Reaching new heights:

Ketones to improve adaptations to exercise & high altitude?

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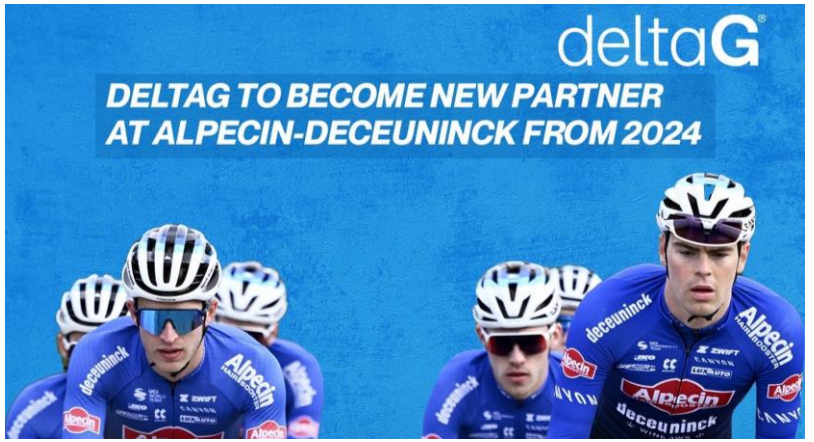
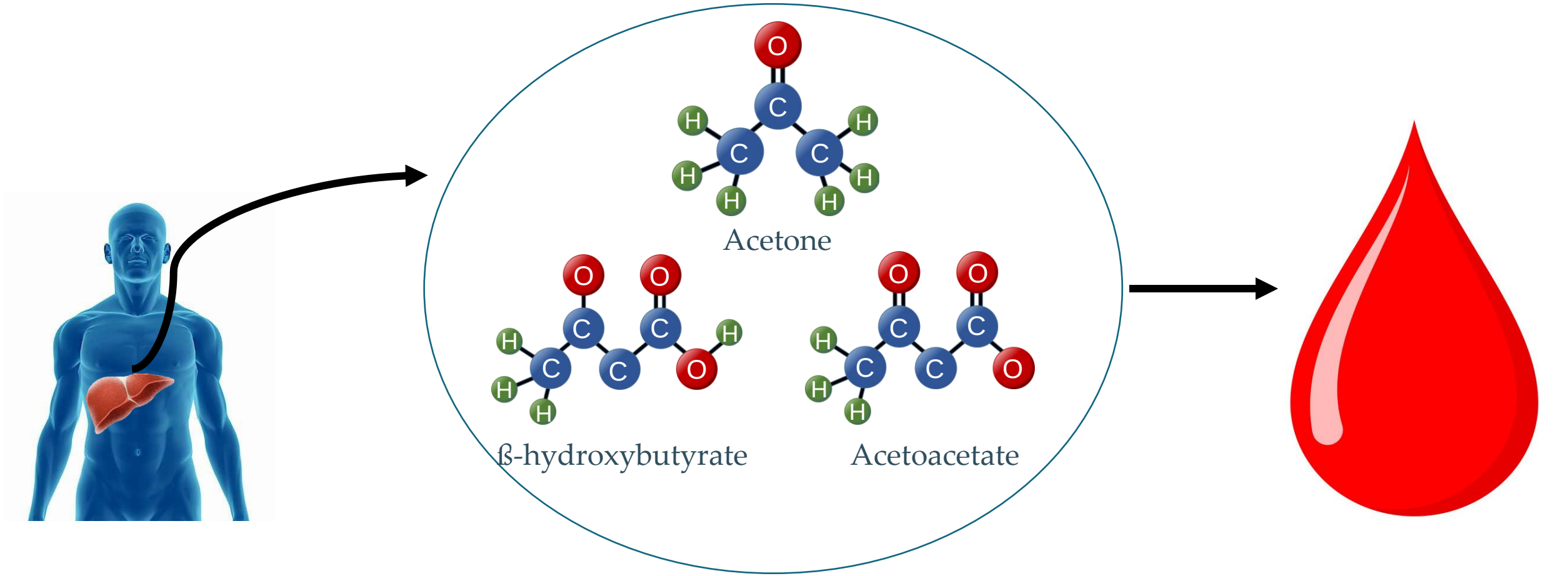
Science & Cycling

