Is swimming just different?

An endurance training researcher reflects on what makes swimming special…..**and NOT**

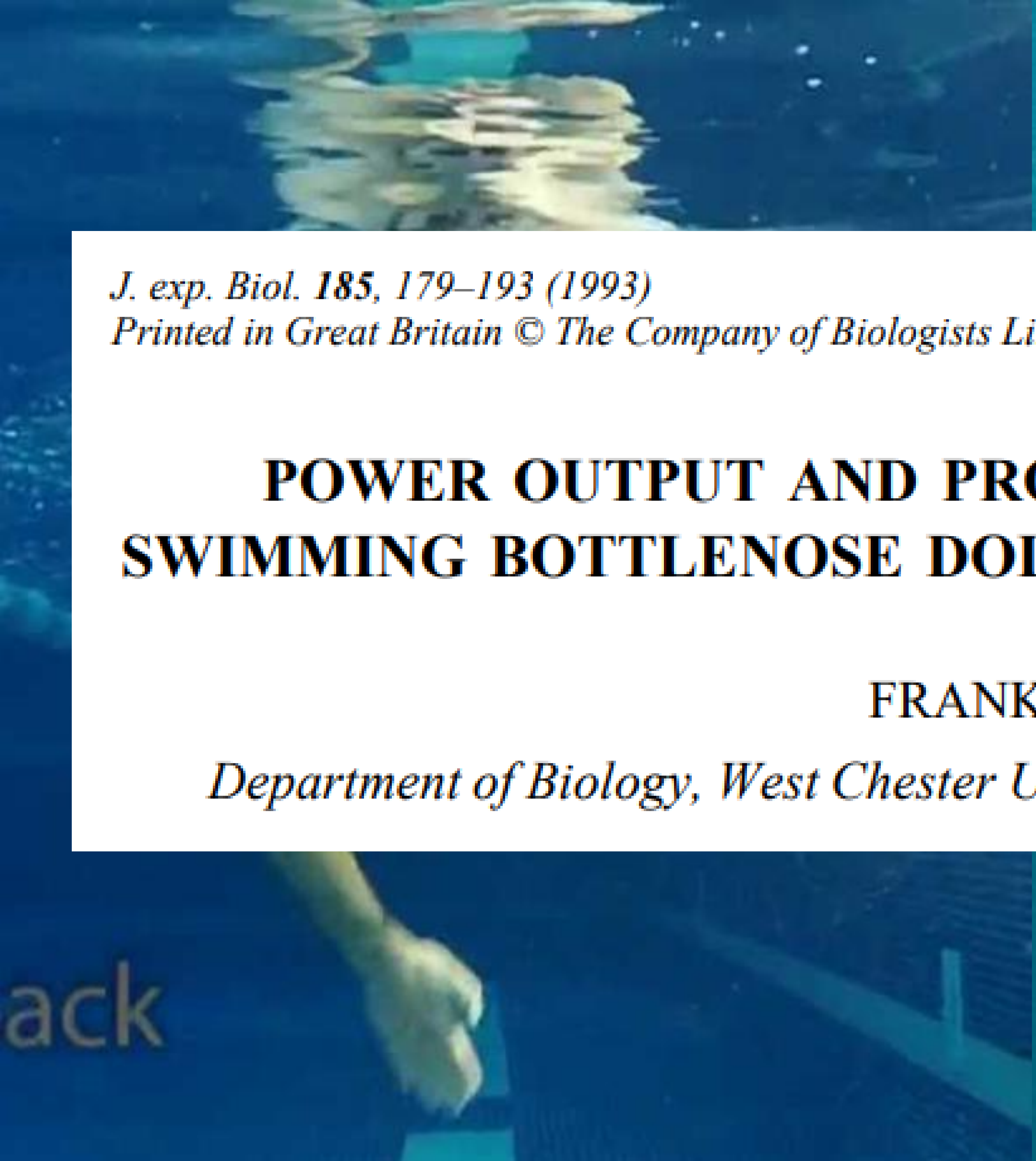
Stephen Seiler PhD

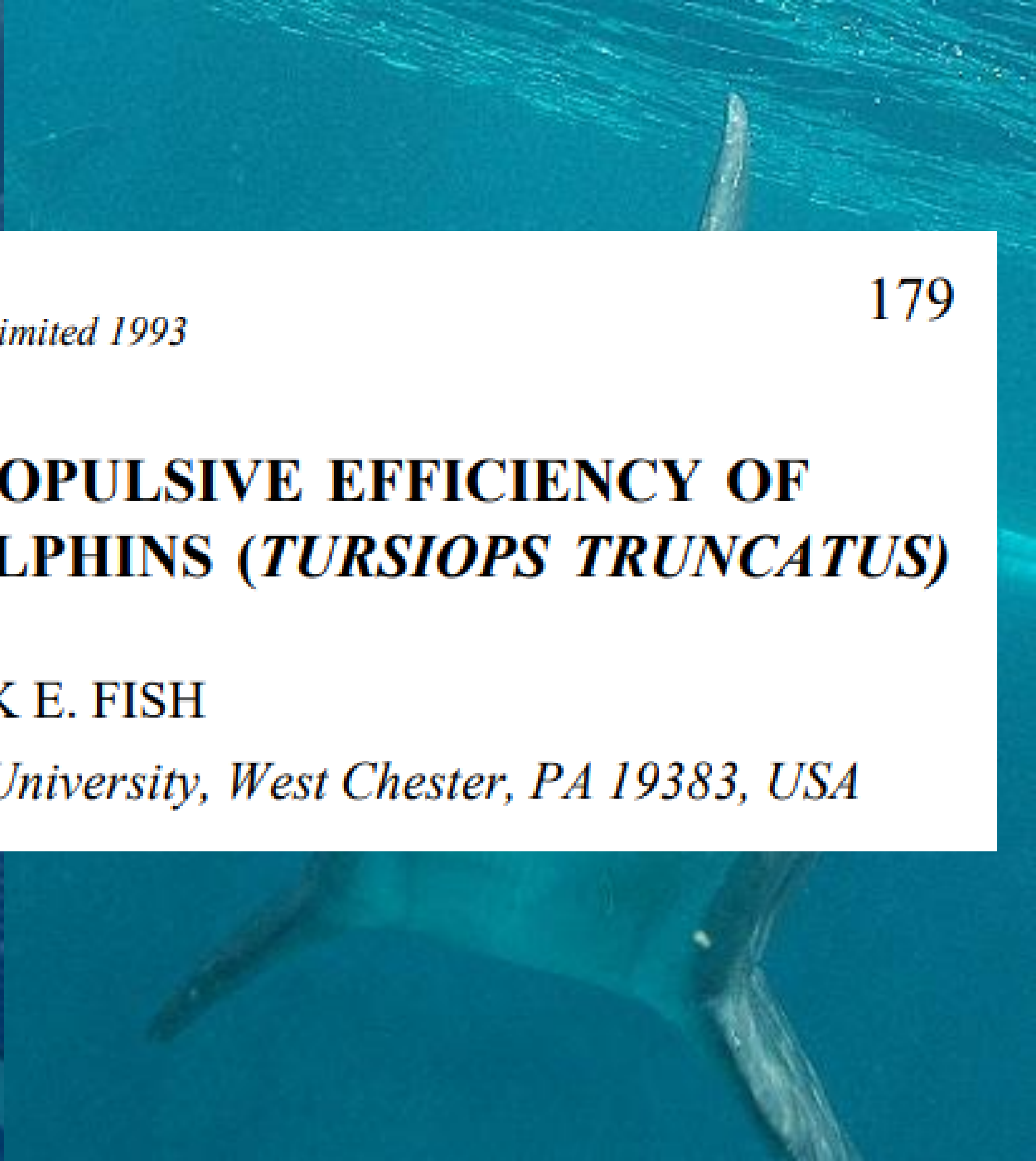
University of Agder

Kristiansand, Norway

My starting point:

Swimming is really hard for humans!





J. exp. Biol. **185**, 179–193 (1993)

POWER OUTPUT AND PROPULSIVE EFFICIENCY OF SWIMMING BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*)

FRANK E. FISH

Department of Biology, West Chester University, West Chester, PA 19383, USA

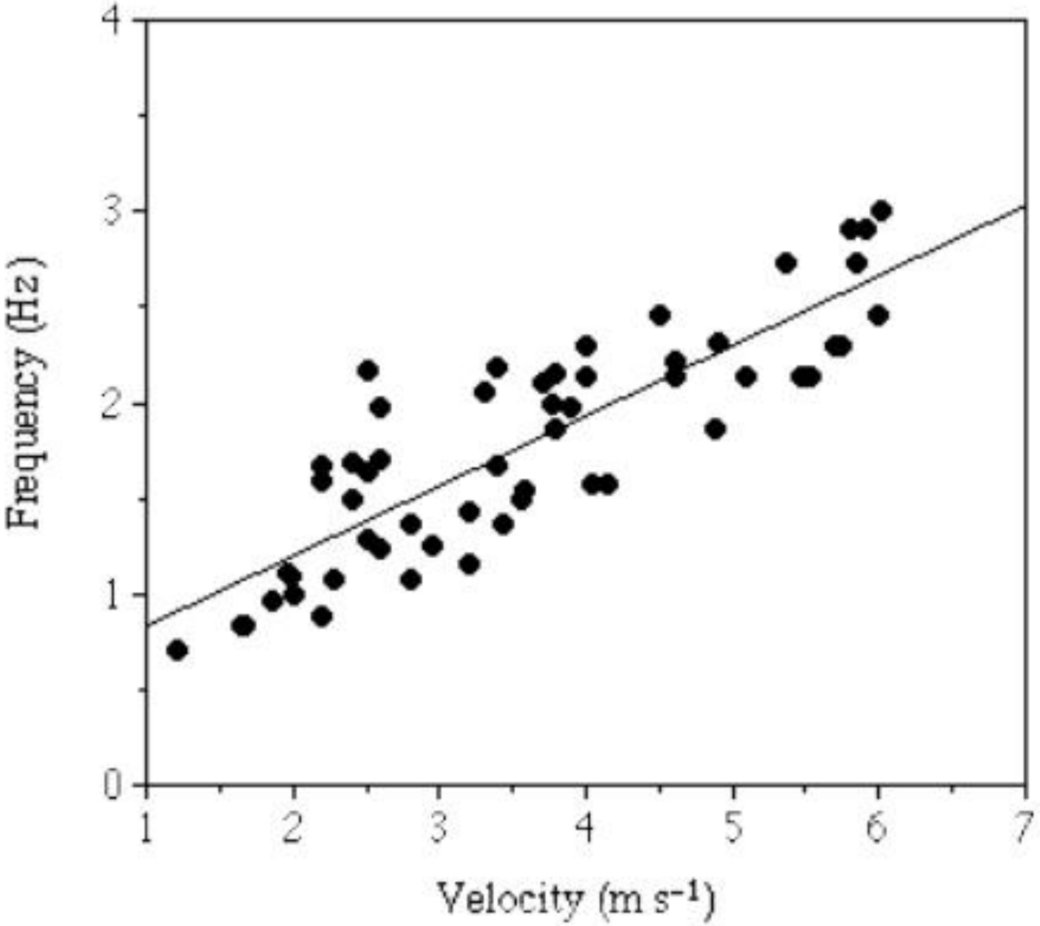


Fig. 4. Tail-beat frequency, f (Hz), as a function of the swimming velocity, U ($m\,s^{-1}$). Regression equation for line provided in text.

Swimming Distance	World Record Human Swimmer	Out of shape and lazy Dolphin 3 to 4x faster
50 meters	20-24 seconds	6 seconds
200 meters	100-113 sec	<30 seconds
10,000 meters	110-120min	35-40min

- **Same Power/kg body mass**
- **Very different propulsive and hydrodynamic efficiency**

- ~80% of Olympic swimming events are ≤200m (~ 2min)
- Yet, swimmers perform more training volume relative to competition duration than any other «endurance» discipline.
- Training load is very monotone and *overreaching* seems to be very common or even planned!

