APPLIED HEALTH & HUMAN PERFORMANCE SPECIALIST

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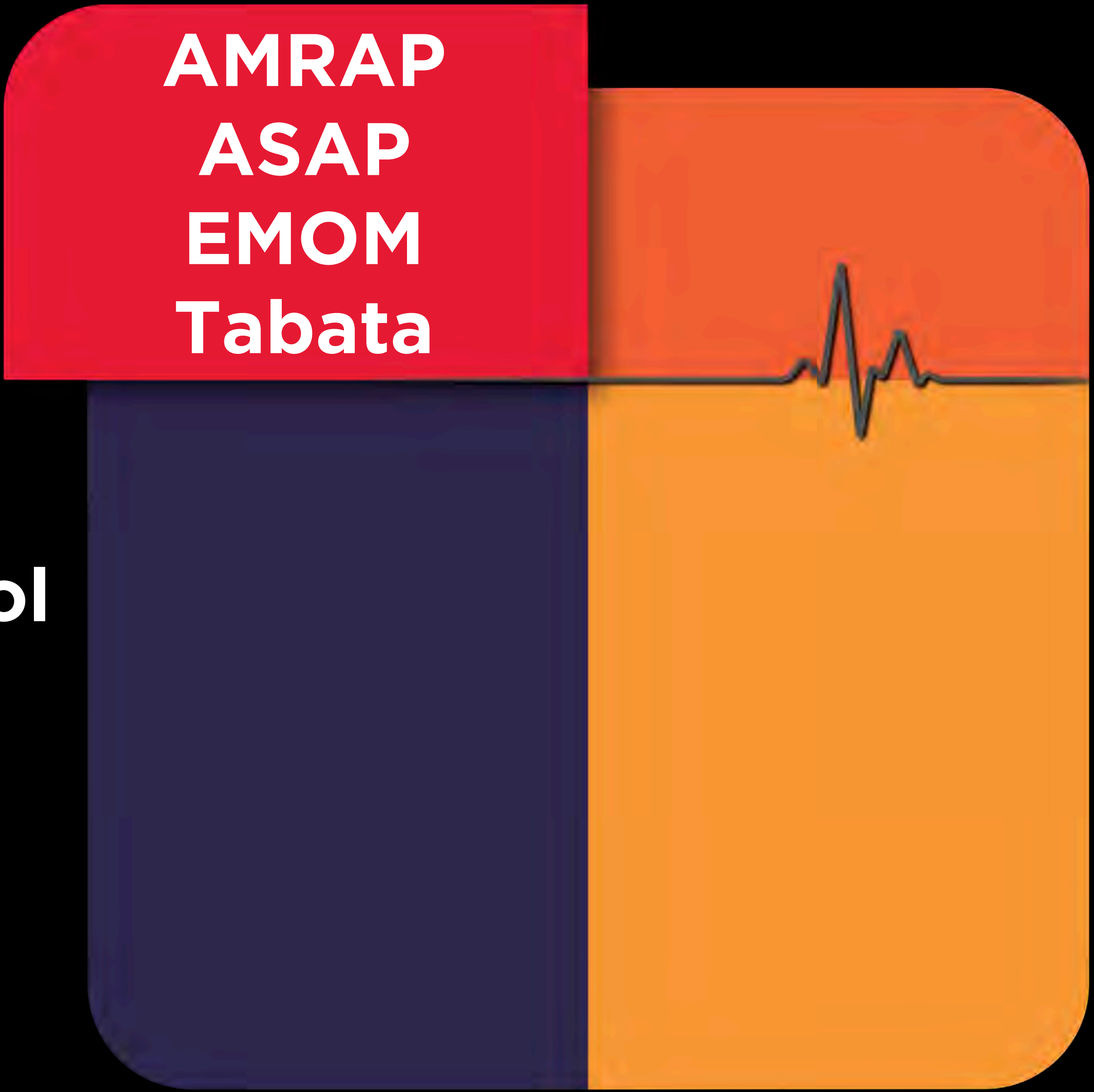
LEVEL 2

Week 05

Step 1:
Pick Quadrant(s)

Step 3:
Pick Protocol



AMRAP
ASAP
EMOM
Tabata

Agenda

- **Section 1: Announcements**
- **Section 2: HIIT Session Review**
- **Section 3: Threshold and Recovery**
- **Section 4: Questions**

Community Workouts

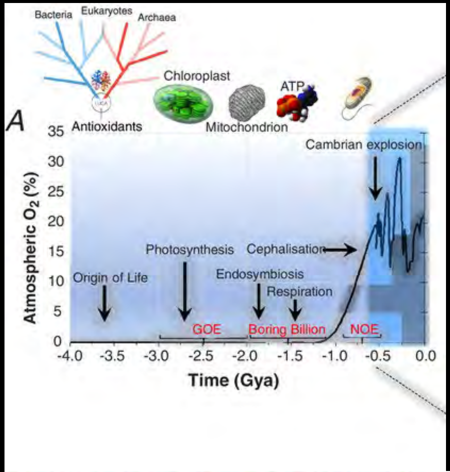
- HISS Session Sat March 6th @5pmEST
- LPR/L R Recovery Session March 27th 5pmEST
- 4Q Recovery Session April 17th 9amEST

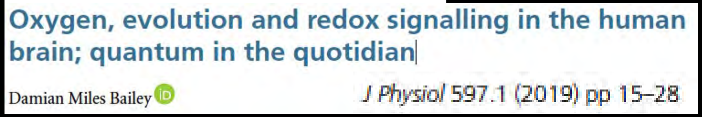
Tequila and Coffee

- Tentative: March 19th @ 5pm PST

Week 5
Exercise-induced Oxidative Stress

Oxygen- Friend or Foe



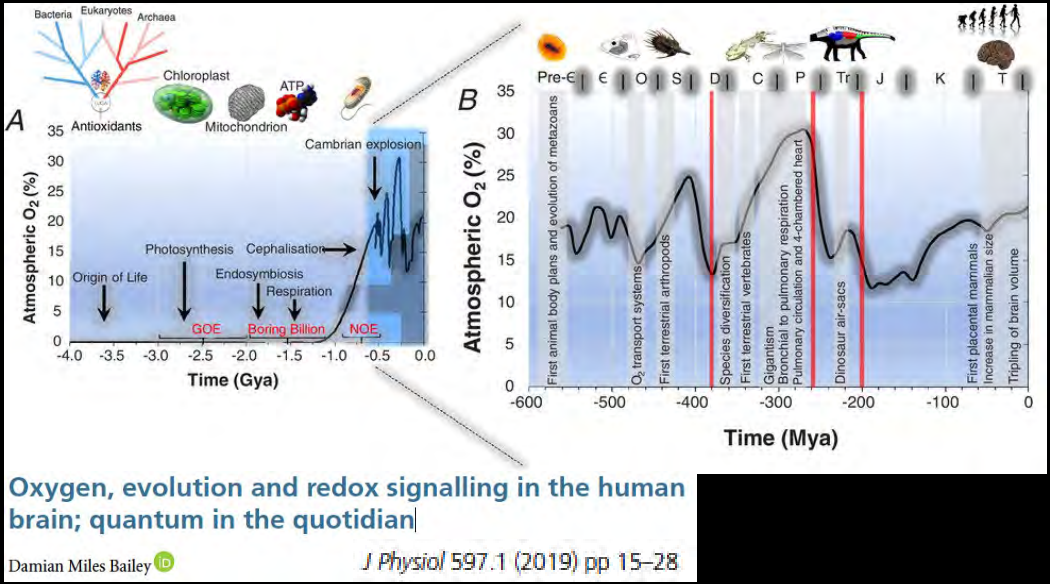


Oxygen, evolution and redox signalling in the human brain; quantum in the quotidian