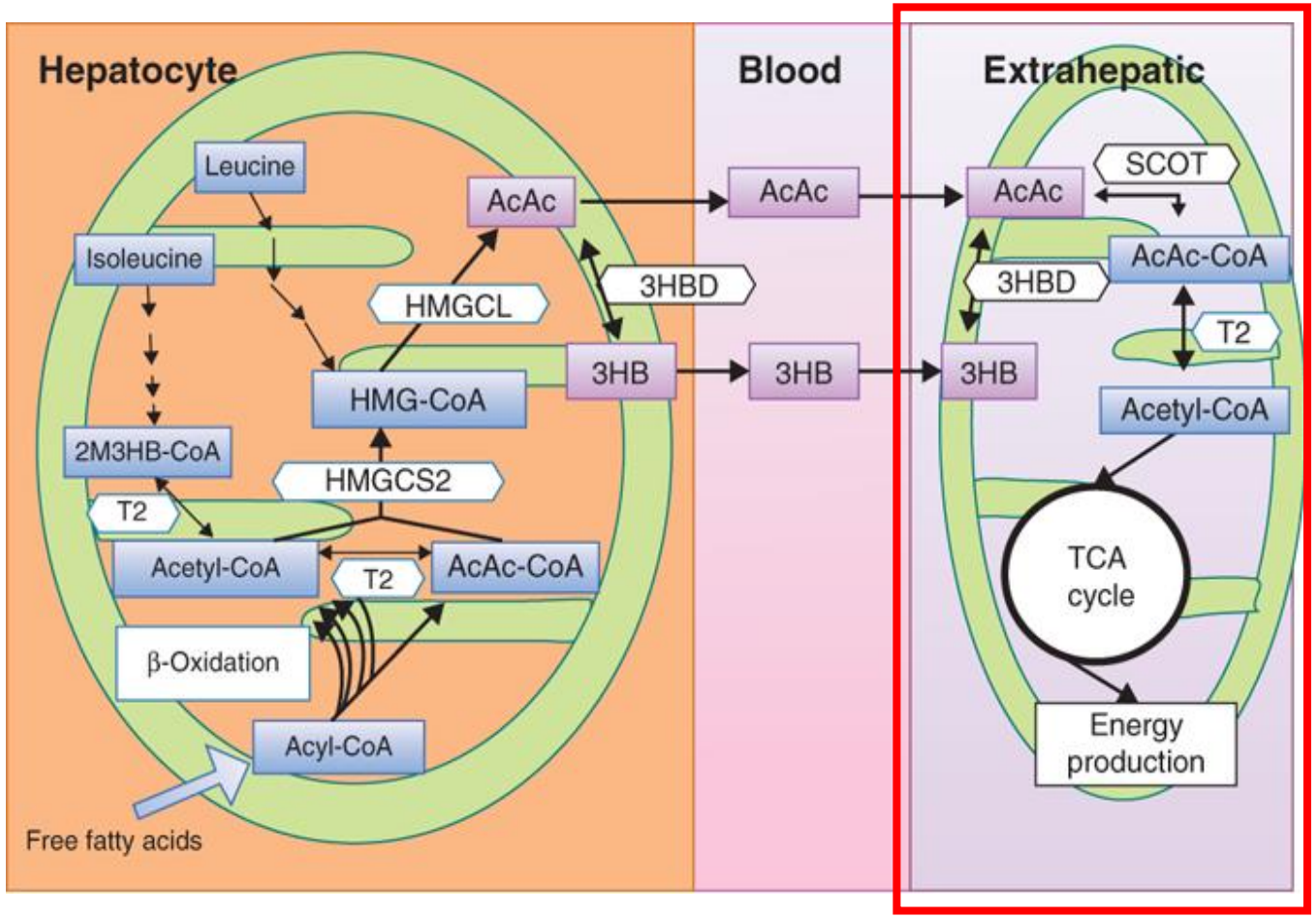
Ketone supplements are widely used in the peloton

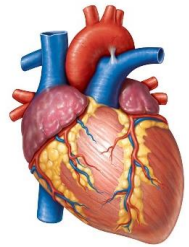


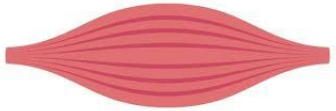
What are ketone bodies?



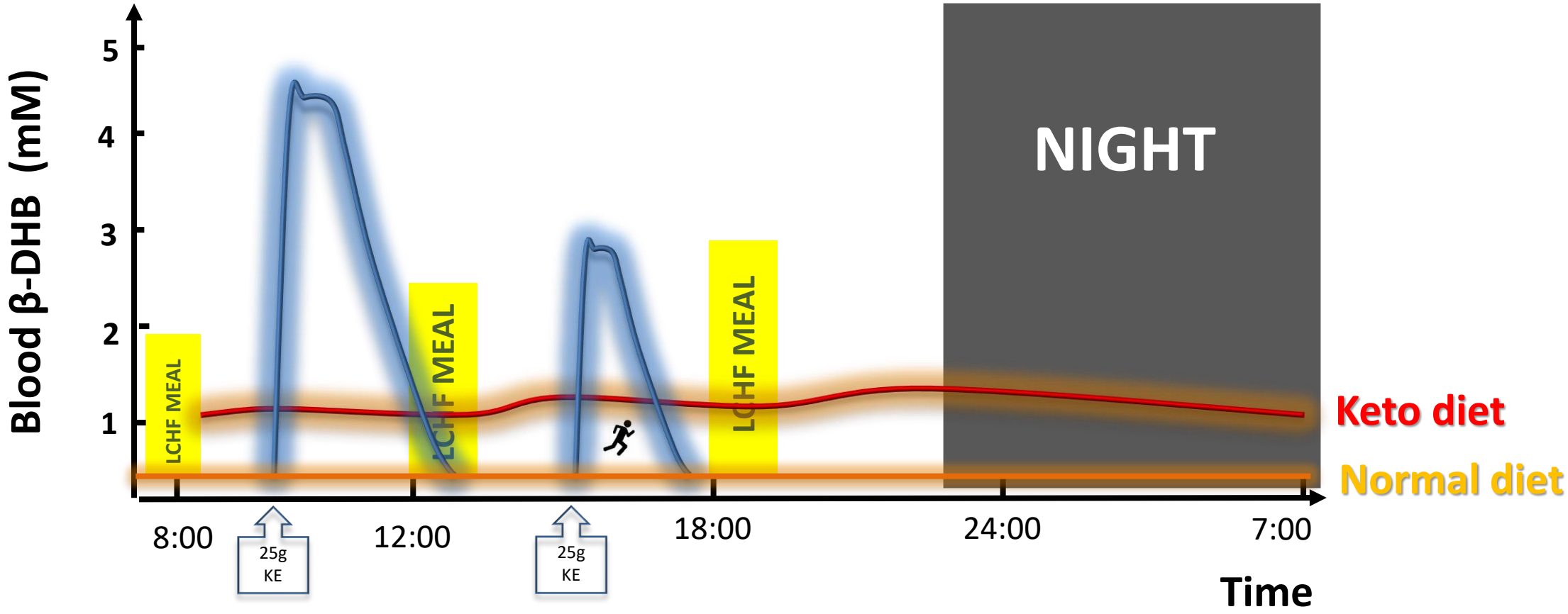
Ketone bodies: ‘the fourth fuel”