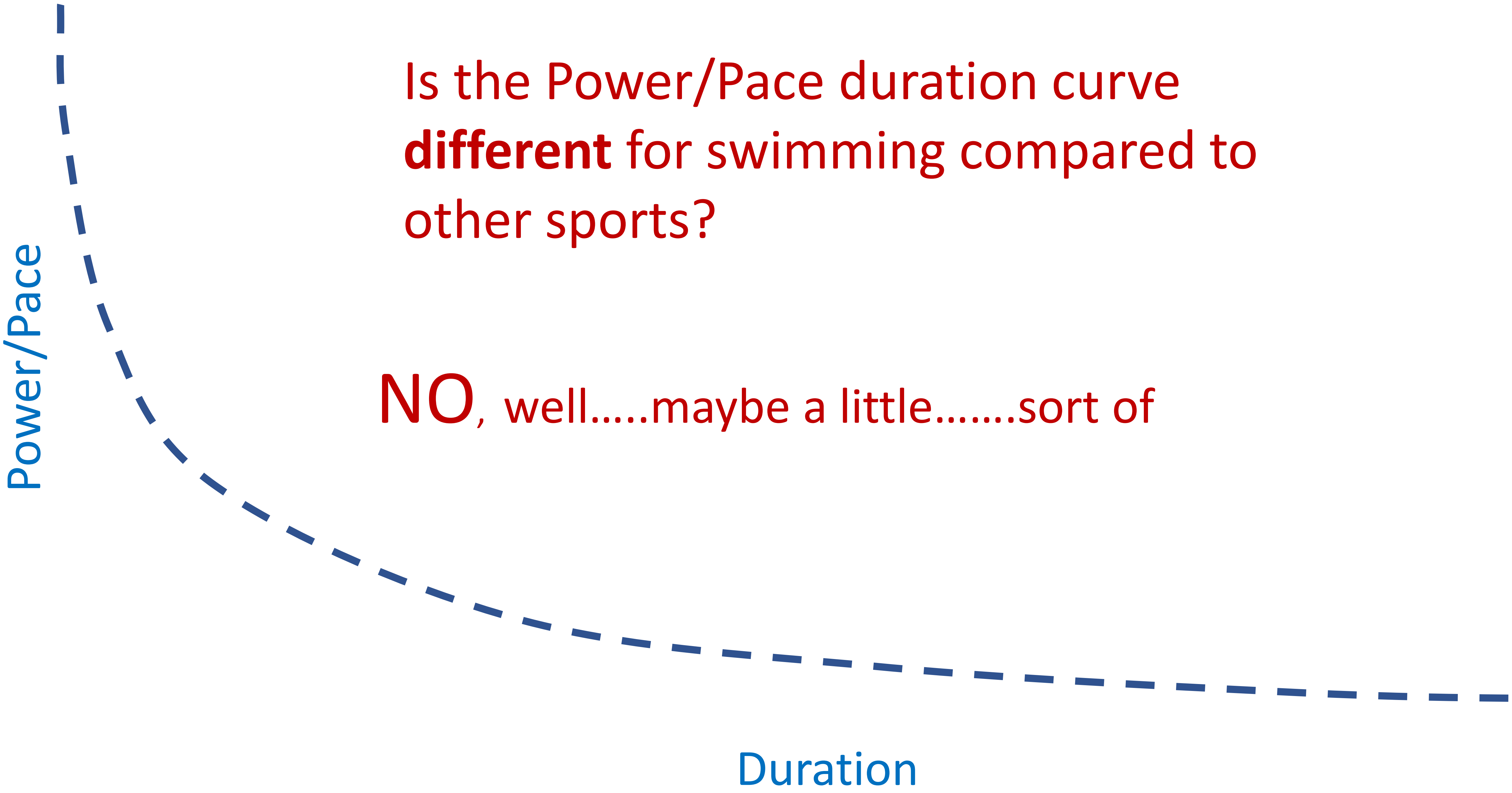
2 questions that I will pursue:

- What makes Swimming "defensibly different" from other "endurance" sports
- Where *might* the swimming training culture have something to learn?

Hva kan gå galt?

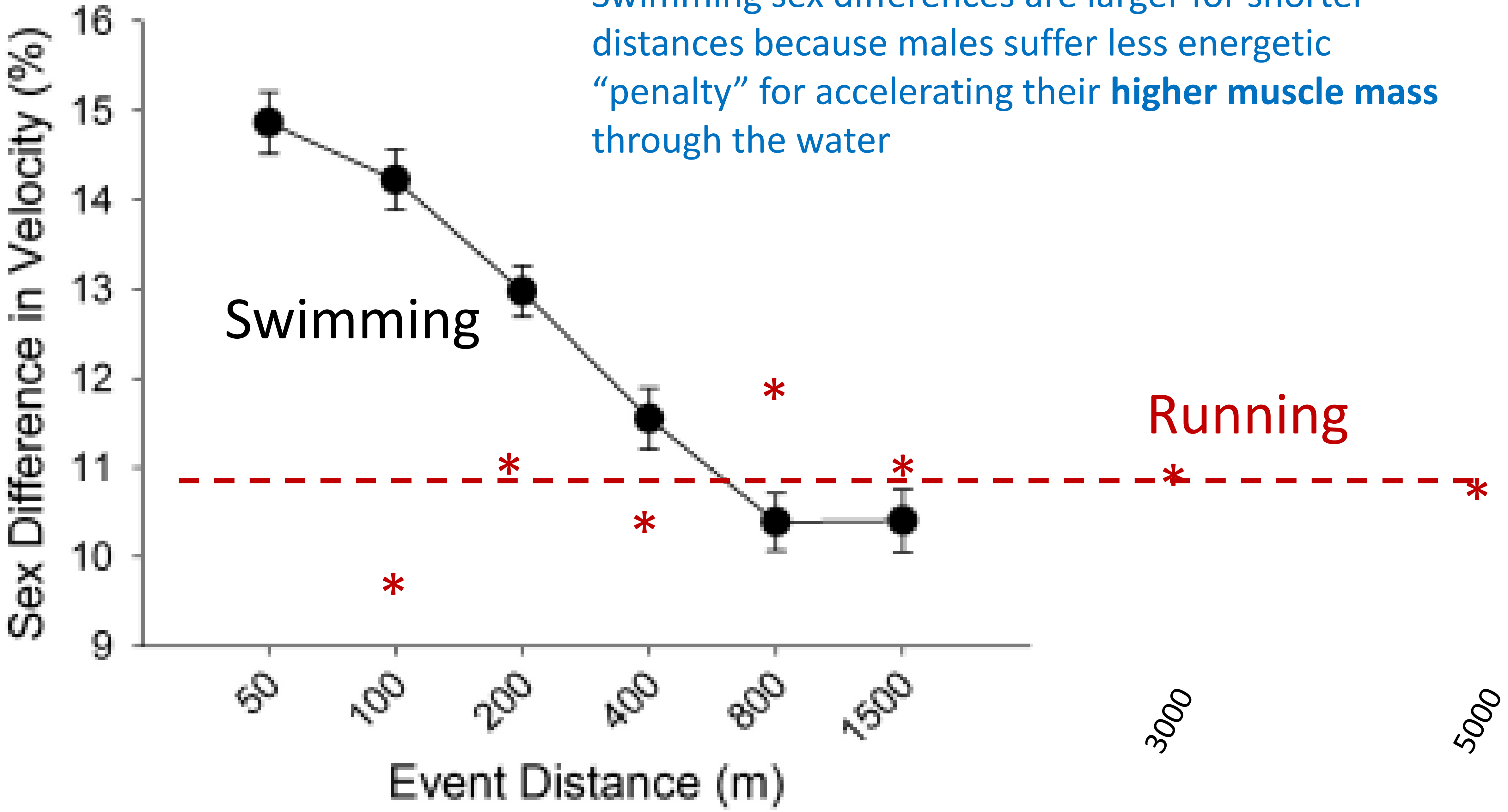
Is the Power/Pace duration curve **different** for swimming compared to other sports?

NO, well…..maybe a little…….sort of




Haugen et al. Sports Medicine - Open (2019) 5:44
https://doi.org/10.1186/s40798-019-0221-0
Sports Medicine - Open
REVIEW ARTICLE
Open Access
The Training and Development of Elite Sprint Performance: an Integration of Scientific and Best Practice Literature
Thomas Haugen1*, Stephen Seiler2, Øyvind Sandbakk3 and Espen Tønnessen1
2019
Sports Medicine
https://doi.org/10.1007/s40279-021-01481-2
REVIEW ARTICLE
Crossing the Golden Training Divide: The Science and Practice of Training World-Class 800- and 1500-m Runners
Thomas Haugen1 · Øyvind Sandbakk2 · Eystein Enoksen3 · Stephen Seiler4 · Espen Tønnessen1
2021
Haugen et al. Sports Medicine - Open (2022) 8:46
https://doi.org/10.1186/s40798-022-00438-7
Sports Medicine - Open
REVIEW ARTICLE
Open Access
The Training Characteristics of World-Class Distance Runners: An Integration of Scientific Literature and Results-Proven Practice
Thomas Haugen1*, Øyvind Sandbakk2,3, Stephen Seiler4 and Espen Tønnessen1
2022
Power/Pace
Duration

Swimming sex differences are larger for shorter distances because males suffer less energetic "penalty" for accelerating their **higher muscle mass** through the water



Athlete overlap on the FINA top 200 performance lists- freestyle

MEN

	50m	100m	200m	400m	800m	1500m
Duration	21-22s	46-48s	1:40-1:45	3:40-3:45	7:32-7:47	14:31-14:50
50m		27%	<2%	0%	0%	0%
100m			20%	0%	0%	0%
200m				32%	6%	6%
400m					**38%**	22%
800m						**80%**
1500m						100

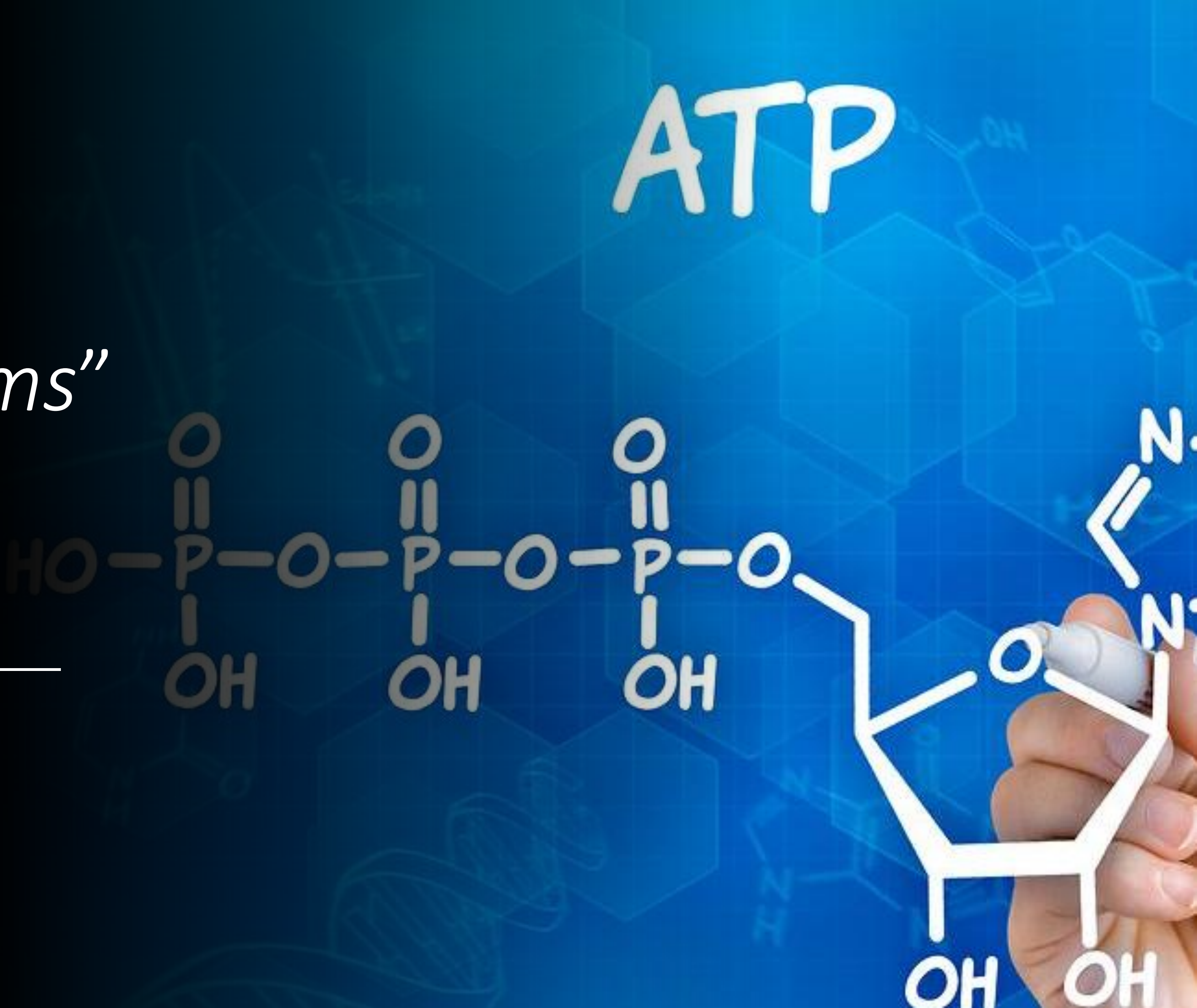
Athlete overlap on the FINA top 200 performance lists