Damian Miles Bailey

J Physiol 597.1 (2019) pp 15–28

Oxygen- Friend or Foe



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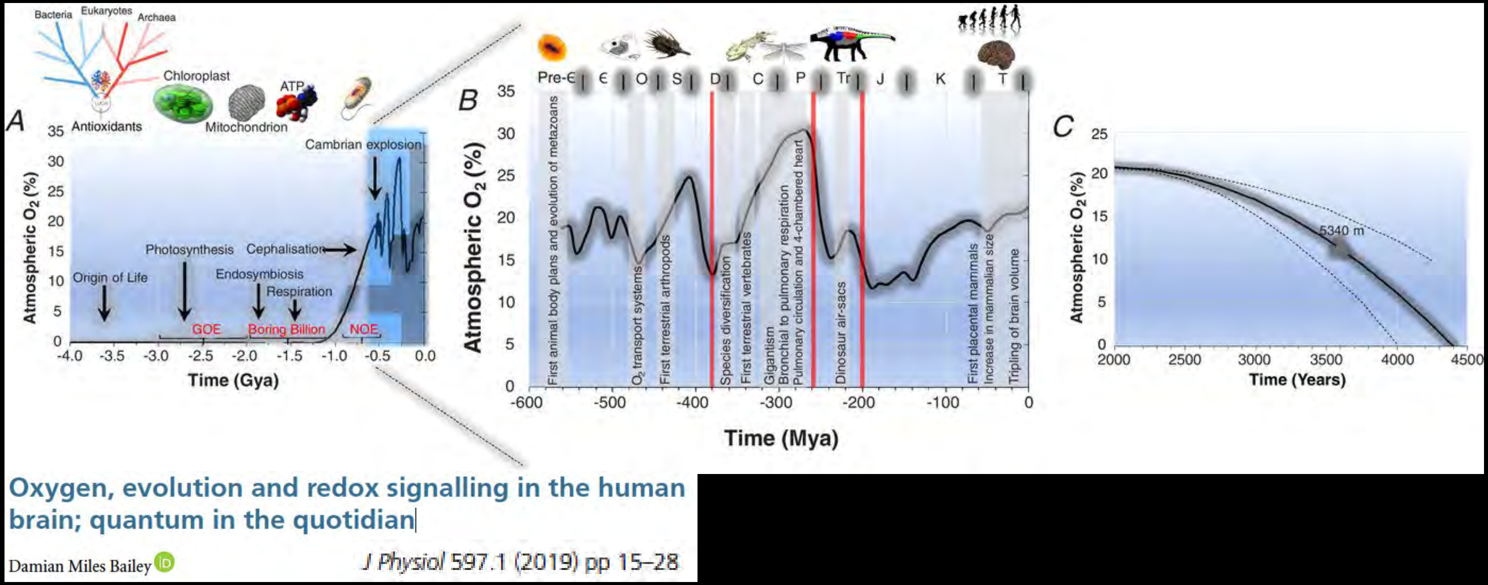

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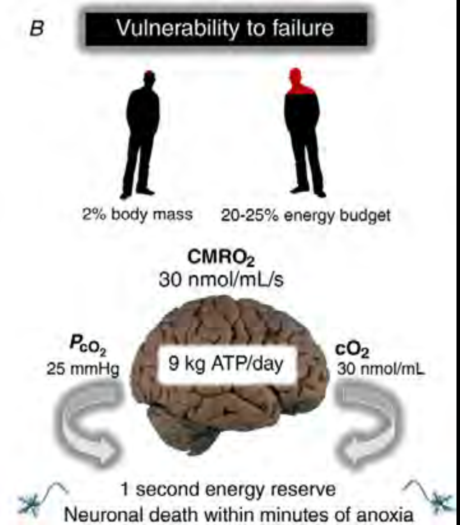

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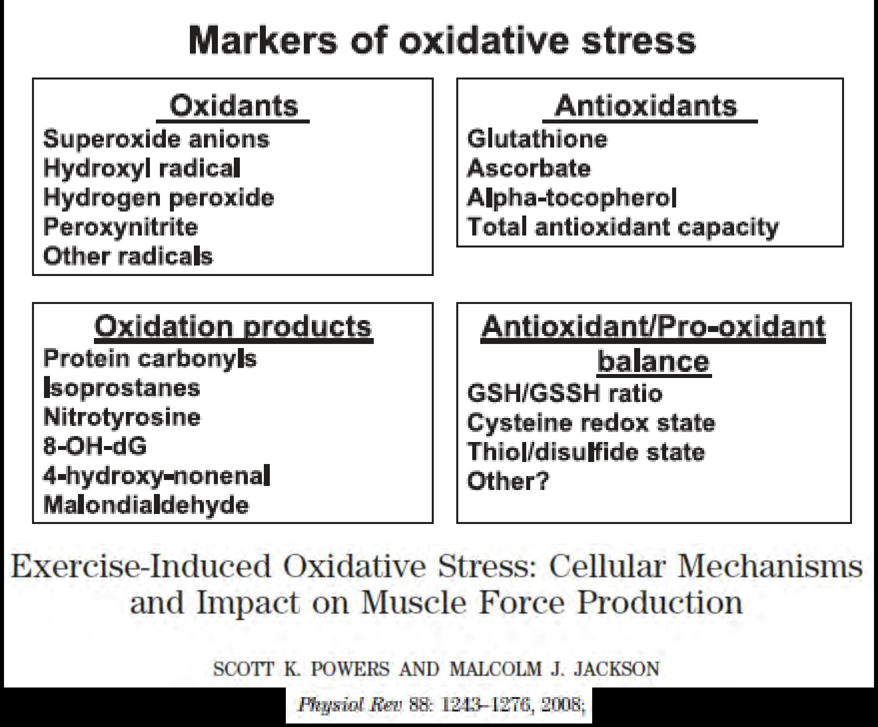
Oxidative Stress



Markers of oxidative stress

Oxidants
- Superoxide anions
- Hydroxyl radical
- Hydrogen peroxide
- Peroxynitrite
- Other radicals

Antioxidants
- Glutathione
- Ascorbate
- Alpha-tocopherol
- Total antioxidant capacity

Oxidation products
- Protein carbonyls
- Isoprostanes
- Nitrotyrosine
- 8-OH-dG
- 4-hydroxy-nonenal
- Malondialdehyde

