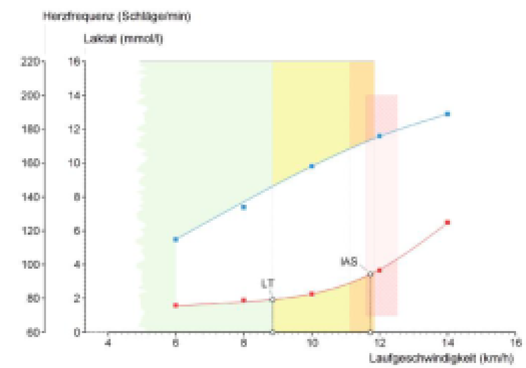
Lactate curves and sports performance



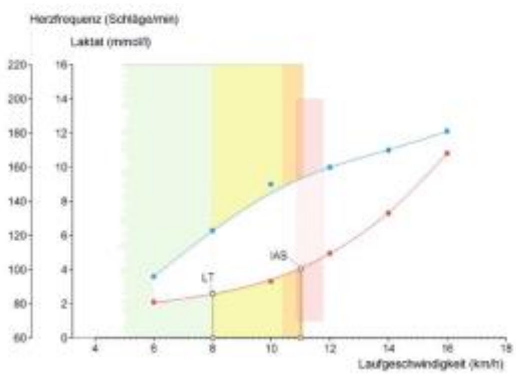
Untrained



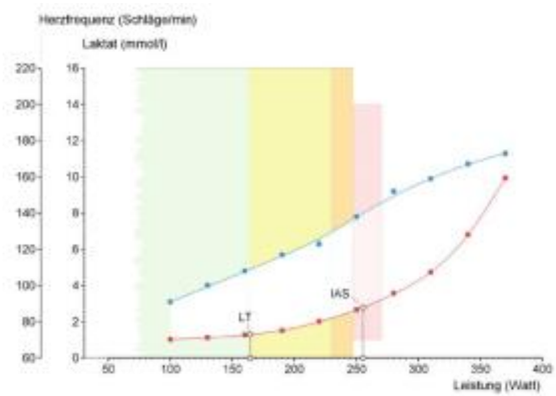
Strongest man of the world



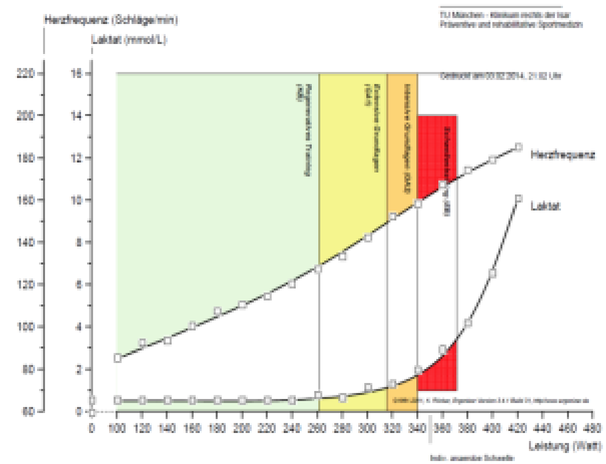
Bobsled World champion



Soccer pro

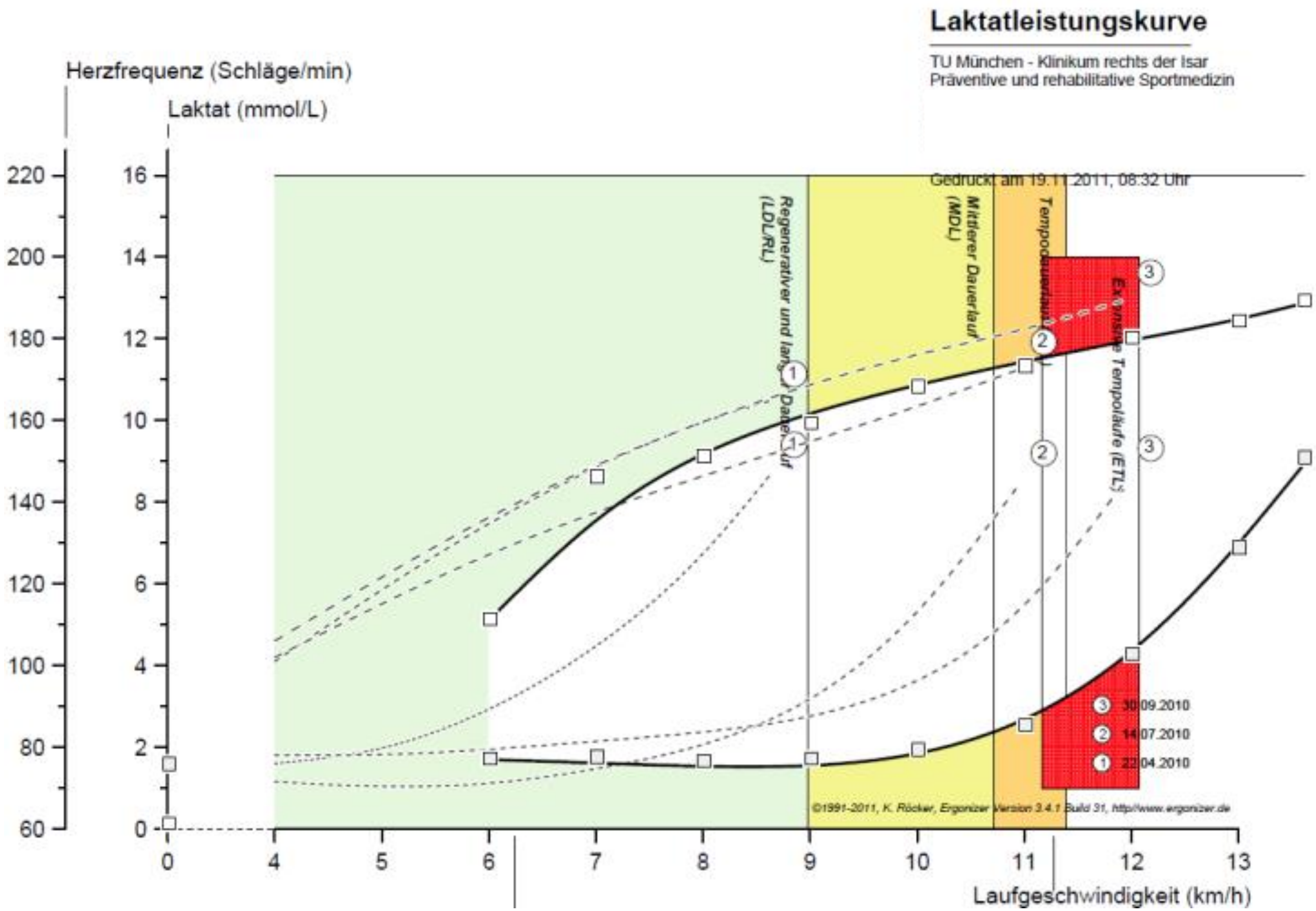