WOMEN

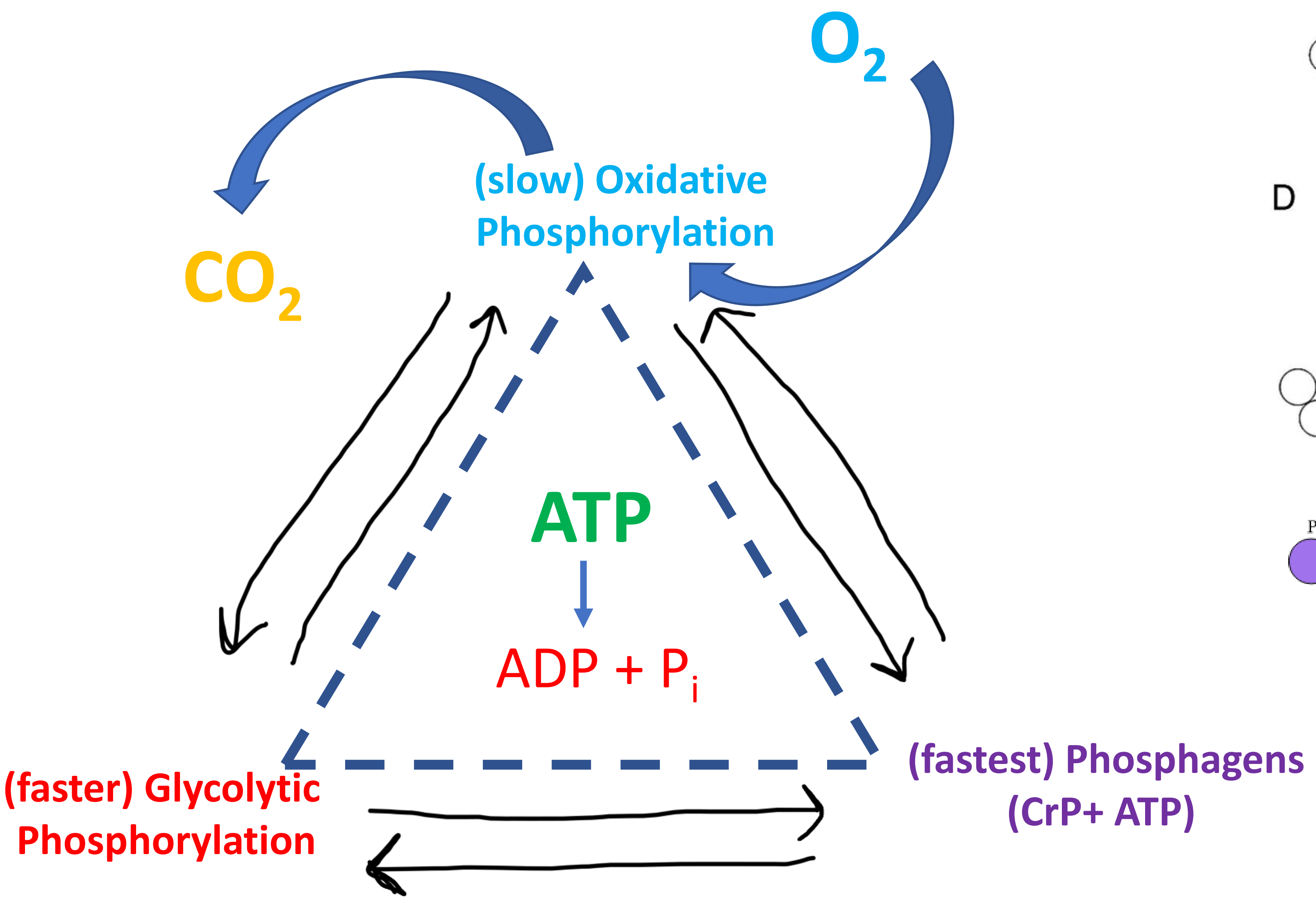
	50m	100m	200m	400m	800m	1500m
Duration	23-24s	52-53s	1:53-1:56	3:55-4:03	8:04-8:21	15:20-16:01
50m		52%	10%	0%	0%	0%
100m			21%	0%	0%	0%
200m				32%	14%	0%
400m					46%	13%
800m						55%
1500m						100

Are swimming *"Energy Systems"* different?

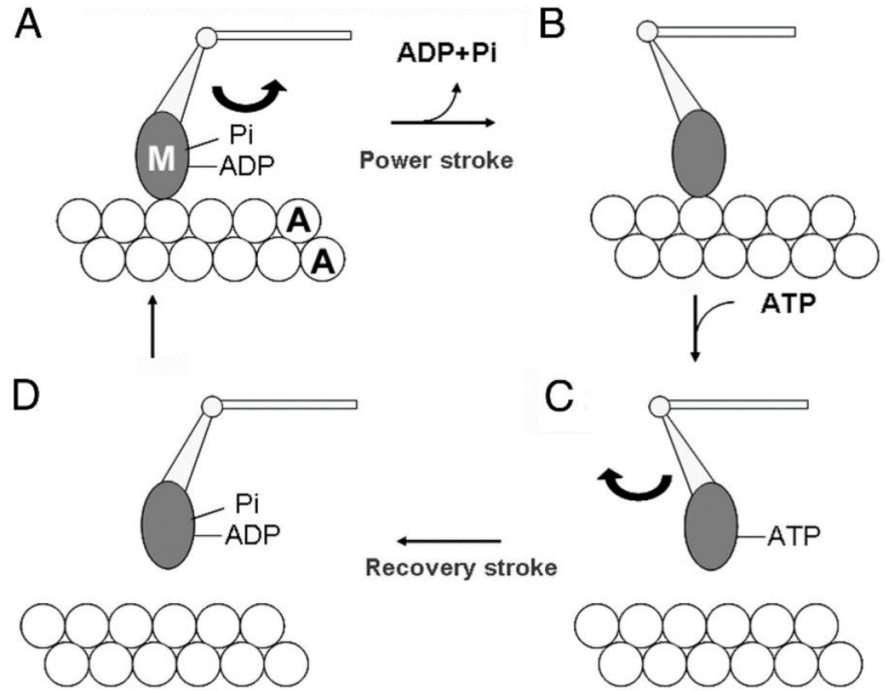
NO

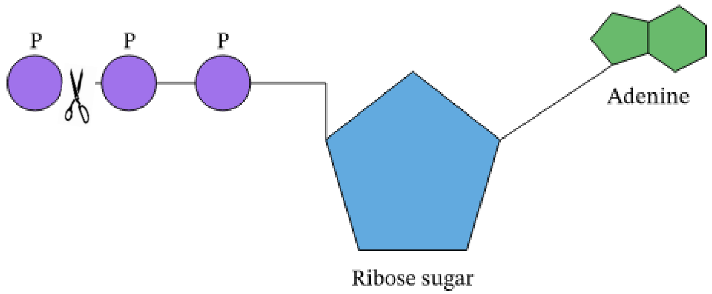


The **rate of ATP Hydrolysis** at all active muscle myofilaments determines total energy demand



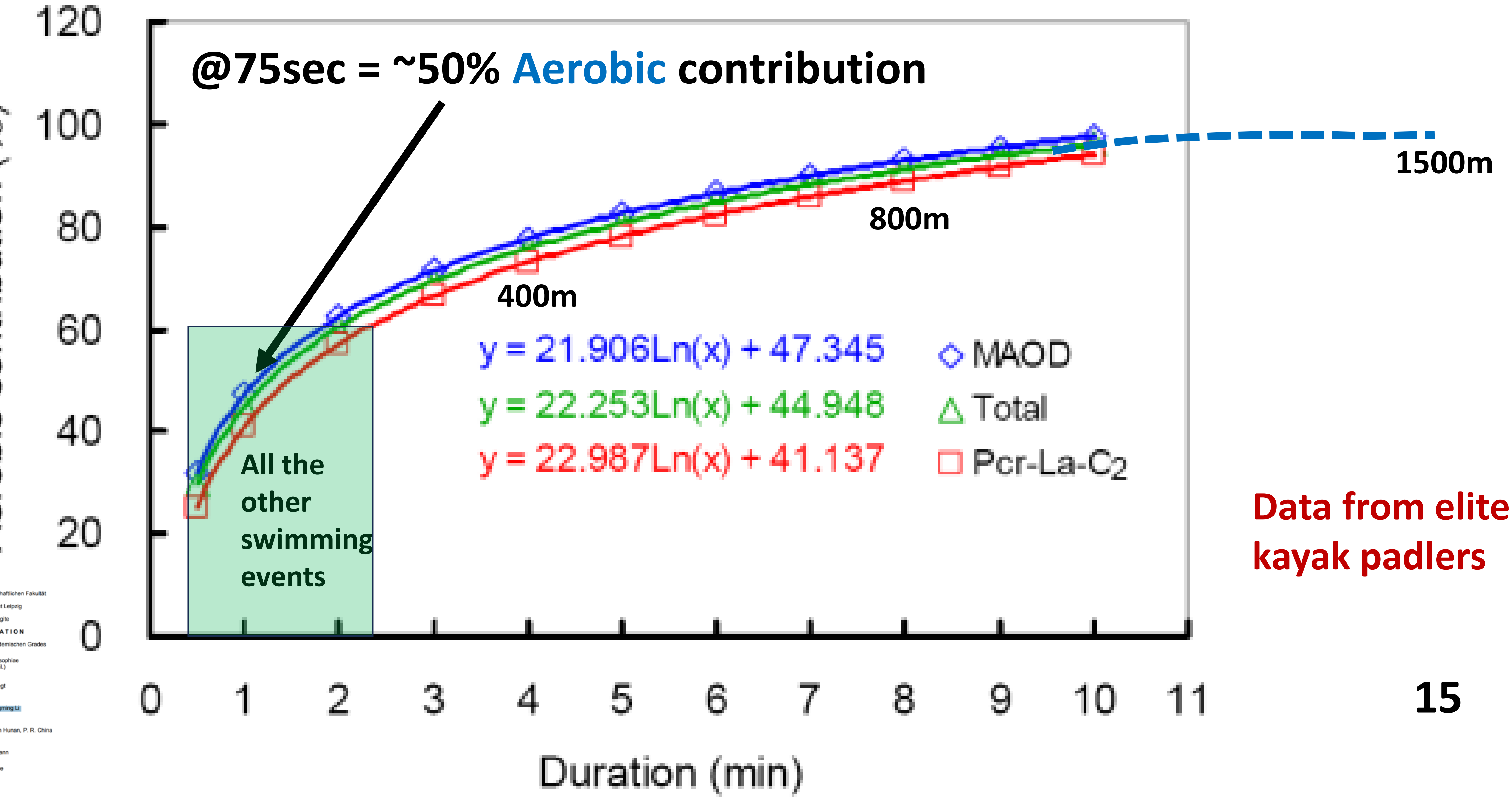
Contracting muscle

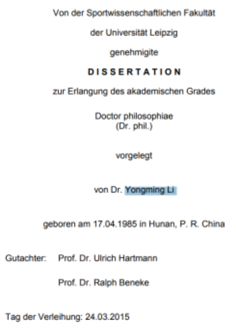




Adenosine Tri-Phosphate

THE direct energy source for muscle contraction




Von der Sportwissenschaftlichen Fakultät

der Universität Leipzig

genehmigite

DISSERTATION

zur Erlangung des akademischen Grades

Doctor philosophiae
(Dr. phil.)