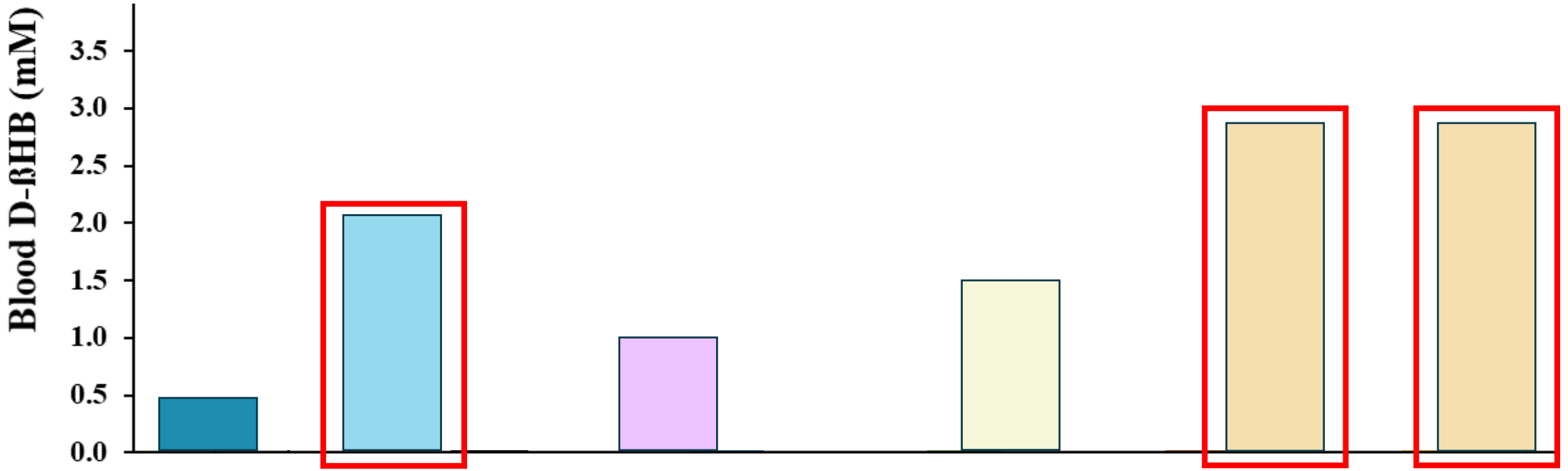




Ketone supplements *vs.* ketogenic diet



Ketone supplements: which one to choose as an athlete?



Ketone precursors | **Ketone salts** | **Ketone di-esters** | **Ketone mono-esters**

Fake ‘keto’ supplements

How to use ketones to improve performance?