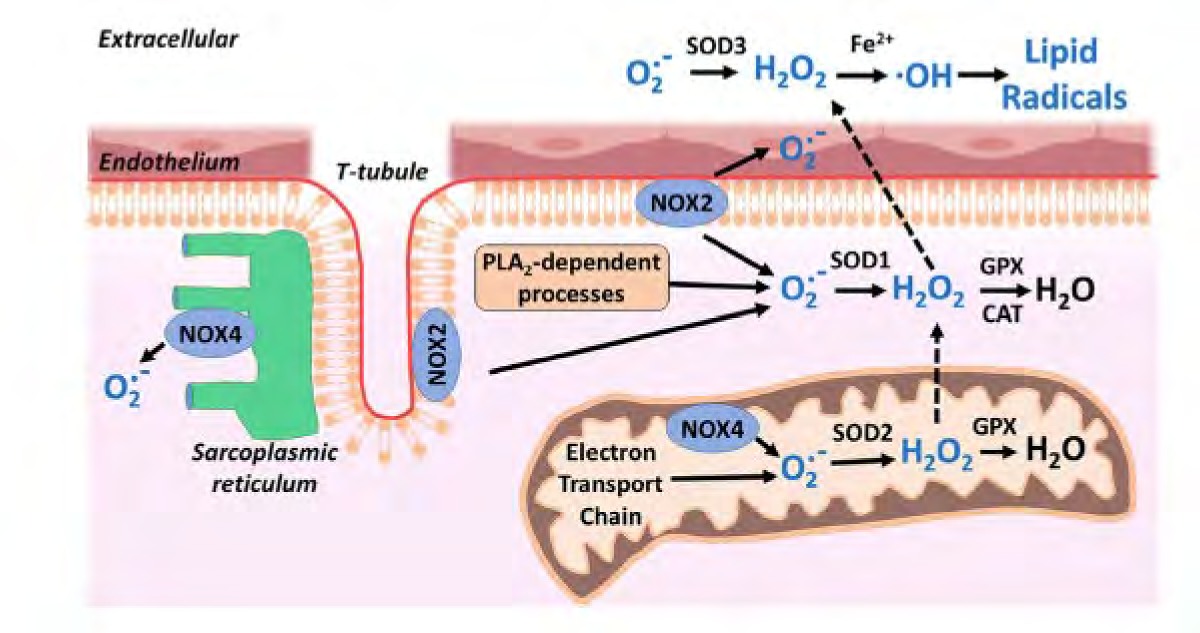
Antioxidant/Pro-oxidant balance
- GSH/GSSH ratio
- Cysteine redox state
- Thiol/disulfide state
- Other?

Exercise-Induced Oxidative Stress: Cellular Mechanisms and Impact on Muscle Force Production

SCOTT K. POWERS AND MALCOLM J. JACKSON

Physiol Rev 88: 1243–1276, 2008;

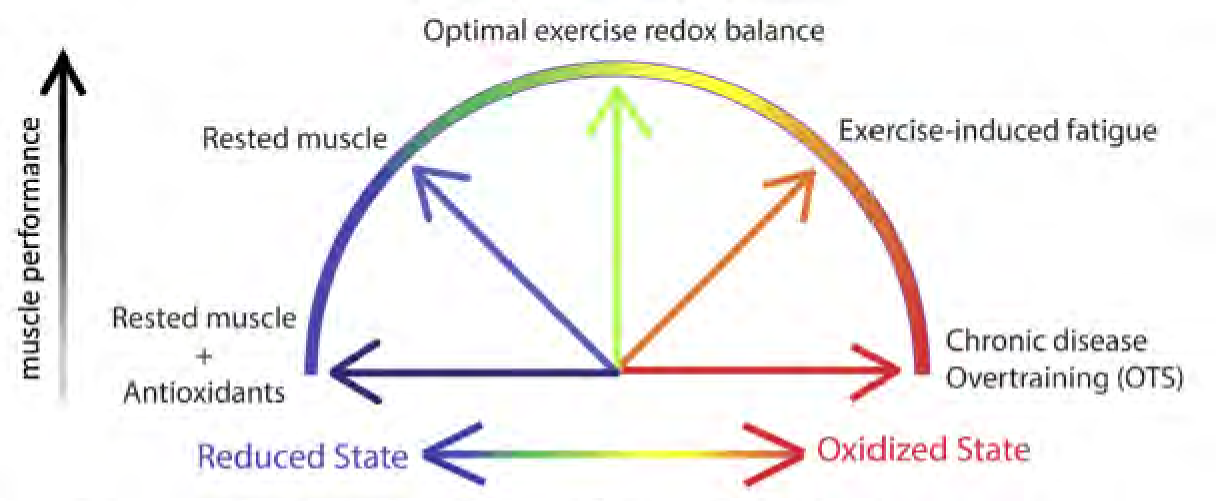
Sources of Radicals



Exercise-induced oxidative stress: Friend or foe?

Scott K. Powers[a], Rafael Deminice[b], Mustafa Ozdemir[a,c,*], Toshinori Yoshihara[a,d], Matthew P. Bomkamp[a], Hayden Hyatt[a]

Journal of Sport and Health Science 9 (2020) 415–425



Intramuscular mechanisms of overtraining

Redox Biology 35 (2020) 101480

Arthur J. Cheng[a], Baptiste Jude[b], Johanna T. Lanner[b,*] The consequences of exercise-induced oxidative stress continue to be a controversial topic. In theory, exercise-induced ROS production could be a double-edged sword, whereby a moderate level of ROS production during exercise promotes positive physiological adaptation in the active skeletal muscles (e.g., mitochondrial biogenesis, synthesis of antioxidant enzymes, and stress proteins), whereas high levels of ROS production result in damage to macromolecular structures (e.g., proteins, lipids, and DNA). Although the impact of exercise-induced ROS production in skeletal muscle has been postulated to be a bell-shaped hormesis curve, there is not convincing evidence that prolonged, high-intensity exercise results in tissue damage and impaired physiological function. Indeed, research consistently demonstrates that long duration and high-intensity exercise provides the greatest health benefits. Therefore, based on the available evidence, it appears unlikely that rigorous and prolonged exercise results in an oxidative stress level that is detrimental to human health.

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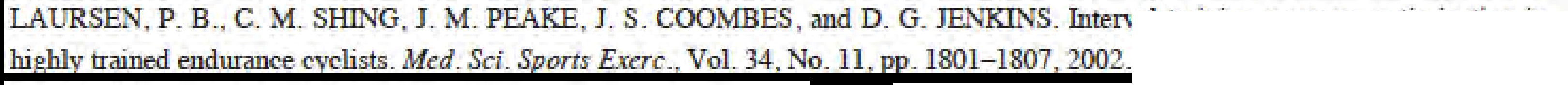

LAURSEN, P. B., C. M. SHING, J. M. PEAKE, J. S. COOMBES, and D. G. JENKINS. Interv
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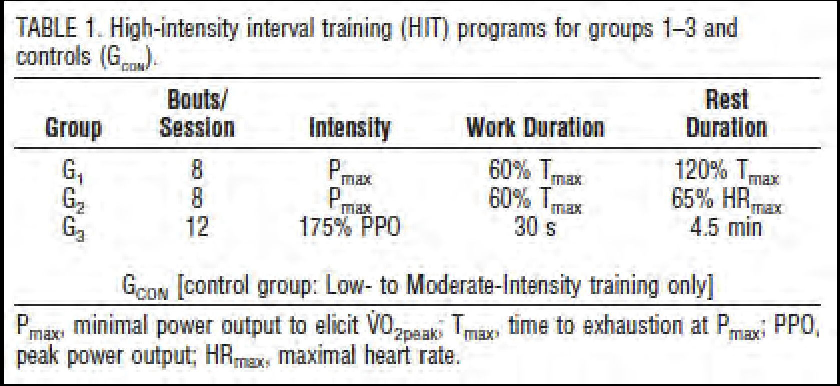

TABLE 1. High-intensity interval training (HIT) programs for groups 1–3 and controls (G_{con}).