vorgelegt

von Dr. Yongming Li

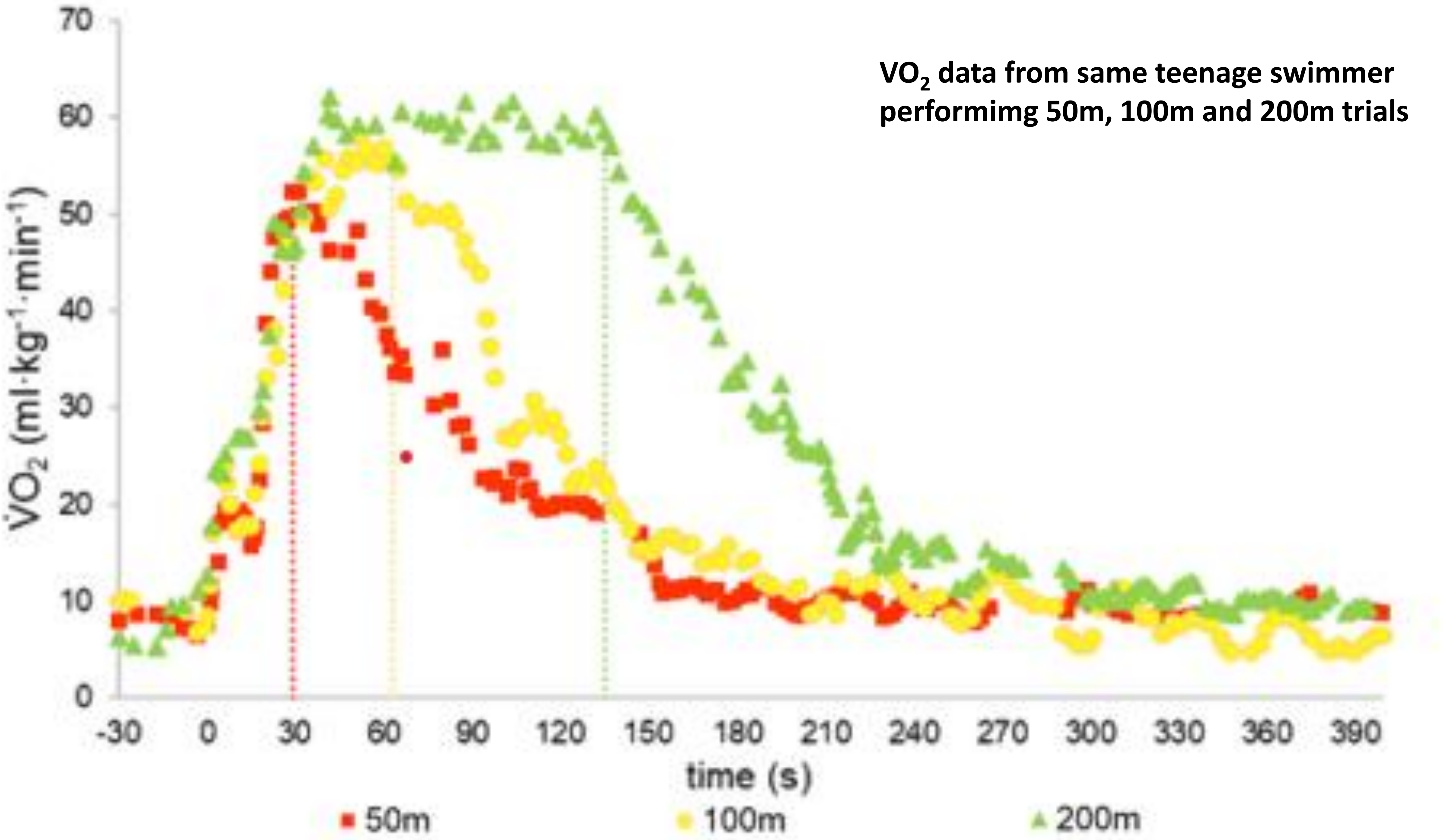
geboren am 17.04.1985 in Hunan, P. R. China

Gutachter: Prof. Dr. Ulrich Hartmann

Prof. Dr. Ralph Beneke

Tag der Verleihung: 24.03.2015

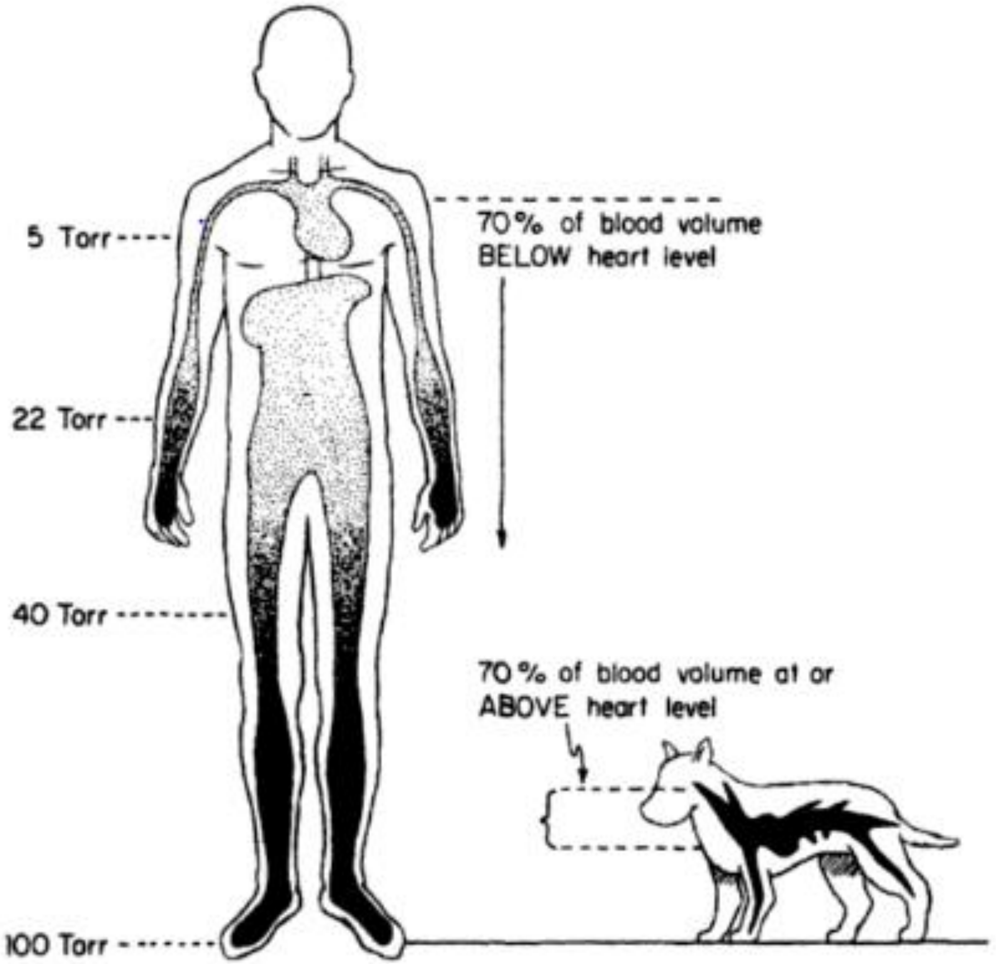
Data from elite kayak padlers



VO2 data from same teenage swimmer performimg 50m, 100m and 200m trials
VO2 (ml·kg-1·min-1)
0
10
20
30
40
50
60
70
-30
0
30
60
90
120
150
180
210
240
270
300
330
360
390
time (s)
50m
100m
200m

Does swimming impose a different challenge for the heart and lungs?

YES



igure 1-1 Schematic illustration of gravitationally dependent distribution of bloo olume and venous pressures in the upright human compared with that in th log. (Adapted from Folkow and Neil, 1971, reproduced from Rowell, 1983, wit ermission from the American Physiological Society.)

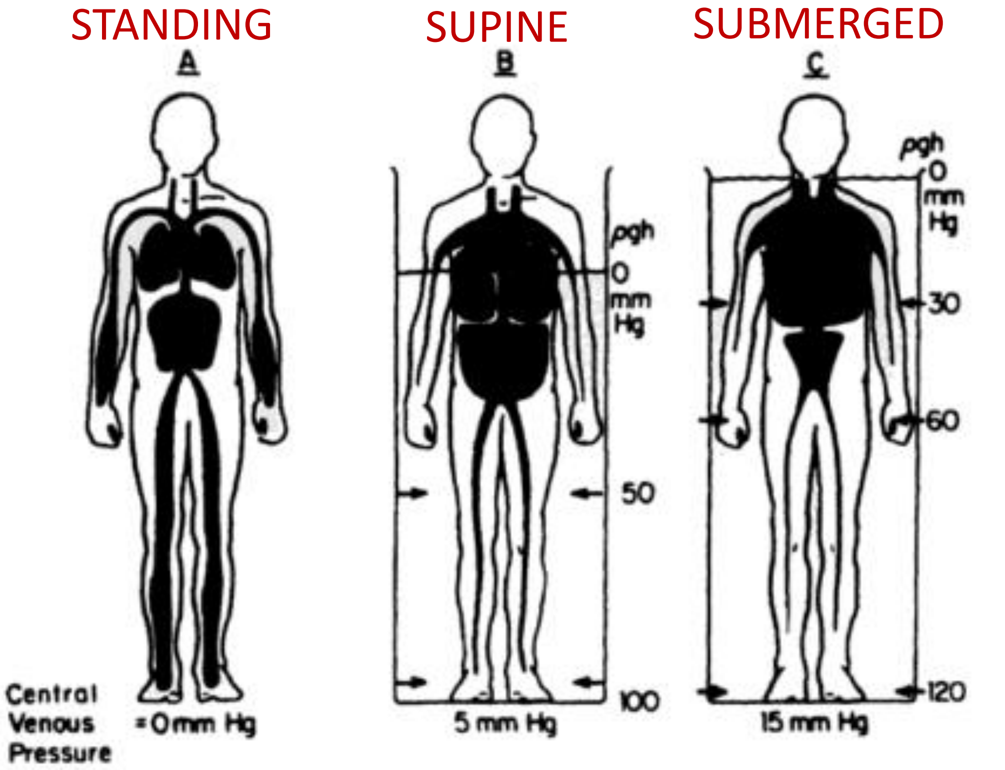


Figure 1-9 **(A)** Central venous pressure and blood volume distribution in upright human in air. **(B)** Immersed in water to level of diaphragm. **(C)** Immersed to chin. Densities of water and blood are similar so that water can counteract gravitational displacement of blood volume (effect of ρgh canceled). In Figure B, water level simulates supine posture (water pressure = venous hydrostatic pressure in legs; water hydrostatic pressures shown beside the tank). Figure C shows additional hydrostatic effects of higher water levels: counterpressure squeezes blood flow from legs and visceral organs into the thorax, raising central venous pressure even higher. Thoracic engorgement with blood causes diuresis. See text and the discussion of vasopressin and water immersion in Chapter 3 in the section "Humoral Control." (From Rowell, 1986, with permission from Oxford University Press.)