During exercise
to improve
endurance exercise performance

After exercise
to improve
training adaptation and recovery

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During exercise
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After exercise
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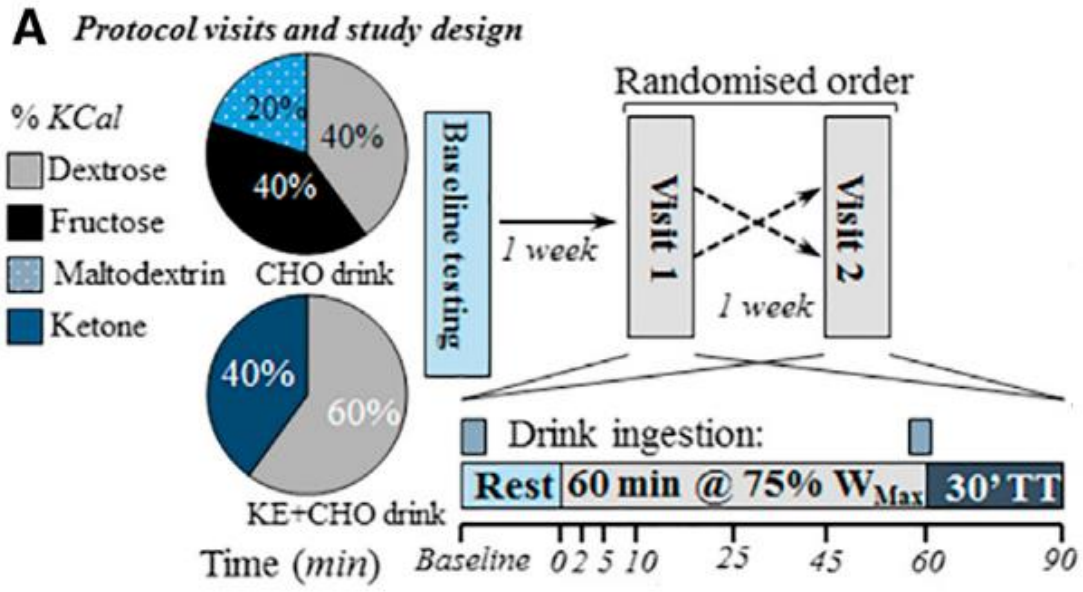
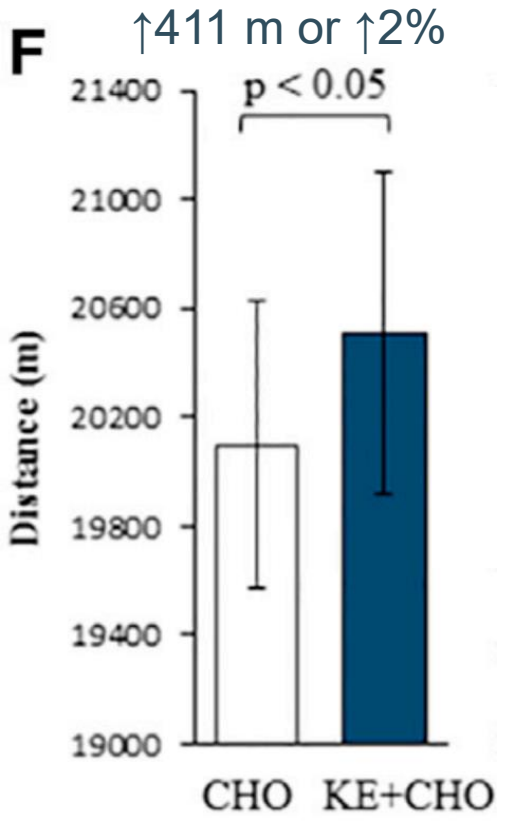
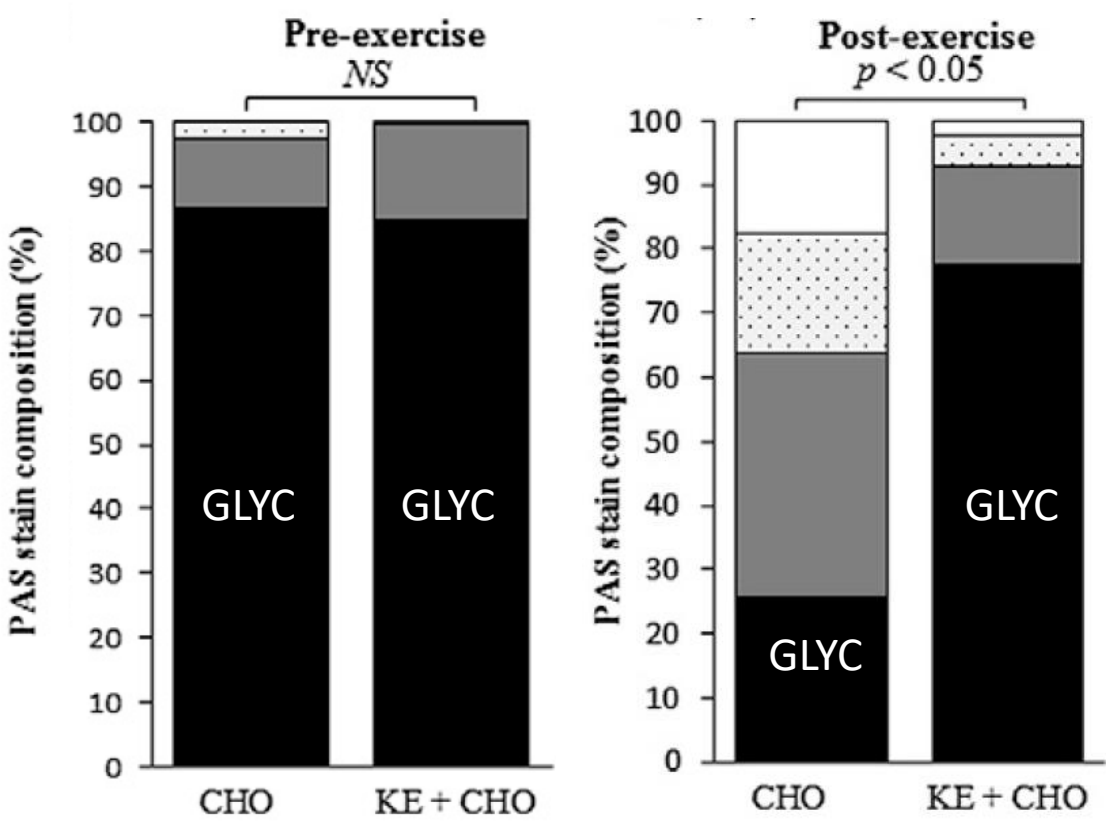
KE intake improved cycling time-trial performance