Group	Bouts/ Session	Intensity	Work Duration	Rest Duration
G_1	8	P_{max}	60% T_{max}	120% T_{max}
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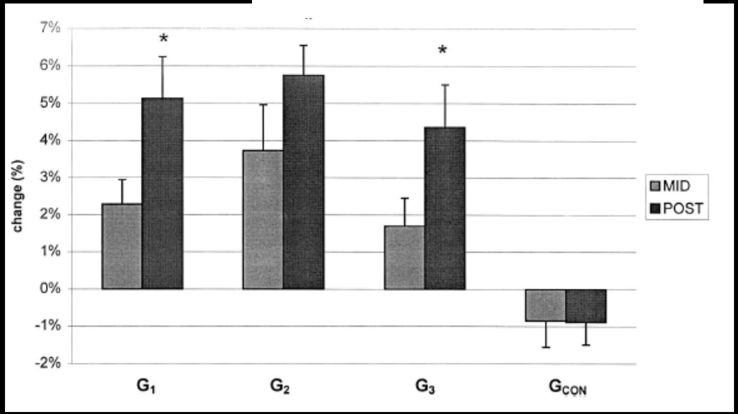
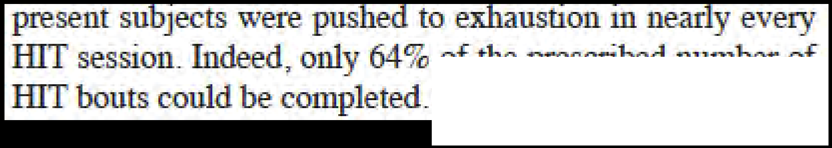
P_{max}, minimal power output to elicit $\dot{V}O_{2peak}$; T_{max}, time to exhaustion at P_{max}; PPO, peak power output; HR_{max}, maximal heart rate.



40 km time trial



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HIT bouts could be completed.

Oxidative Resynthesis of PCr

- Oxidative (aerobic) pathways resynthesize PCr during periods of recovery or submaximal intensity exercise
  - Intensity of submaximal exercise limits rate of PCr resynthesis
- ½ time of recovery for PCr is approximately 30s
- Full recovery is 3-5 min

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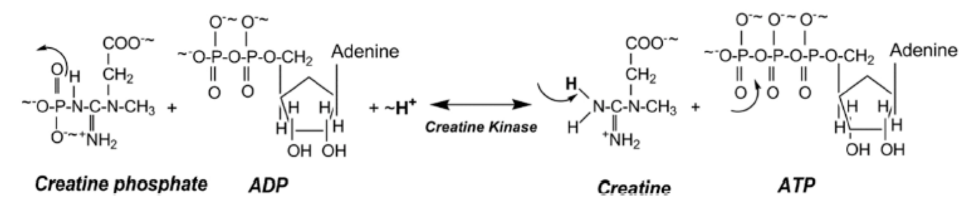
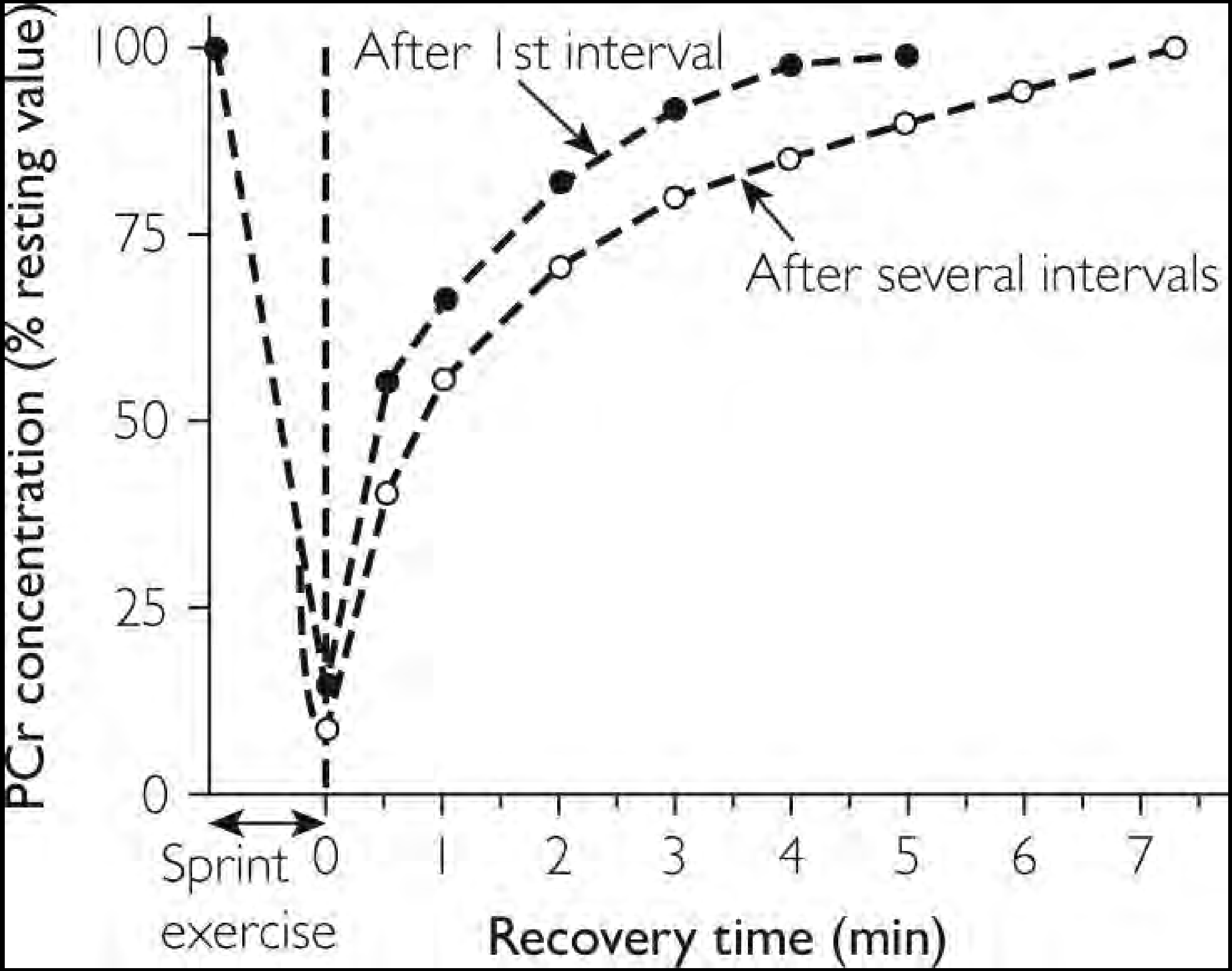
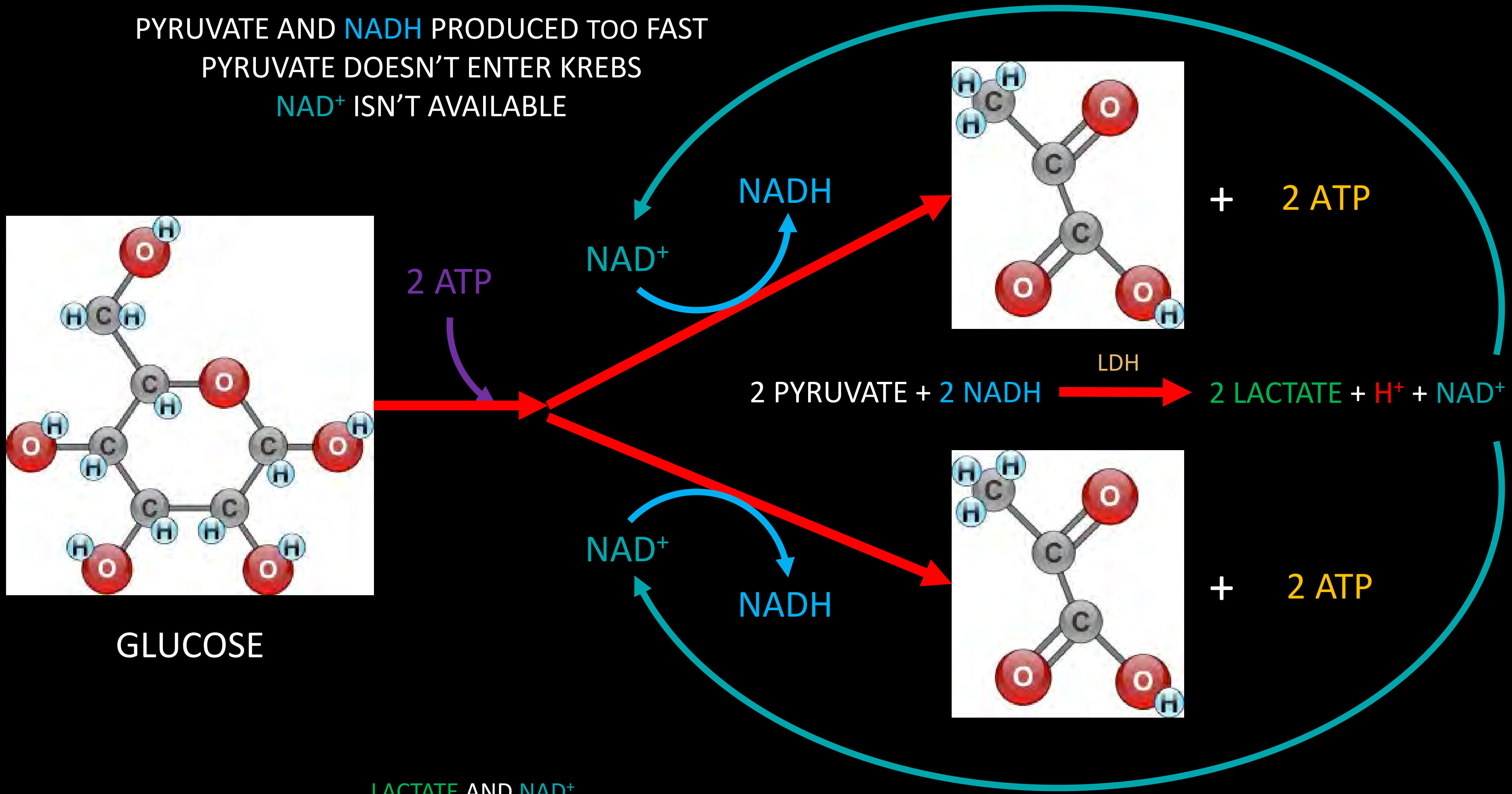