TABLE 1. *Mean values and SD for 12 male and 11 female elite swimmers during maximum running and swimming*

	♂ n = 12			♀ n = 11		
	Swim		Run	Swim		Run
Swim times						
Freestyle	2:01.4	(*n*=8)		2:22.3	(*n*=6)	
200 m	3.3			2.1		
Breaststroke	2:37.8	(*n*=2)		2:49.5	(*n*=3)	
200 m	2.8			0.4		
Backstroke	2:11.7	(*n*=2)		2:36.3	(*n*=2)	
200 m	0.4			0.9		
Heart rate	184		199	186		201
beats·min^{-1}	11		10	10		7
Blood lactate,	11.6		12.6	10.5		11.7
mmoles·l^{-1}	1.6		1.4	1.3		2.2
$\dot{V}O_2$, l·min^{-1}	5.05		5.38	3.42		3.64
	0.53		0.46	0.24		0.26
$\dot{V}O_2$ ml·kg^{-1}·min^{-1}			68.6			55.3
			5.4			4.3
$\dot{V}E_{BTPS}$, l·min^{-1}	152.1		182.3	103.1		132.6
	21.9		16.0	12.4		14.9
R	1.07		1.11	1.05		1.12
	0.05		0.05	0.08		0.05
Work time, min	4:08		5:17	4:52		5:00

Measurements were made in the swimmer's best style. Distribution on the styles is indicated by number of subjects (*n*).

JOURNAL OF APPLIED PHYSIOLOGY
Vol. 36, No. 6, June 1974. *Printed in U.S.A.*

Maximum oxygen uptake during swimming and running by elite swimmers

INGVAR HOLMÉR, ANDERS LUNDIN, AND BENGT O. ERIKSSON
Department of Physiology, Gymnastik- och Idrottshögskolan, S-114 33 Stockholm; and
Work Physiology Division, National Board of Occupational Safety and Health, S-100 26 Stockholm, Sweden

Maximal HR during **Swimming** averaged 15bpm lower versus **Running** among well-trained swimmers

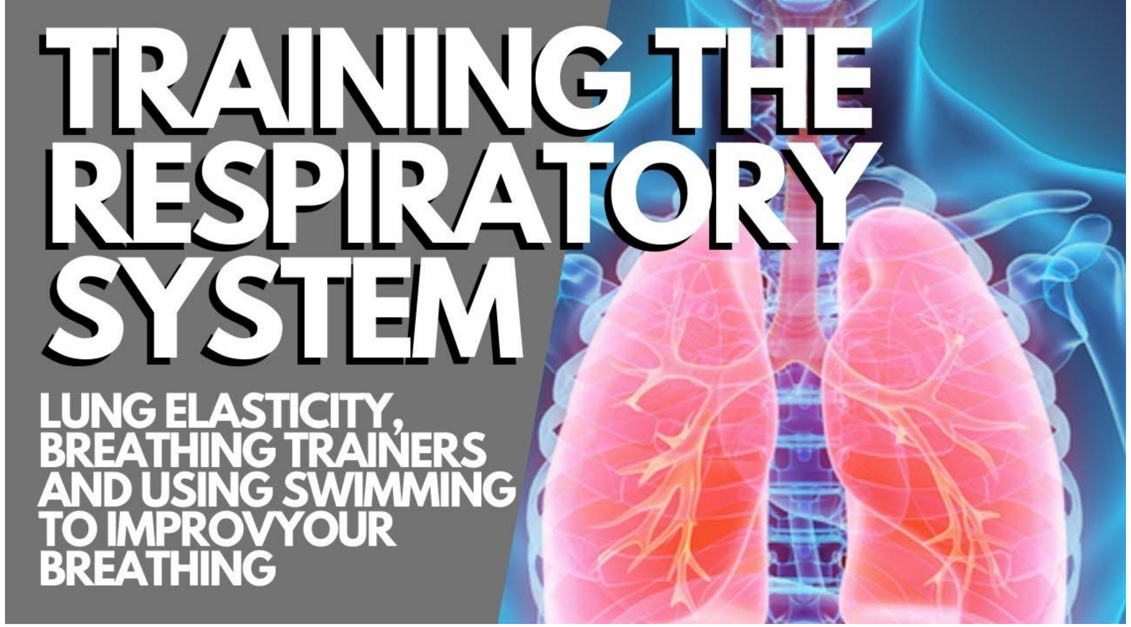
VO_2 max was higher when RUNNING in these well-trained SWIMMERS by ~6%

Maximal ventilation was 20-30% higher during running


Is **ventilation** more limiting?

Breathing rhythm in Swimming MUST be linked to stroke rhythm (backstroke as possible exception?), and INspiration has to happen FAST (like dolphins!)

EXpiration is performed against a much higher resistance compared to other sports

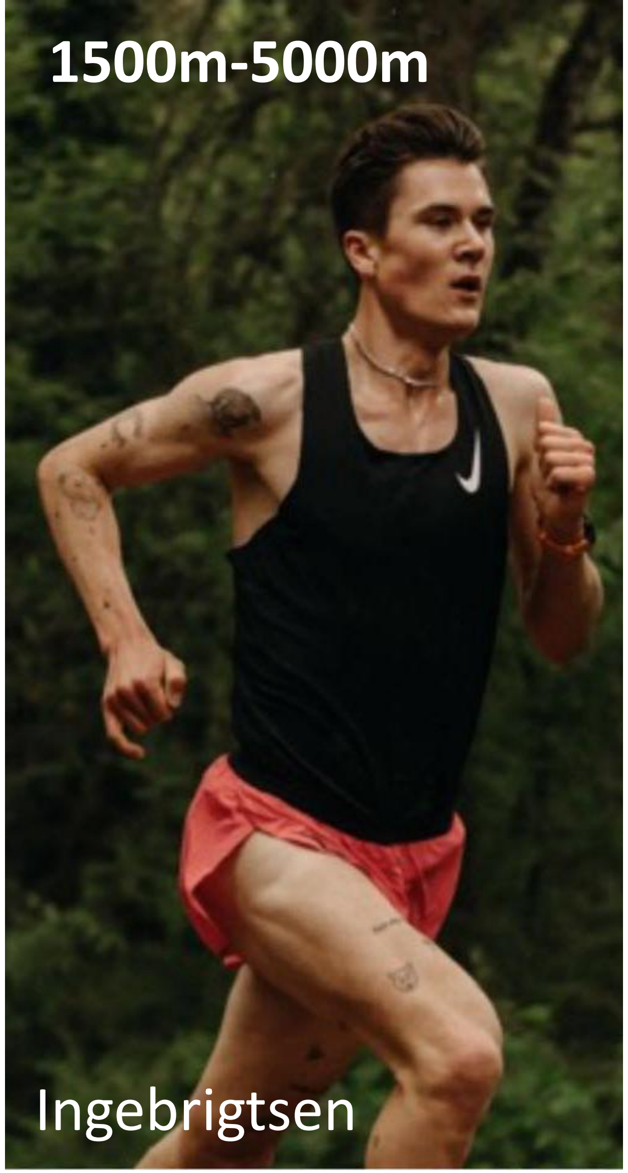

TRAINING THE RESPIRATORY SYSTEM
LUNG ELASTICITY, BREATHING TRAINERS AND USING SWIMMING TO IMPROVYOUR BREATHING


VitalPro Strap
Breathing sensor
Professional-grade accuracy meets everyday training.
Breathing sensor
• Measures Breathing Rate, Tidal Volume, and Minute Ventilation
• 99% breath detection accuracy
Movement Sensor
• Elevation change
• Run cadence, ground-contact, player load


WHAT MAKES MICHAEL PHELPS SUCH A GREAT SWIMMER
6'4" • 194 lbs.
Exceptional lung capacity allows him to power through races without being overcome by fatigue.
80" wingspan gives him significantly longer than average arms — even for someone his height.
Relatively short legs reduce his drag in the pool.
A long torso helps him pull himself through the water more quickly.
SOURCE: Dr. Michael Joyner
TECH INSIDER

Muscle mass involvement and limitations?

75kg



68kg

52kg

Mean height, body weight, body mass index and body surface for the all-time top 30 runners in races from 100 m to the marathon.

Distance (m)	Height (m)	Body weight (kg)	Body mass index	Body surface (m)	
100[a]	1.81 ± 0.07	75.90 ± 5.53	23.19 ± 1.54	1.95 ± 0.09	Sprint
200[a]	1.84 ± 0.06	76.80 ± 6.58	22.82 ± 1.74	1.98 ± 0.11	
400[a]	1.84 ± 0.05	76.07 ± 6.18	22.42 ± 1.33	1.97 ± 0.10	
800[a]	1.81 ± 0.06	68.23 ± 5.89	20.69 ± 1.04	1.85 ± 0.11	Middle Distance
1500[a]	1.76 ± 0.07	61.43 ± 6.75	19.75 ± 1.37	1.81 ± 0.12	
5000[a]	1.70 ± 0.06	57.33 ± 4.76	19.78 ± 1.48	1.65 ± 0.09	Endurance
10,000[a]	1.70 ± 0.06	56.23 ± 4.87	19.55 ± 1.27	1.63 ± 0.09	
42,195[b]	1.70 ± 0.05	55.39 ± 2.91	19.13 ± 0.80	1.62 ± 0.06	

The limitations of scaling laws in the prediction of performance in endurance events

J.M. García-Manso[a], J.M. Martín-González[a], D. Vaamonde[b], M.E. Da Silva-Grigoletto[c,*]

Journal of Theoretical Biology 300 (2012) 324–329

~210-220sec work duration

~210-220sec work duration

Muscle mass activation > cardiac pumping capacity

Cardiac Pumping Capacity > upper body muscle mass activation …..**Unless**….

Kelvin Kiptum 2:00:35


Marcel Hug: 1:17:47

Other sports with events lasting 60-300s

1000m TT ~60secs

97kg

4000m TT ~240secs

82kg

1980s

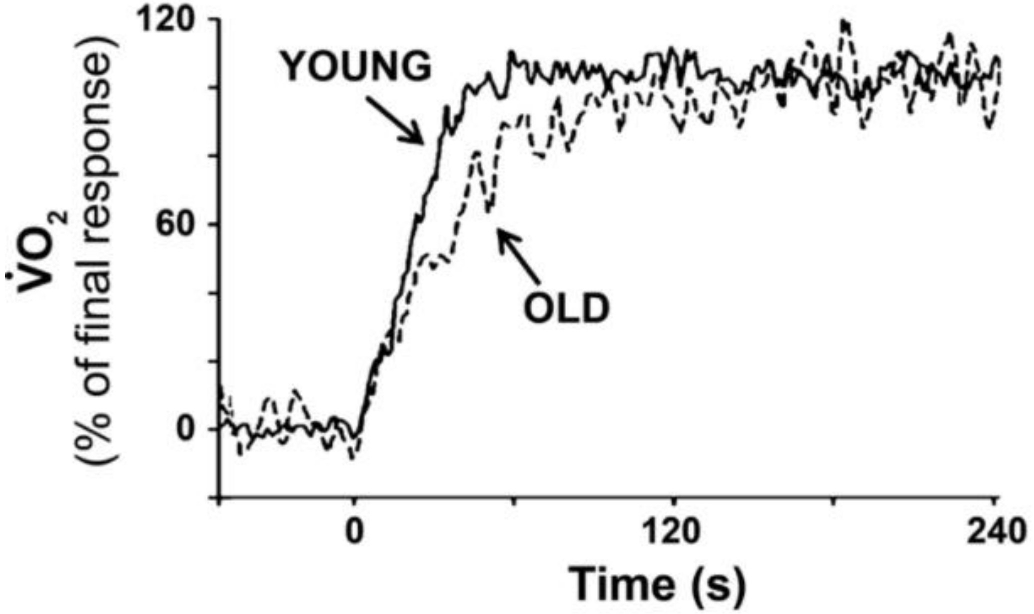
2000s


51
41
21
swix
FISCHER

Middle Distance Science :
"Everything matters"
(but much of it is **very hard** to quantify or monitor!)