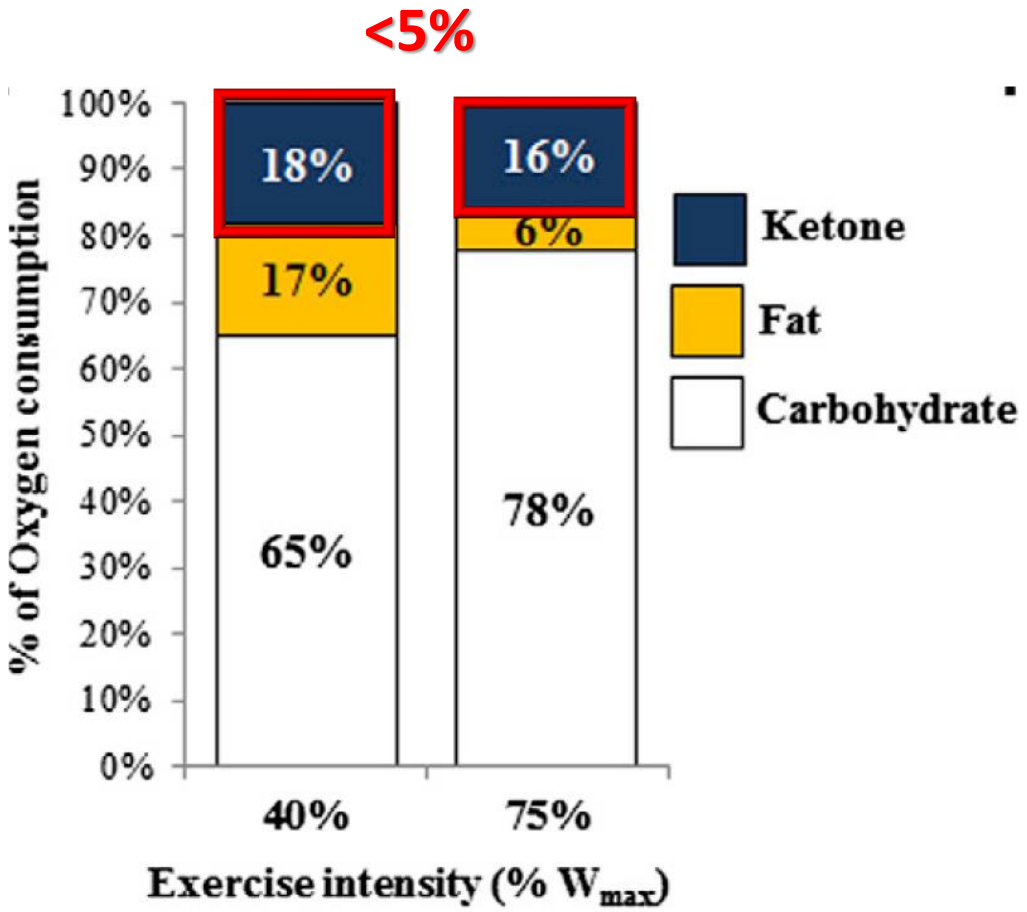




Cox et al., *Cell Metab* (2016)

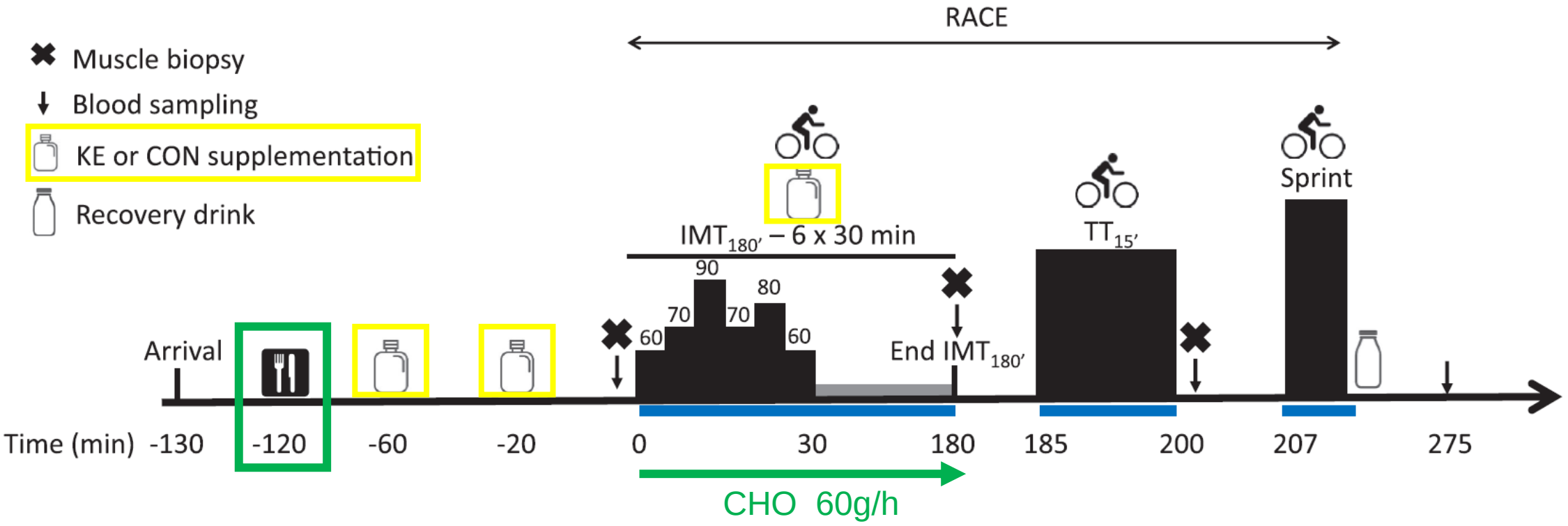
Mechanism: glycogen sparing + extra energy source