MacDougall & Sale (2015) Physiology of Training for High Performance

Glycolysis

PYRUVATE AND NADH PRODUCED TOO FAST
PYRUVATE DOESN’T ENTER KREBS
NAD^+ ISN’T AVAILABLE



2 PYRUVATE + 2 NADH $\xrightarrow{\text{LDH}}$ 2 LACTATE + H^+ + NAD^+

LACTATE AND NAD^+
PRODUCTION KEEPS GLYCOLYSIS GOING

H^+ DROPS pH AND LEADS TO FATIGUE

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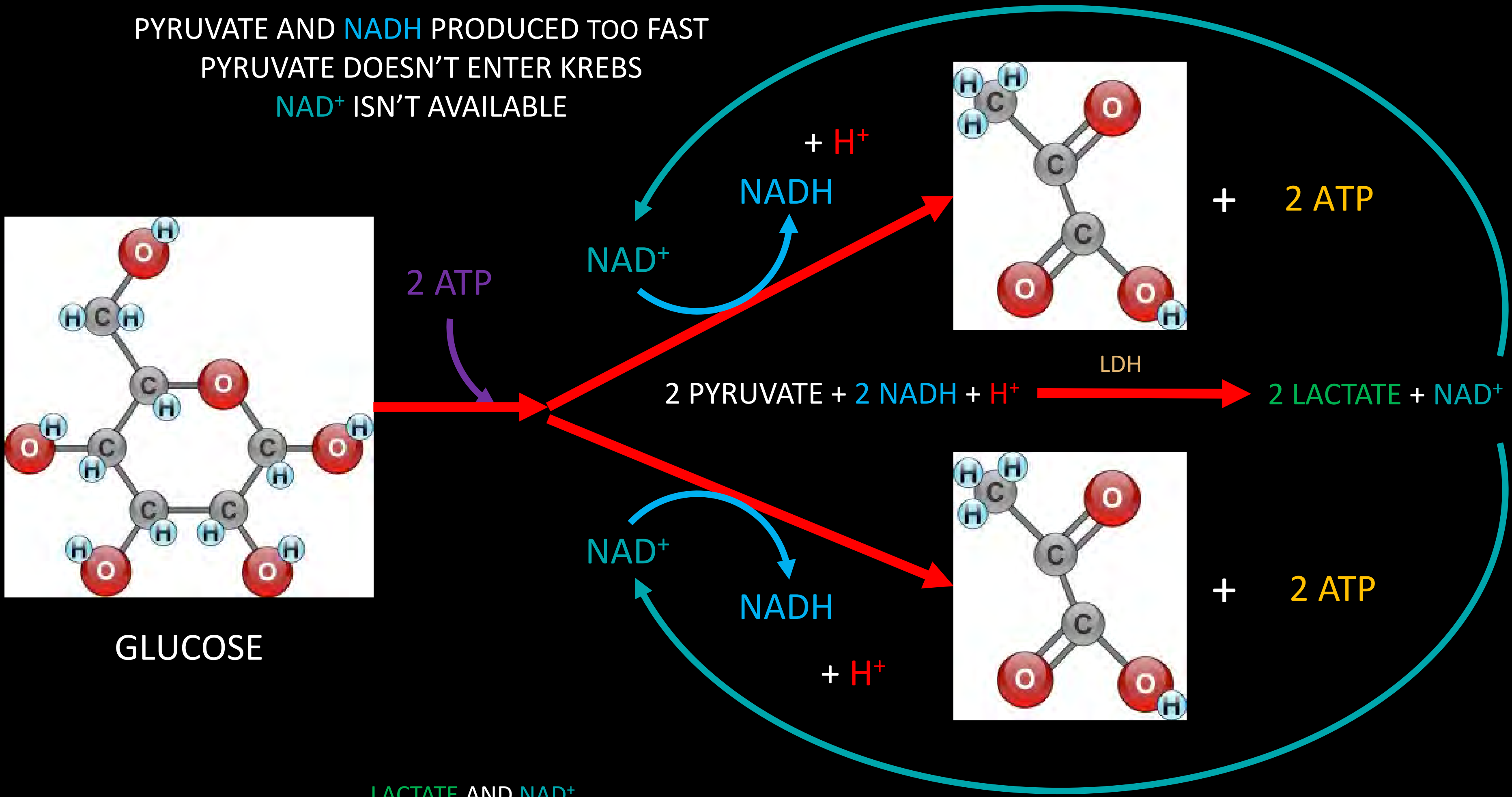