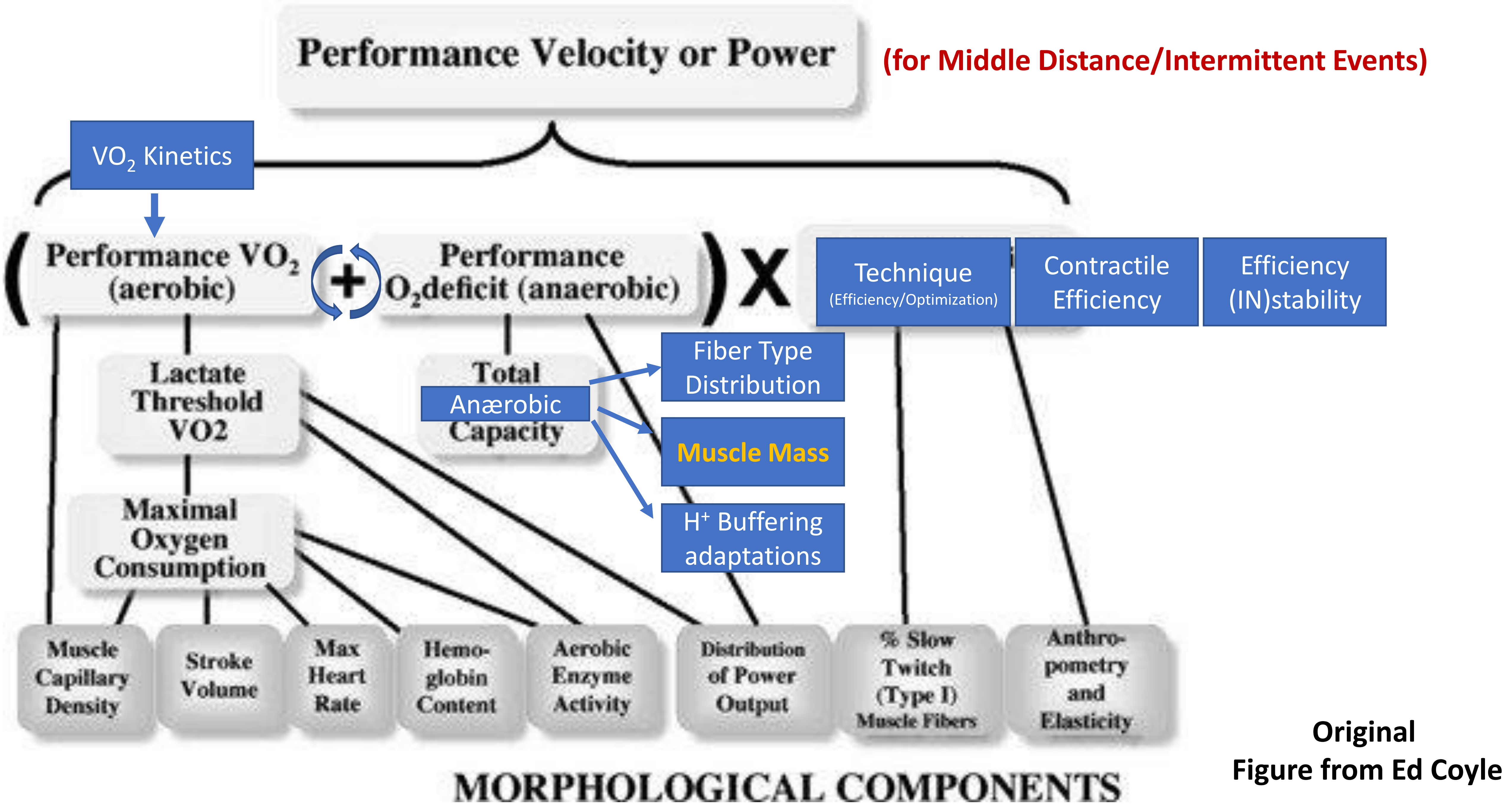
- "Energy Systems"/Energetics balance (Aer + Anaerobic Alactic + AnLactic)
- VO_2 kinetics
- Anaerobic work capacity (MAOD, PCr-Lactic-O_2, Critical Power/W')
- Maximum Aerobic Speed/Power
- Neuromuscular fatigue resistance
- Morphology (Height, Arm length, Joint Mobility, Hand and Foot size)
- Fiber type distribution across active muscles
- Maximum Sprinting Power/Velocity
- (Dynamic) Efficiency/Economy
- Power pacing optimization

Fast O_2 kinetics is critical for middle distance!



"It does not matter if I can reach a higher VO_2 max in 5 minutes when I have to cross the finish line in 102 seconds"

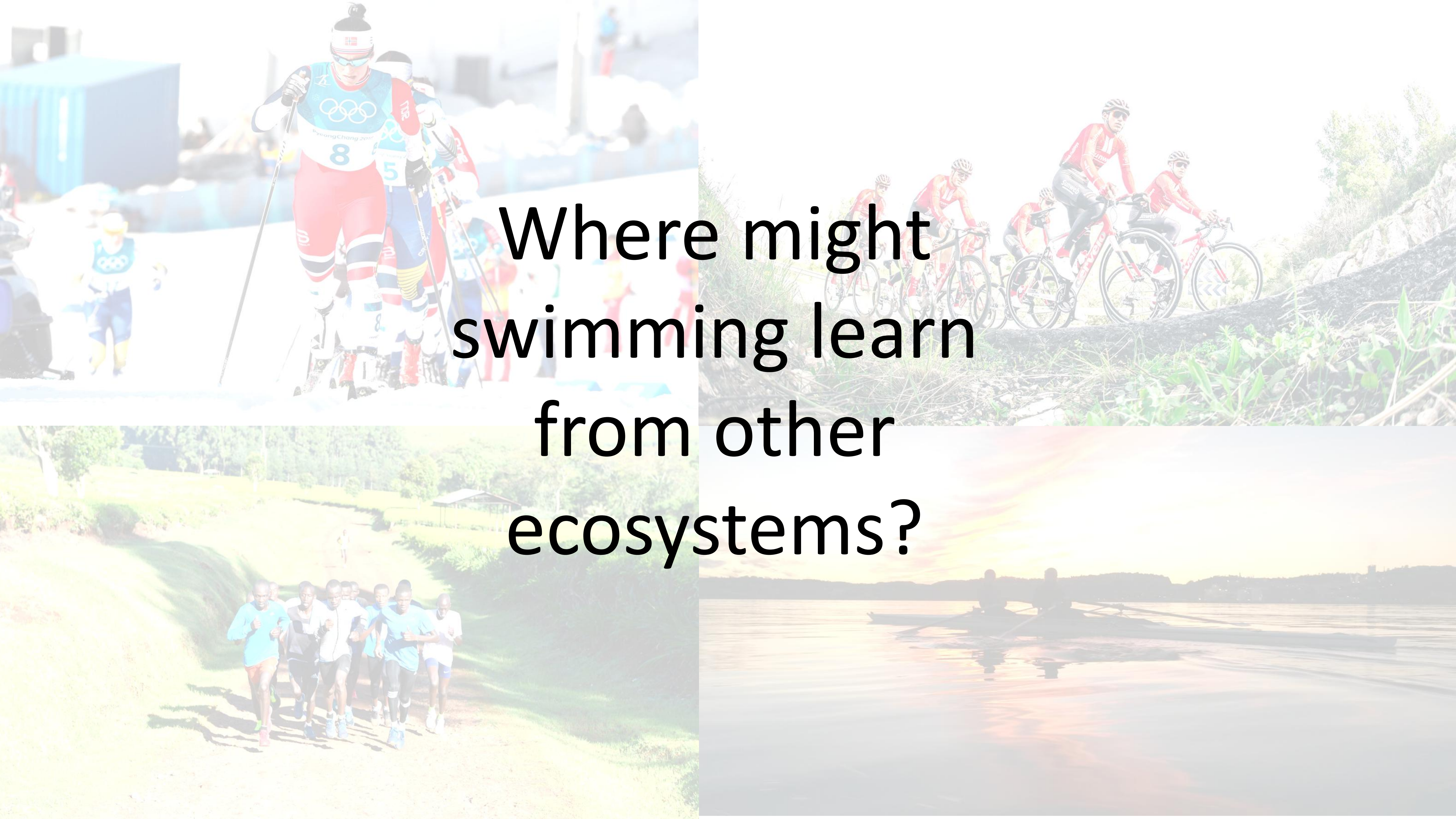
Vebjørn Rodal, 1996 Olympic gold medalist, 800m running, 1:42.58


Performance Velocity or Power
(for Middle Distance/Intermittent Events)
VO2 Kinetics
Performance VO2 (aerobic)
+
Performance O2deficit (anaerobic)
X
Technique
(Efficiency/Optimization)
Contractile Efficiency
Efficiency (IN)stability
Lactate Threshold VO2
Total Anærobic Capacity
Fiber Type Distribution
Muscle Mass
H+ Buffering adaptations
Maximal Oxygen Consumption
Muscle Capillary Density
Stroke Volume
Max Heart Rate
Hemo-globin Content
Aerobic Enzyme Activity
Distribution of Power Output
% Slow Twitch (Type I) Muscle Fibers
Anthro-pometry and Elasticity
MORPHOLOGICAL COMPONENTS
Original
Figure from Ed Coyle

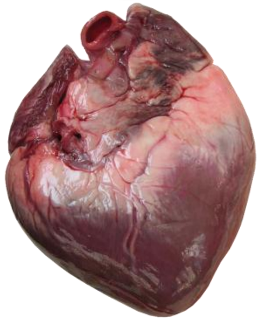
Potentially Important Differences

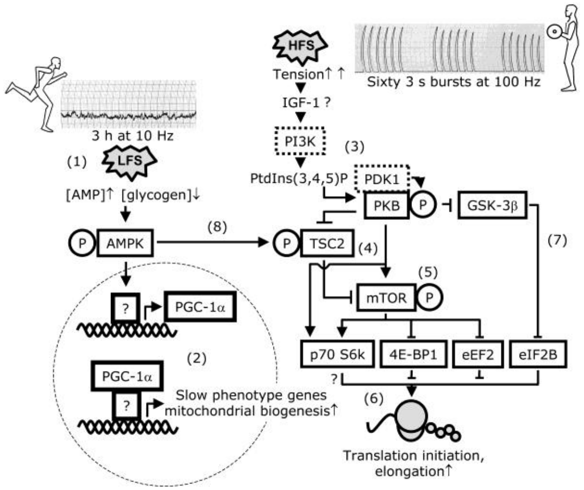
- Olympic Swimming is primarily a **middle distance** sport
- Propulsion is upper-body dominant (and upper-body muscles tend to be more type 2 fibers)
- Ventilation is probably a more limiting factor
- Heat Removal is never a limiting factor
- Variation in *efficiency* is larger and more decisive in swimming
- No eccentric/ballistic loading on the muscles. So, you train more volume because you CAN?
- Race specific stroke mechanics may be difficult to achieve at low metabolic intensity!!

Where might swimming learn from other ecosystems?



Endurance training is an *Optimization* problem!