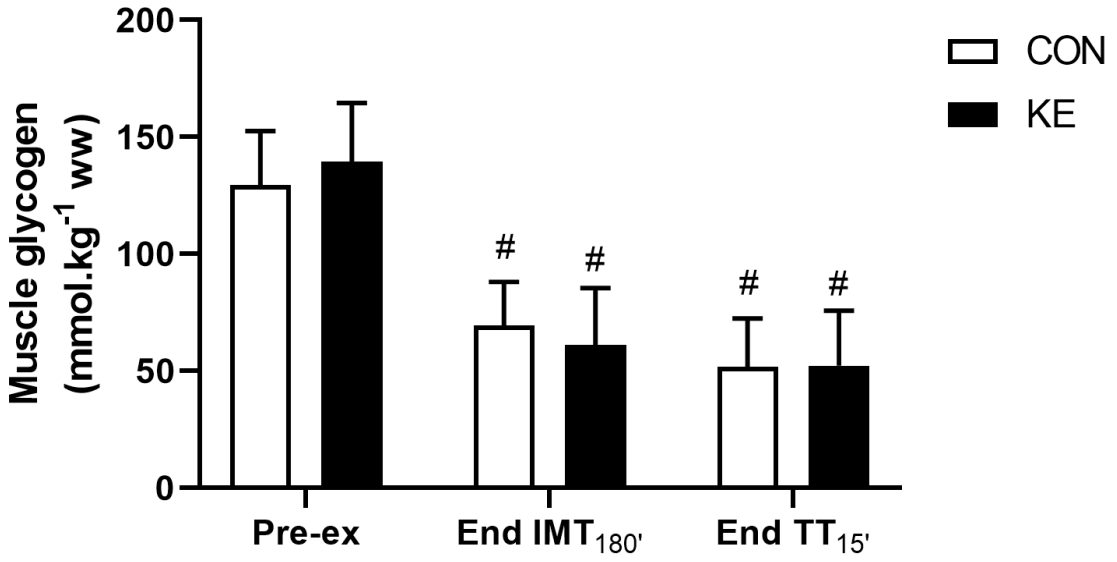
Dearlove et al., MSSE (2020)

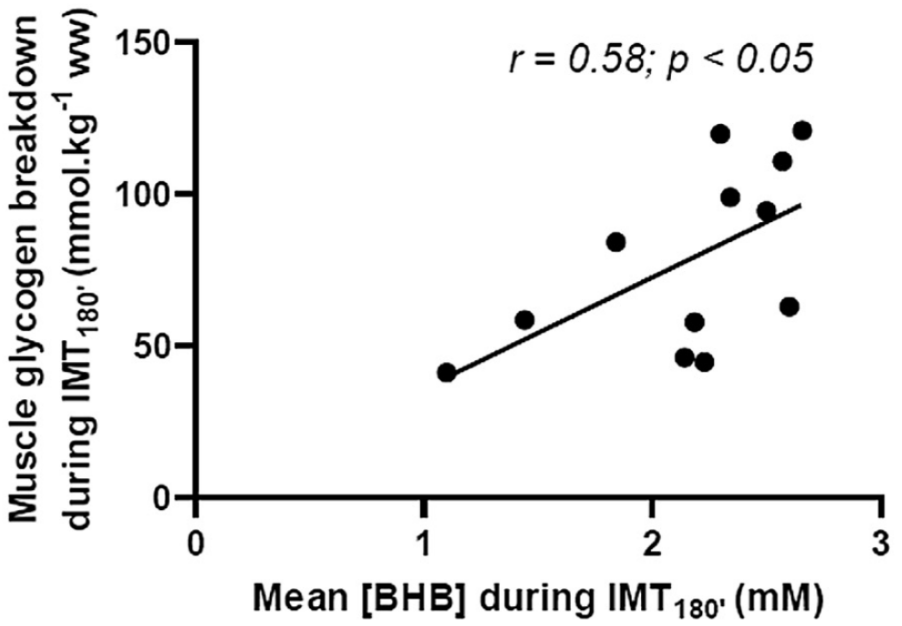
Glycogen sparing in simulated cycling race?