GLUCOSE

2 ATP

NAD^+

NADH

+ H^+

+ 2 ATP

NAD^+

NADH

+ H^+

+ 2 ATP

2 PYRUVATE + 2 NADH + H^+ $\xrightarrow{\text{LDH}}$ 2 LACTATE + NAD^+

LACTATE AND NAD^+
PRODUCTION KEEPS GLYCOLYSIS GOING

H^+ DROPS pH AND LEADS TO FATIGUE

Recovery from Anaerobic Glycolysis

- Is dependent on managing the pH changes in the muscle and blood caused by the increase H^+ production

	½ time	Full Time
Muscle pH	5-8 min	12-20 min
Blood pH	25 min	~60 min

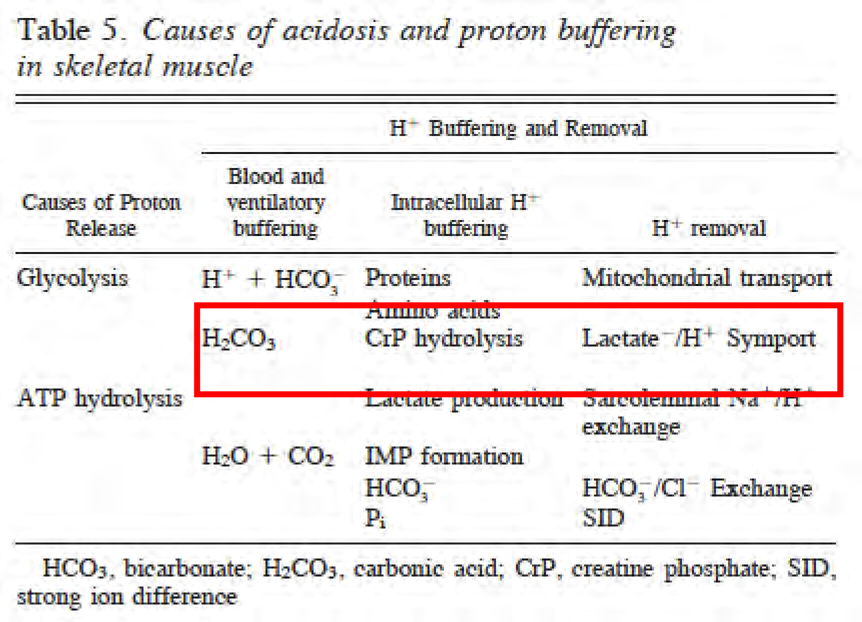
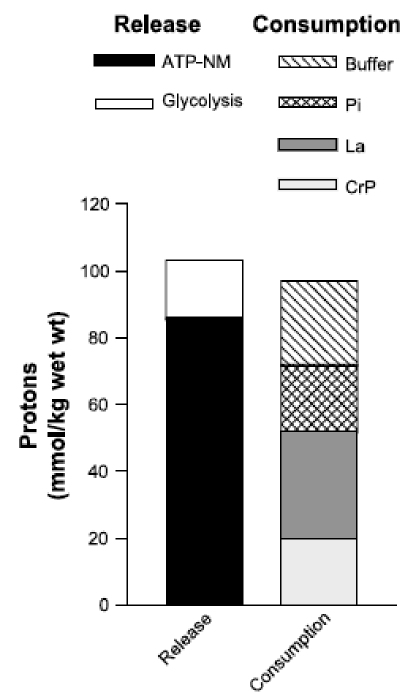


Table 5. *Causes of acidosis and proton buffering in skeletal muscle*

	H⁺ Buffering and Removal		
Causes of Proton Release	Blood and ventilatory buffering	Intracellular H⁺ buffering	H⁺ removal
Glycolysis	$H^+ + HCO_3^-$	Proteins	Mitochondrial transport
		Amino acids	
	H_2CO_3	CrP hydrolysis	Lactate⁻/H⁺ Symport
ATP hydrolysis		Lactate production	Sarcolemmal Na⁺/H⁺ exchange
	$H_2O + CO_2$	IMP formation	
		HCO_3^-	HCO_3^-/Cl^- Exchange
		P_i	SID

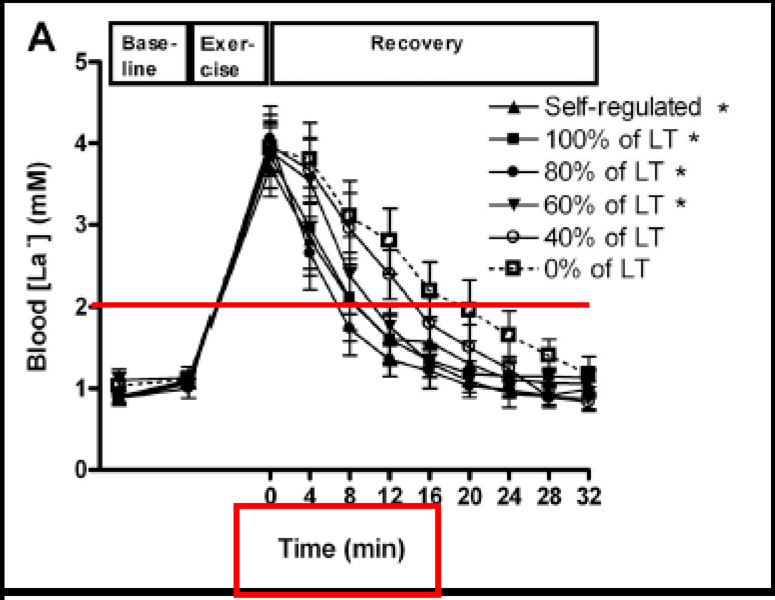
HCO_3, bicarbonate; H_2CO_3, carbonic acid; CrP, creatine phosphate; SID, strong ion difference



Biochemistry of exercise-induced metabolic acidosis

Robert A. Robergs,[1] Farzenah Ghiasvand,[1] and Daryl Parker[2]