Adaptive Stimulus **Stress**

(Adjusting training characteristics)

- Bone-tendon-muscle damage at cellular level
- Inflammation
- Repetitive sympathetic stress
- Immuno-suppression
- Psychological fatigue

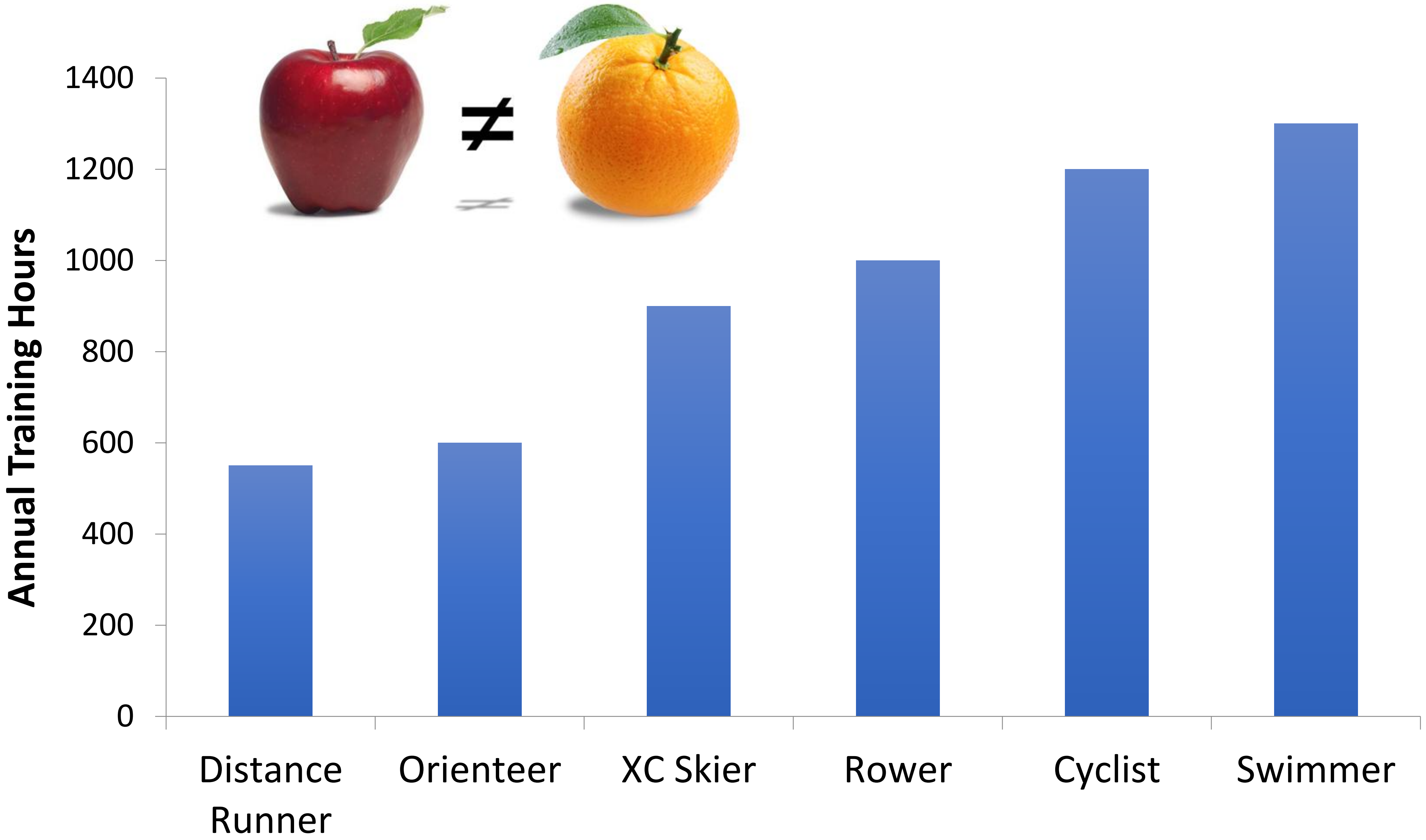
SPENCER, M. R., and P. B. GASTIN. Energy system contribution during 200- to 1500-m running in highly trained athletes. Med. Sci. Sports Exerc., Vol. 33, No. 1, 2001, pp. 157–162.

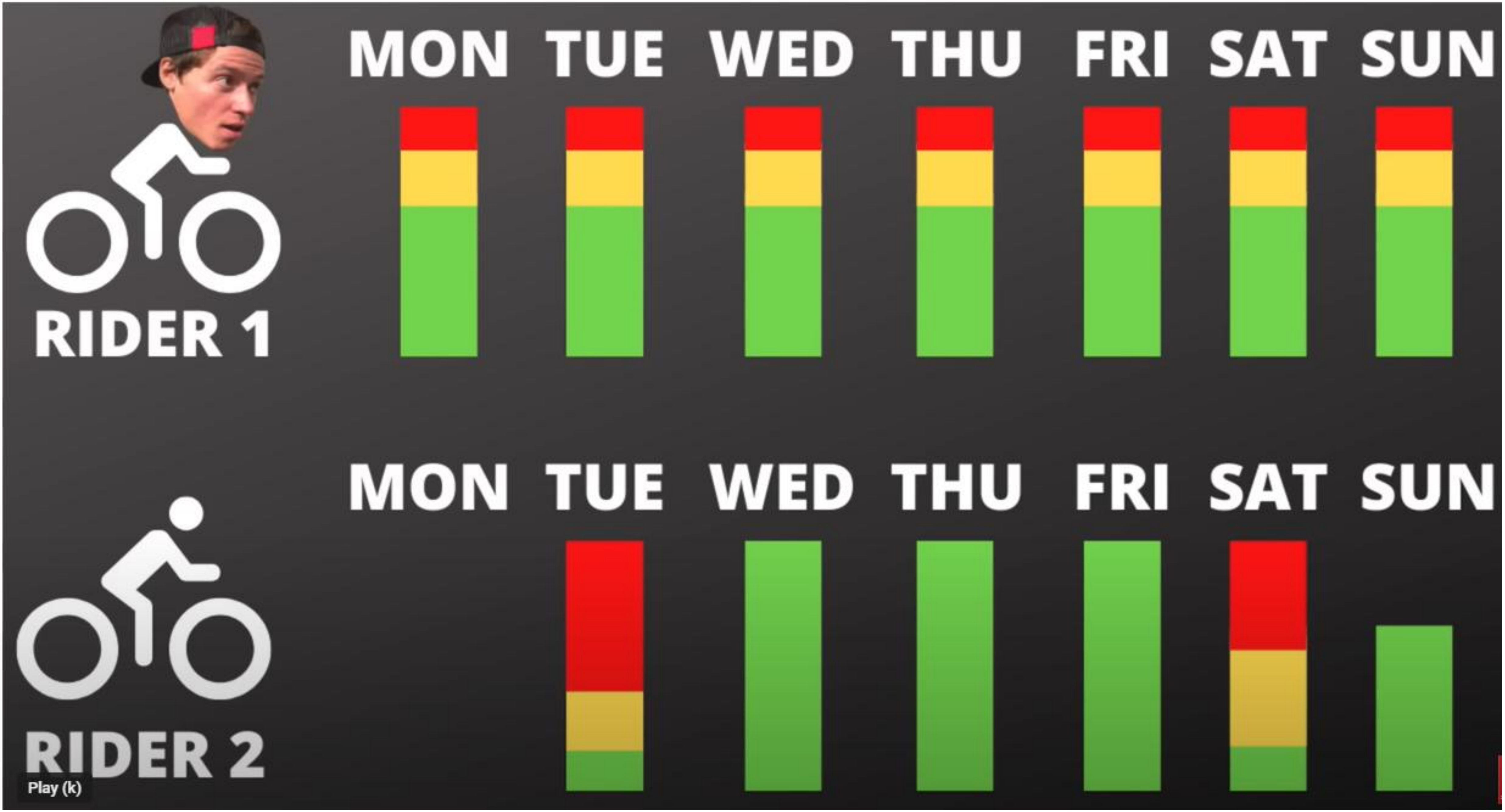
~2 min **~4 min**

	200 m	400 m	800 m	1500 m
Exercise intensity (% $\dot{V}O_2$ peak)	201 ± 3[abc]	151 ± 4[de]	113 ± 9[f]	103 ± 6
Duration (min:s)	22.3 ± 0.2[abc]	49.3 ± 0.2[de]	1:53 ± 0:02[f]	3:55 ± 0:03
Accumulated oxygen deficit ($mL \cdot kg^{-1}$)	30.4 ± 3.2[abc]	41.3 ± 2.3[de]	48.8 ± 10.1	47.1 ± 9.2
Aerobic metabolism (%)	29 ± 5[abc]	43 ± 2[de]	66 ± 4[f]	84 ± 3
Aerobic energy release first 20 s ($mL \cdot kg^{-1}$)	12.9 ± 2.0[ab]	9.5 ± 1.2[e]	10.0 ± 1.6[f]	14.6 ± 2.4
Anaerobic energy release first 20 s ($mL \cdot kg^{-1}$)	24.6 ± 3.6[abc]	20.2 ± 1.6[de]	15.3 ± 3.6[f]	10.1 ± 1.7
Regression line slope* ($mL \cdot kg^{-1} \cdot min^{-1}$)	0.349 ± 0.014[ab]	0.294 ± 0.013[e]	0.303 ± 0.013[f]	0.344 ± 0.022
% $\dot{V}O_2$ peak obtained (%)	70 ± 8[abc]	89 ± 1[e]	88 ± 2[f]	94 ± 2

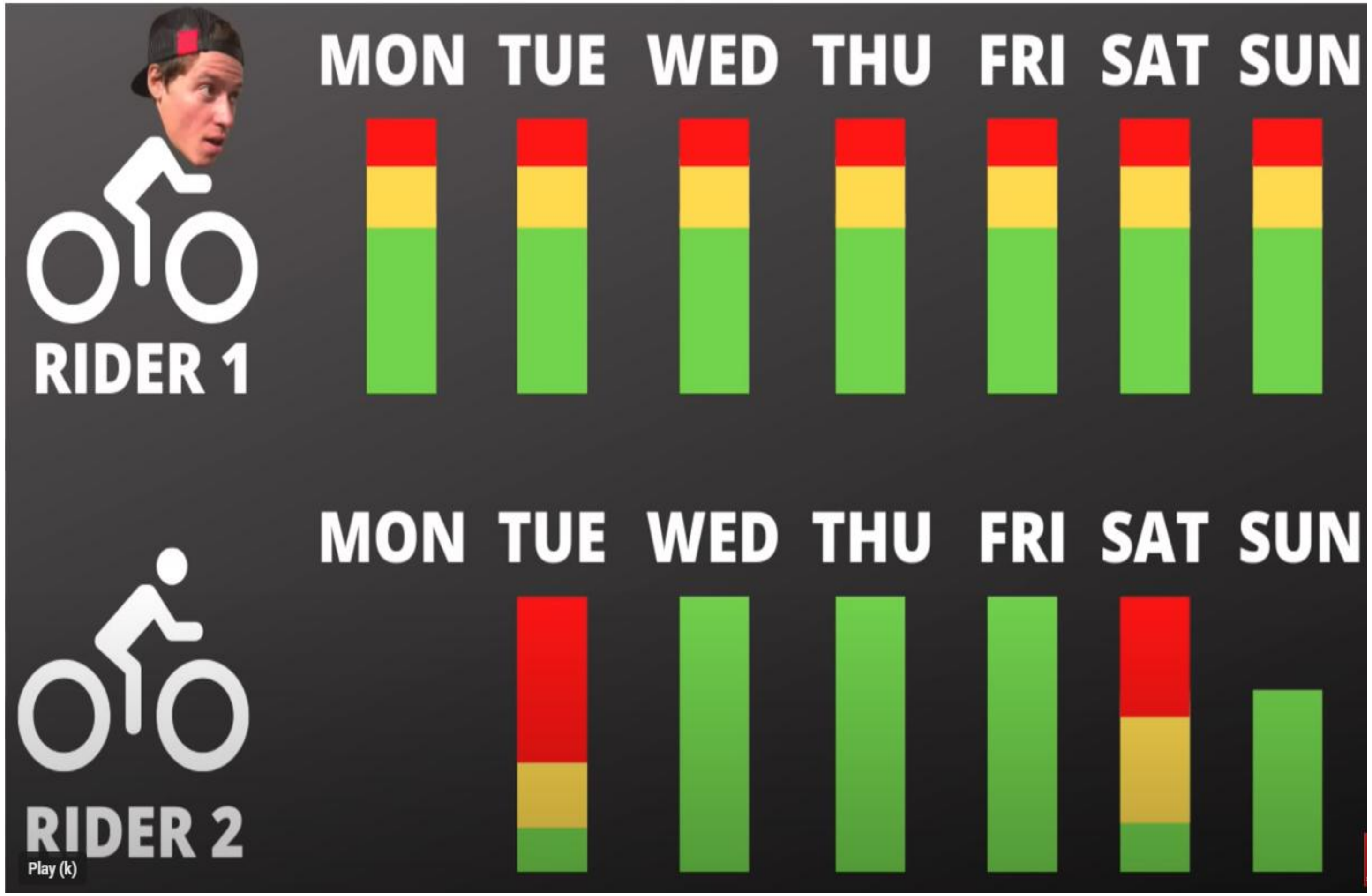
Haugen, T., Sandbakk, Ø., Enoksen, E. *et al.* Crossing the Golden Training Divide: The Science and Practice of Training World-Class 800- and 1500-m Runners. *Sports Med* **51,** 1835–1854 (2021). https://doi.org/10.1007/s40279-021-01481-2