Slalom winner

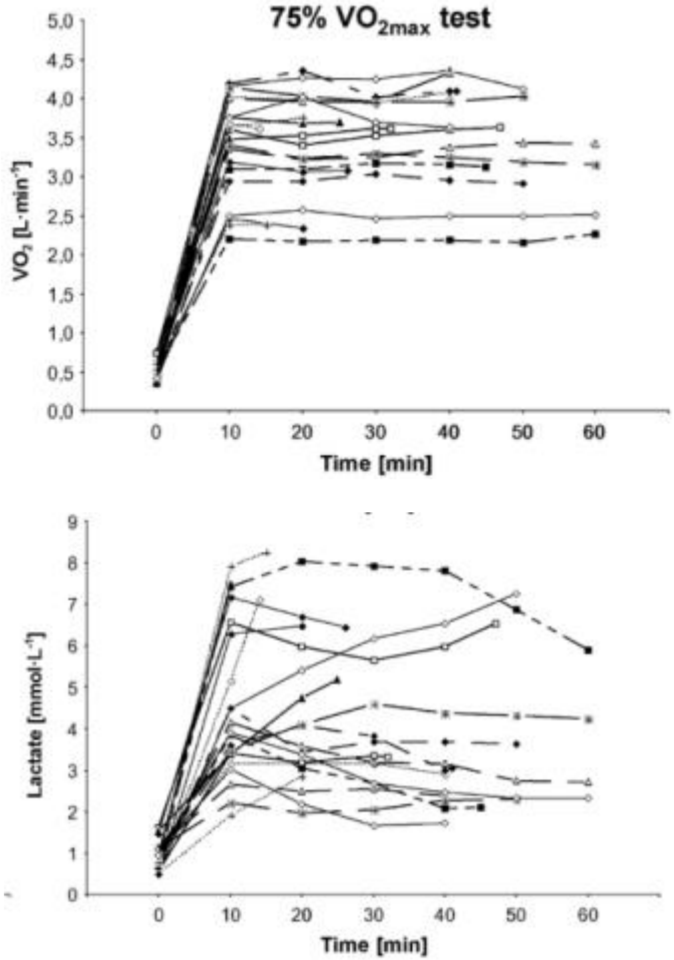


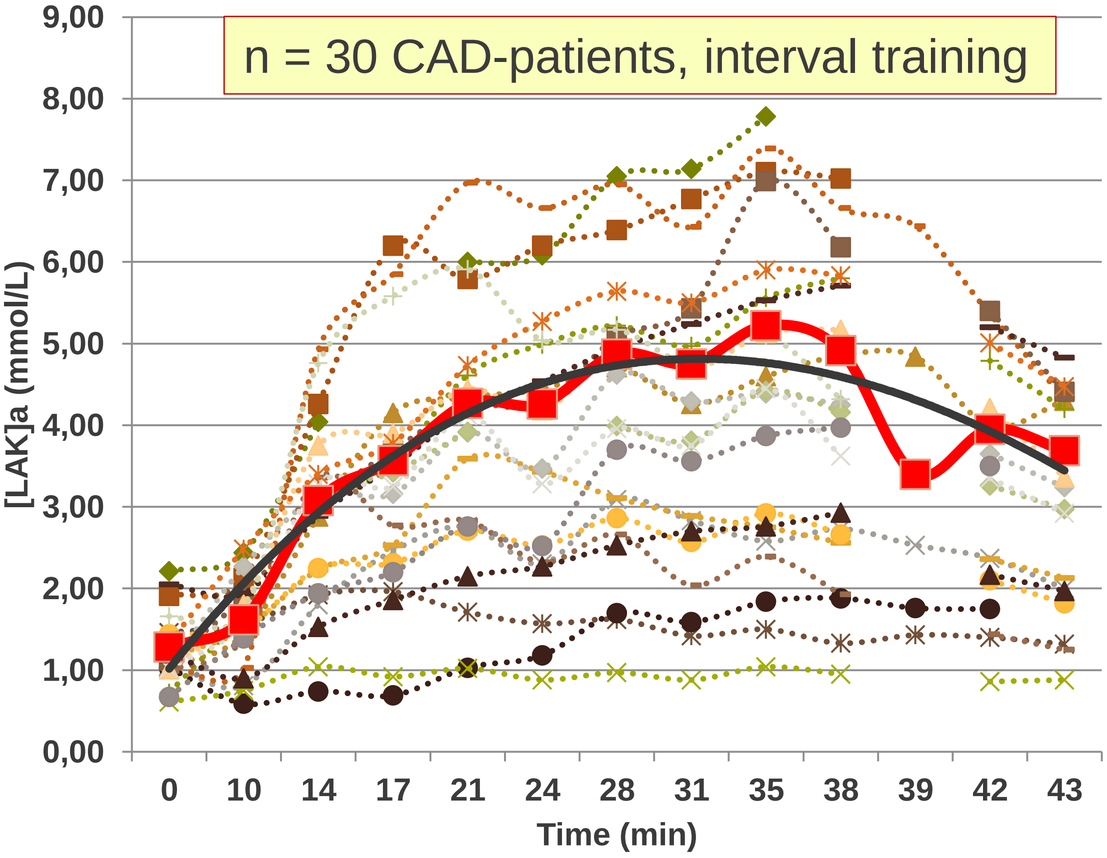
Cycling pro

Increasing aerobic performance



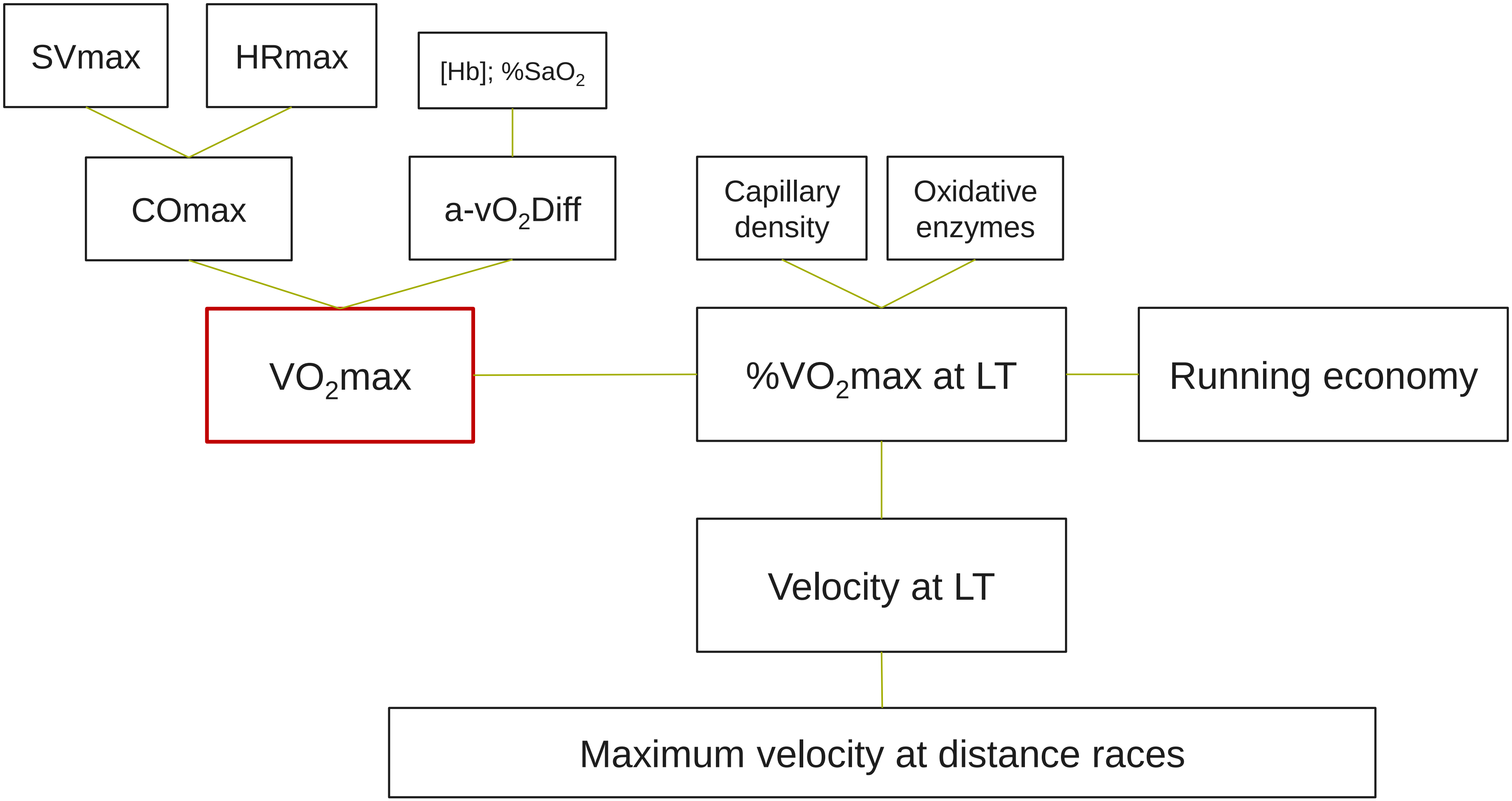
Ventilation vs. metabolism





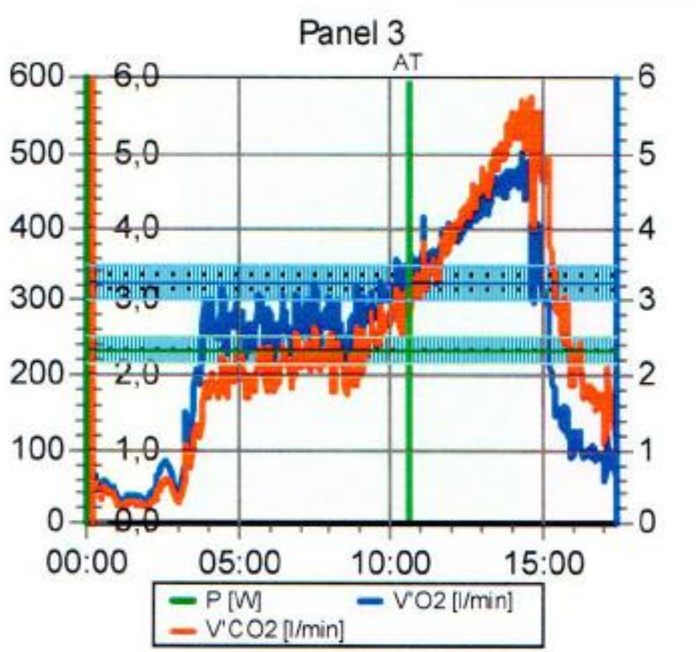
Scharhag-Rosenberger et al, J Sci Med Sport 2010;13:74 // Christle JW, unpublished data