Poffé et al., J Appl Physiol (2020)

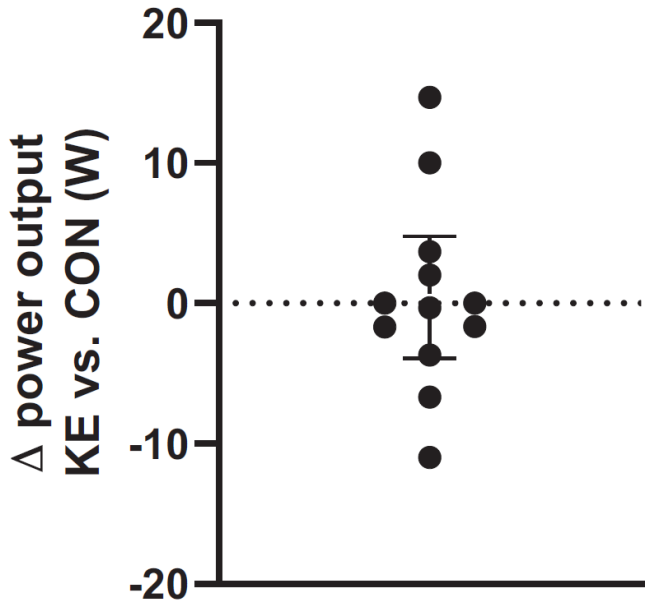
No glycogen sparing effect



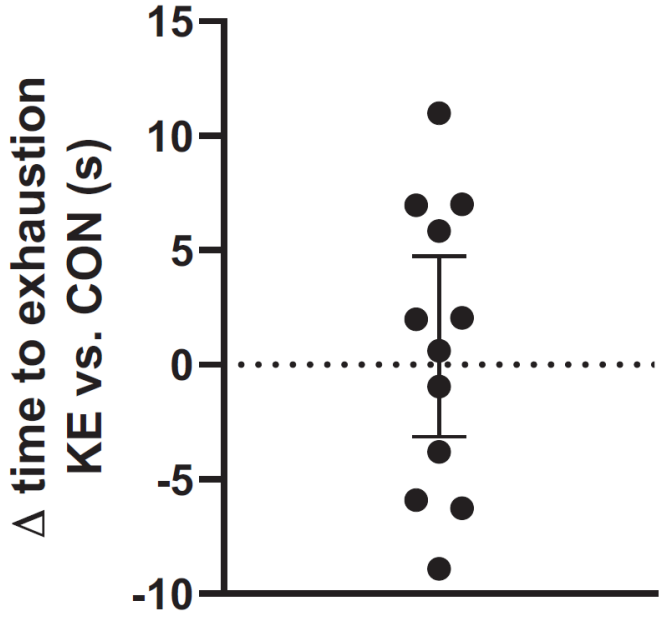


No performance effect

15-min TT



Sprint



Should you take ketones during exercise/cycling?

15s | 20 min | 60 min | 3h + 15 min TT

Evans et al., *MSSE* (2018)
Waldman et al., *Appl Physiol Nutr Metab* (2018)

Leckey et al., *Front Physiol* (2017)
Poffé et al., *MSSE* (2020)
McCarthy et al., *Int J Sport Nutr Exerc Metab* (2023)

Poffé et al., *J Appl Physiol* (2020)
Poffé et al., *MSSE* (2021)
Robberechts et al., *J Appl Physiol* (2022)

When CHO intake is adequate

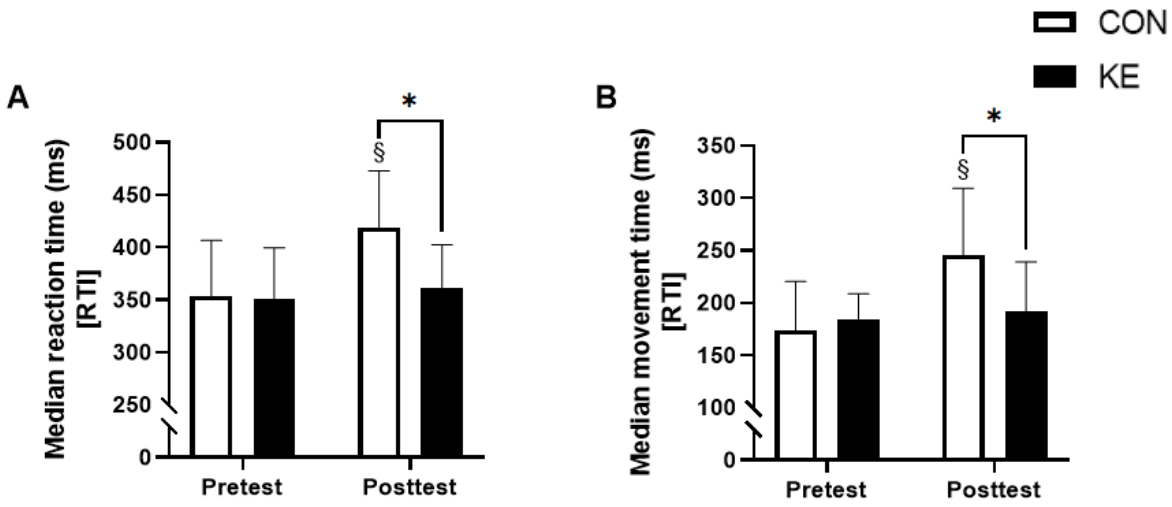
Should you take ketones during exercise/cycling?

?