→ The "Golden Divide" in training methods


1400
1200
1000
800
600
400
200
0
Annual Training Hours
Distance Runner
Orienteer
XC Skier
Rower
Cyclist
Swimmer



Screenshot from video by Dylan Johnsen: https://www.youtube.com/watch?v=oLsBXW3mTDI&t=603s



Screenshot from video by Dylan Johnsen:
https://www.youtube.com/watch?v=oLsBXW3mTDI&t=603s

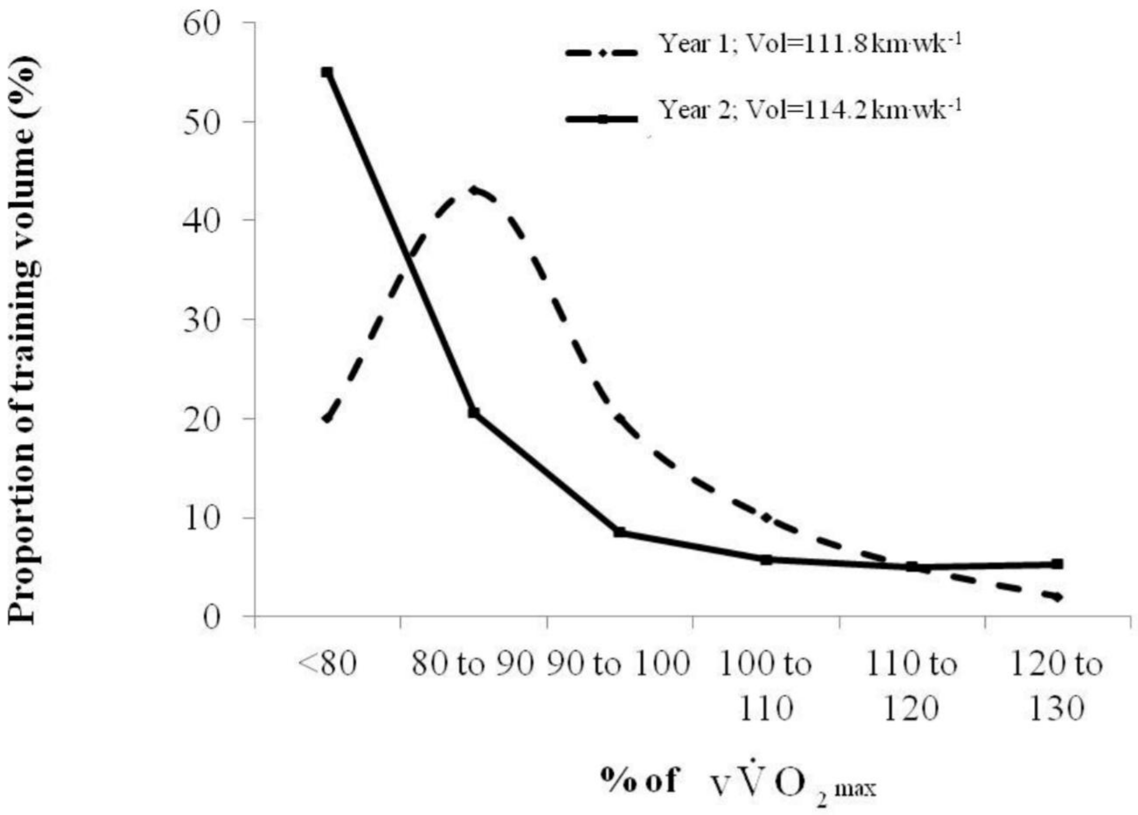
Monotone stress load, stagnation and overreaching are likely

High Stress efforts concentrated in specific workouts with different intensity x duration combinations. Delayed recovery after hard sessions is “taken into account” in the training rhythm

26y old male 1500m runner

3:39 PB at start of study

3:32 PB 2 years later



International Journal of Sports Physiology and Performance, 2012, 7, 193-195

Training Distribution, Physiological Profile, and Performance for a Male International 1500-m Runner

Stephen A. Ingham, Barry W. Fudge, and Jamie S. Pringle

The difference between the prescribed and actual training intensity was 18% in year 1 and 2.8% in year 2 ($P <$ .001) for low-intensity training. High-intensity training was performed close to the prescribed intensity, with no differences noted between years (1.2 vs 1.3%, $P = .85$).

Training designed to elicit MLSS was performed at an intensity greater than MLSS criteria in both years but greater in year 1 than year 2 (Δ [blood lactate], 6.7 vs 2.5 mM; $P < .001$).

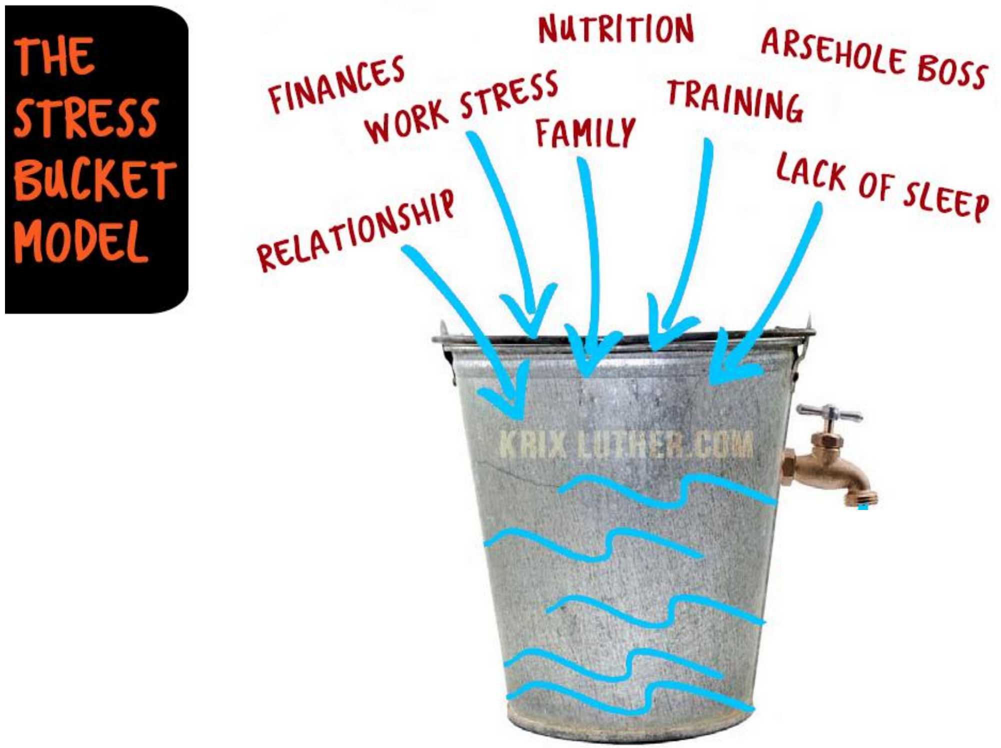
Nils van der Poel- Swedish speedskater

Spent weeks and months at a time off the ice focusing on aerobic capacity building using cycling

All training on the ice was **race pace** and technically matched to race conditions

Trained 5 days with huge loads and took 2 consecutive rest days every week for 3 years!

https://www.howtoskate.se/



Source: https://phuketfighters.com/the-stress-bucket/

Chronic Psychological Stress Impairs Recovery of Muscular Function and Somatic Sensations Over a 96-Hour Period

Matthew A. Stults-Kolehmainen,[1,2] John B. Bartholomew,[1] and Rajita Sinha[2]

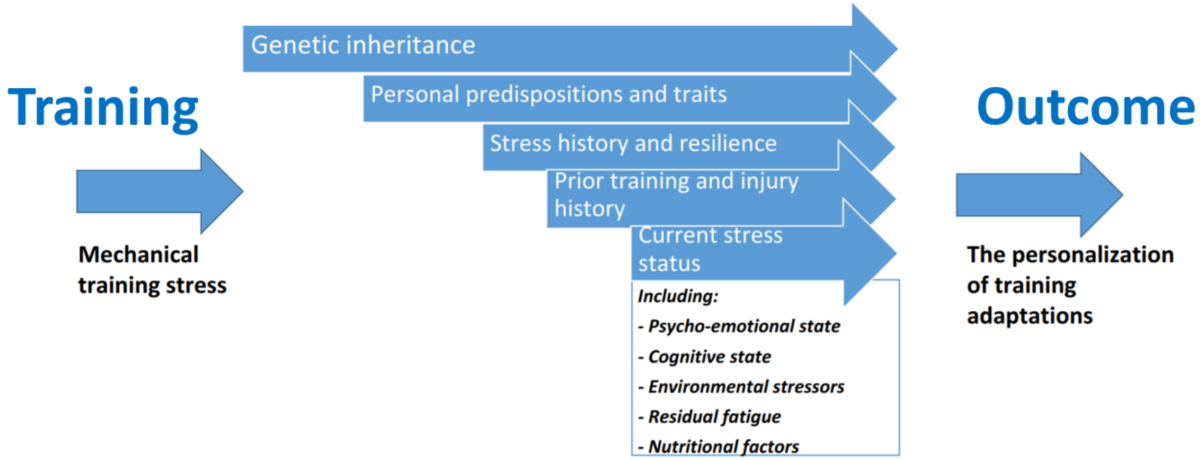
[1]*Department of Kinesiology and Health Education, The University of Texas at Austin, Austin, Texas; and* [2]*Department of Psychiatry, Yale Stress Center, Yale School of Medicine, New Haven, Connecticut*

Abstract

Stults-Kolehmainen, MA, Bartholomew, JB, and Sinha, R. Chronic psychological stress impairs recovery of muscular function and somatic sensations over a 96-hour period. *J Strength Cond Res* 28(7): 2007–2017, 2014—The primary stress, individuals may need to be more mindful about observing an appropriate length of recovery.

Key Words resistance training, mental stress, growth curve analysis

A complex orchestra of individual differences



Fra Kiely, 2018

Training Reality:

Solution:

Some things I have learned about endurance training the last 30 years, summarized in 10 lines:

- There are *universals* and there are *particulars*, understand both
- Training is an **optimization** problem, not a **maximization** problem
- Focus on the big things first, not “marginal gains”
- Program compliance (and other simple metrics) tell us a lot…..KISS
- Good scientists, coaches, and athletes are ALL curious, deliberate, and smart
- Triangulation and “Heads Up Displays” are also important in training
- Periodization models are probably overrated and under-validated.
- Rest days are UNDERRATED!
- Physiology is COMPLEX but training prescription should NOT be!
- FEWER Intensity Zones, not more!


Thank you!