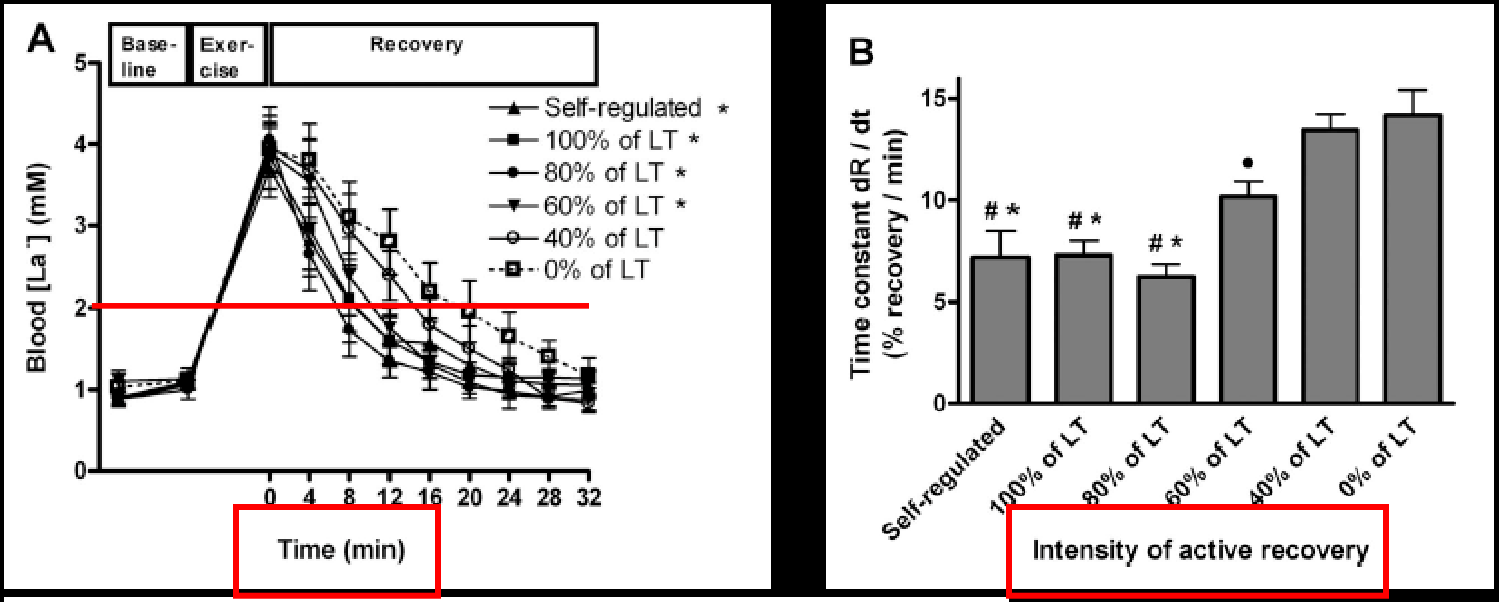
Am J Physiol Regul Integr Comp Physiol 287: R502–R516, 2004;



Blood lactate clearance during active recovery after an intense running bout depends on the intensity of the active recovery

Paul Menzies , Craig Menzies , Laura McIntyre , Paul Paterson , John Wilson & Ole J. Kemi

Journal of Sports Sciences, July 2010; 28(9): 975–982



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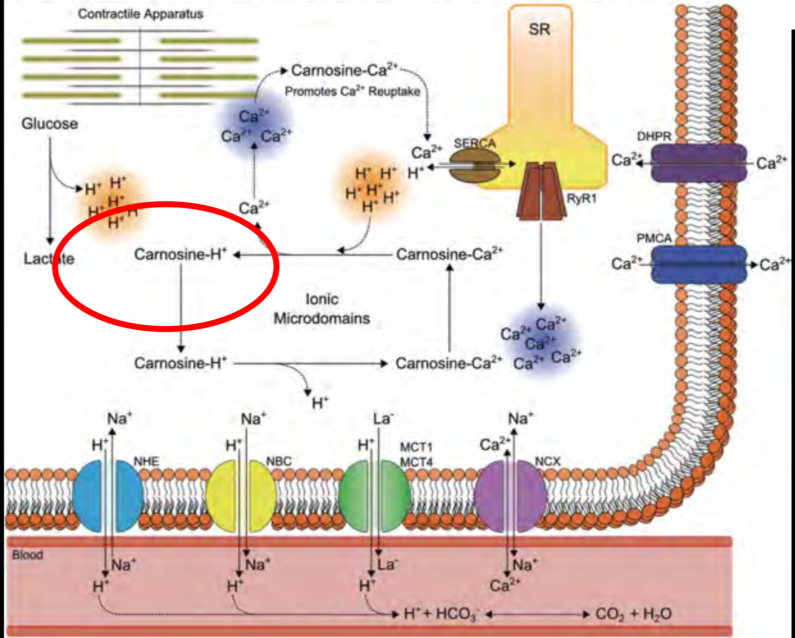
uffering

MATTHEWS, J. J., G. G. ARTIOLI, M. D. TURNER, and C. SALE. The Physiolog
man Skeletal Muscle. *Med. Sci. Sports Exerc.*, Vol. 51, No. 10, pp. 2098–2108, 2019.



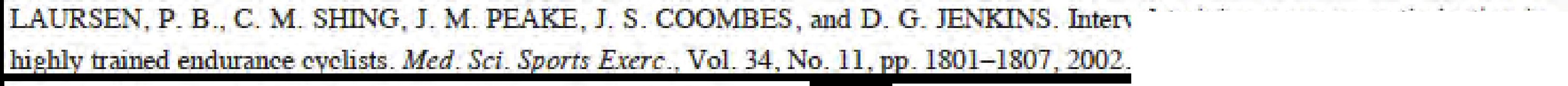
Buffering

- **Must manage reduction in muscle pH (and blood pH) via multiple buffering pathways**

metabolism

$$HCO_3^- + H^+ \longleftrightarrow H_2CO_3 \longleftrightarrow CO_2 + H_2O$$

exhale



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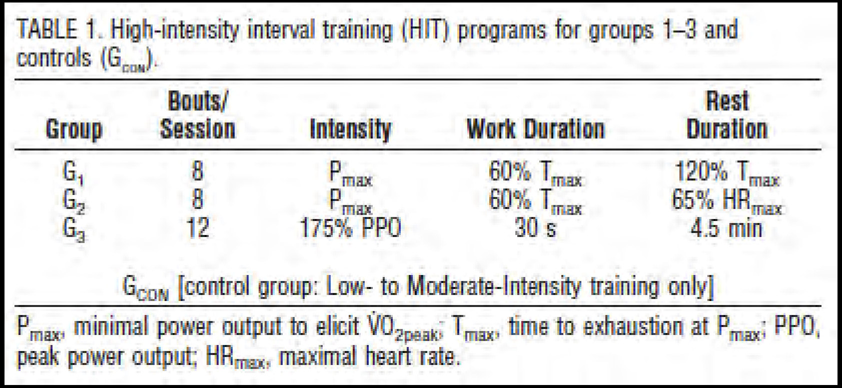

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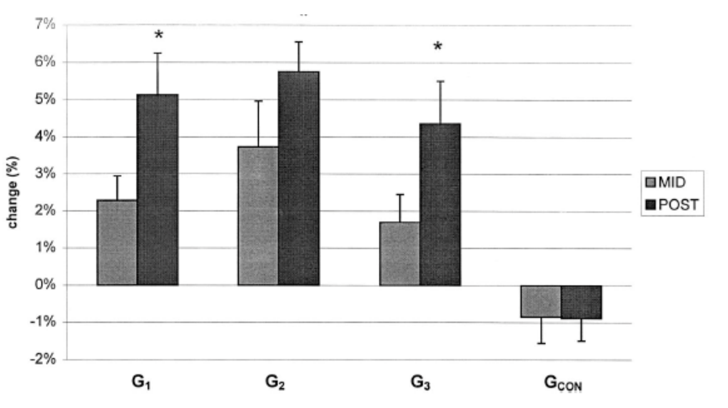