Can we predict performance by VO_2max?

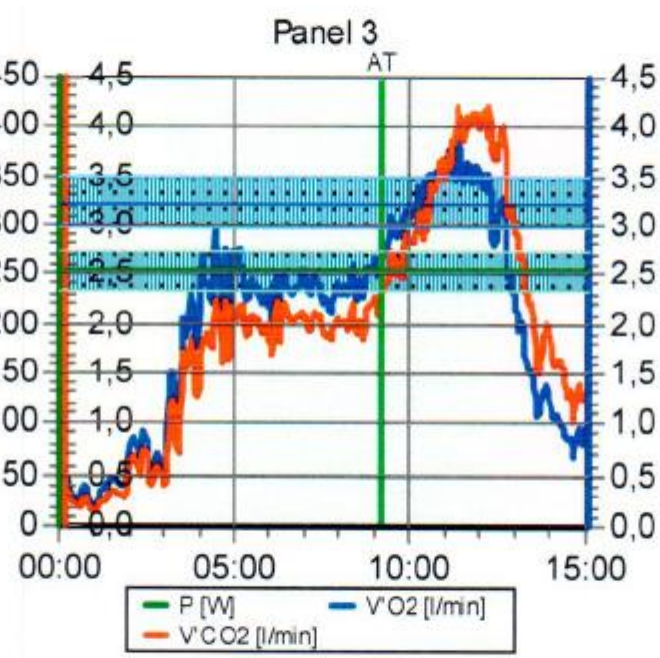


Bassett DR Jr., Howley ET, Med Sci Sports Exerc 1997;29:591-603

Examples from CPET



VO$_2$peak 72 ml/min/kg
VO$_2$AT 49 ml/min/kg
VE 146 l/min
RER 1,13
HR 186/min
Time on treadmill 14:30 min
Finishing time 2:24 h



VO$_2$peak 38 ml/min/kg
VO$_2$AT 29 ml/min/kg
VE 97 l/min
RER 1,02
HR 179/min
Time on treadmill 12:10 min
Finishing time 6:13 h

Conclusion

- There is no uniform measure to characterize sports performance from a physiologic background
- CPET is only one method for assessing exercise performance focusing on physiological backgrounds of aerobic capacity
- Sports performance is limited by physiological upper limits in cardiac output, blood flow and muscular oxidative capacity
- Performance in endurance sports is predicted by submaximal parameters rather than maximal oxygen uptake alone

Kontakt

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