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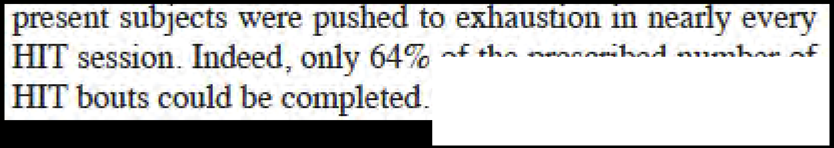

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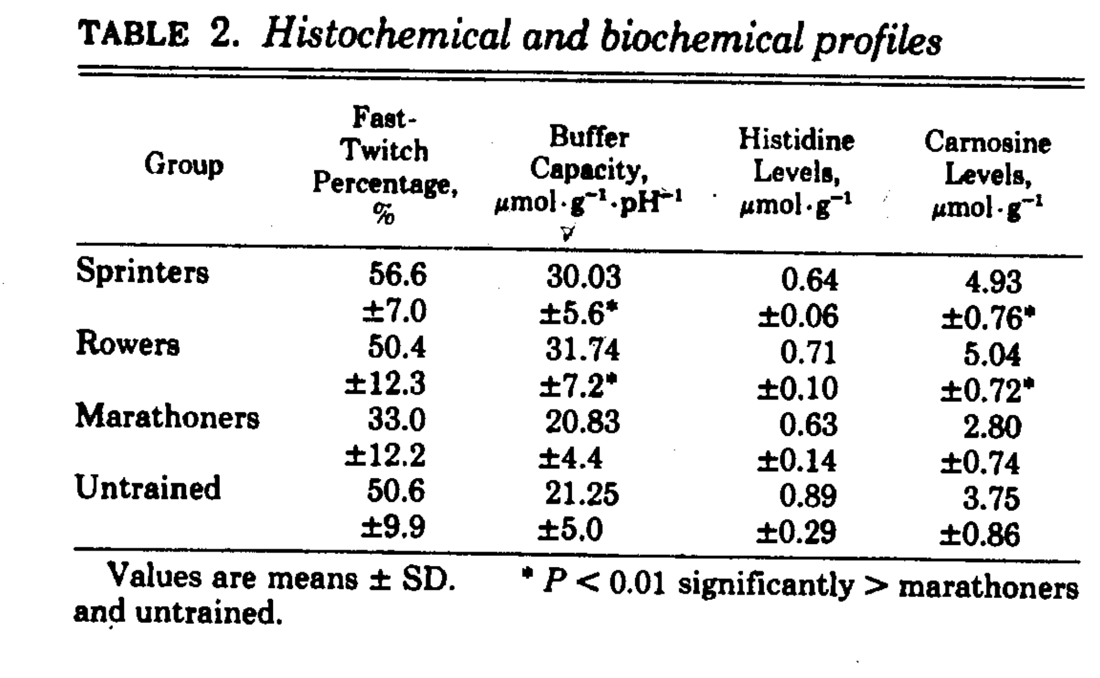

TABLE 2. *Histochemical and biochemical profiles*

Group	Fast-Twitch Percentage, %	Buffer Capacity, $\mu mol \cdot g^{-1} \cdot pH^{-1}$	Histidine Levels, $\mu mol \cdot g^{-1}$	Carnosine Levels, $\mu mol \cdot g^{-1}$
Sprinters	56.6	30.03	0.64	4.93
	±7.0	±5.6*	±0.06	±0.76*
Rowers	50.4	31.74	0.71	5.04
	±12.3	±7.2*	±0.10	±0.72*
Marathoners	33.0	20.83	0.63	2.80
	±12.2	±4.4	±0.14	±0.74
Untrained	50.6	21.25	0.89	3.75
	±9.9	±5.0	±0.29	±0.86

Values are means ± SD. * $P < 0.01$ significantly > marathoners and untrained.

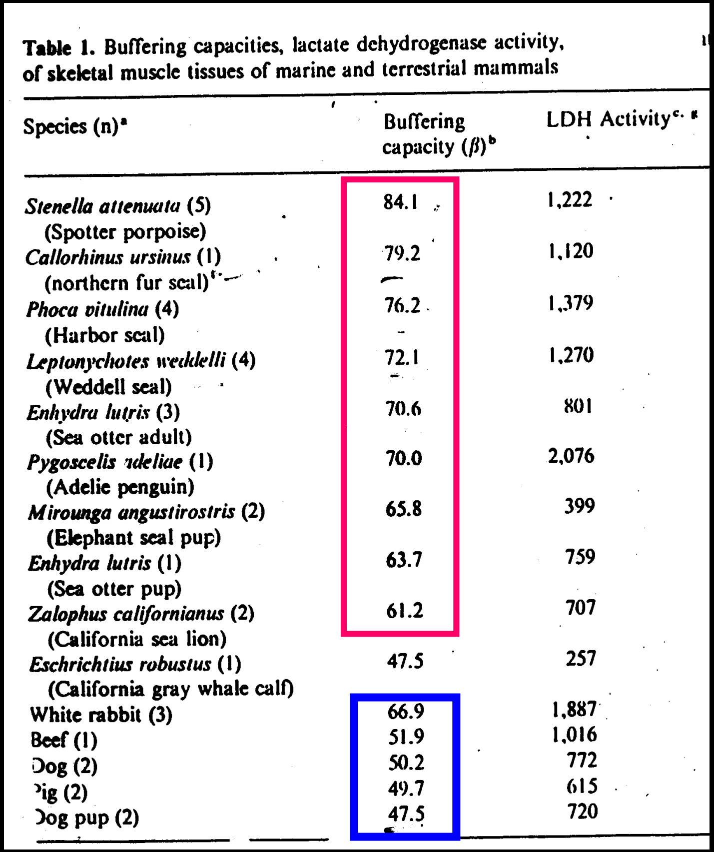

Table 1. Buffering capacities, lactate dehydrogenase activity, of skeletal muscle tissues of marine and terrestrial mammals

Species (n)[a]	Buffering capacity (β)[b]	LDH Activity[c, g]
Stenella attenuata (5) (Spotter porpoise)	84.1	1,222
Callorhinus ursinus (1) (northern fur seal)	79.2	1,120
Phoca vitulina (4) (Harbor seal)	76.2	1,379
Leptonychotes weddelli (4) (Weddell seal)	72.1	1,270
Enhydra lutris (3) (Sea otter adult)	70.6	801
Pygoscelis adeliae (1) (Adelie penguin)	70.0	2,076
Mirounga angustirostris (2) (Elephant seal pup)	65.8	399
Enhydra lutris (1) (Sea otter pup)	63.7	759
Zalophus californianus (2) (California sea lion)	61.2	707
Eschrichtius robustus (1) (California gray whale calf)	47.5	257
White rabbit (3)	66.9	1,887
Beef (1)	51.9	1,016
Dog (2)	50.2	772
Pig (2)	49.7	615
Dog pup (2)	47.5	720

Endurance Activities

Thoughts/Questions