15s 20 min 60 min 3h + 15 min TT

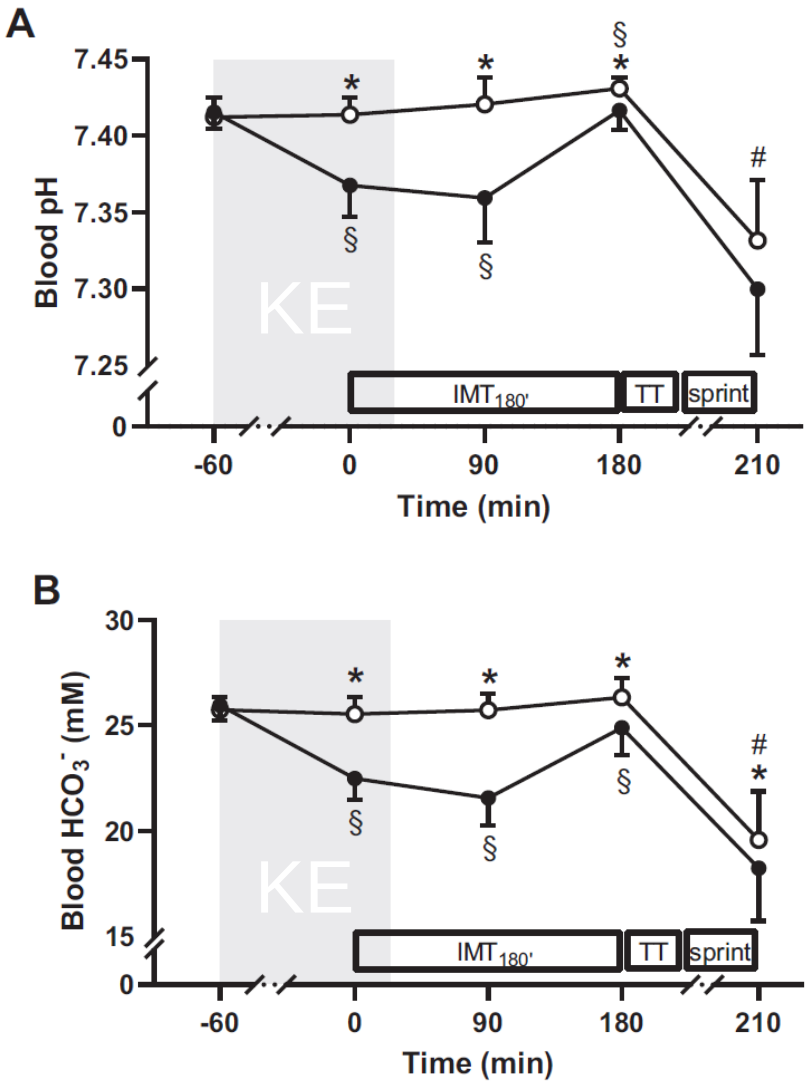
100km ultrarun

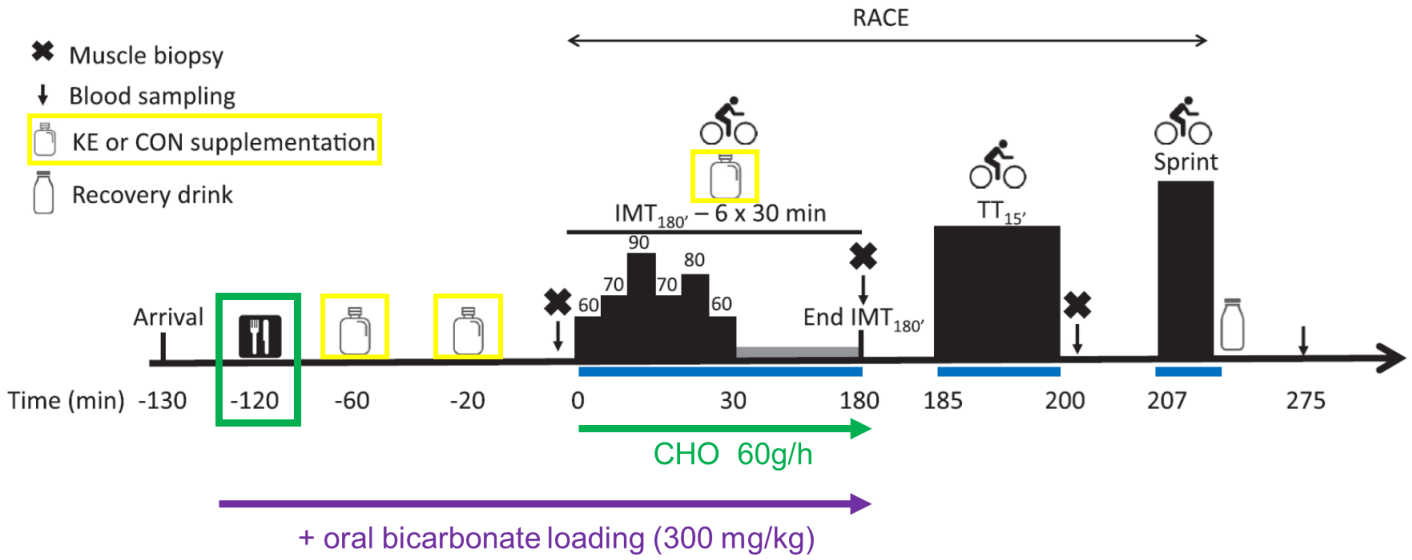
25g KE/h *vs.* placebo



Poffé et al., J Appl Physiol (2023)

KE induces acidosis

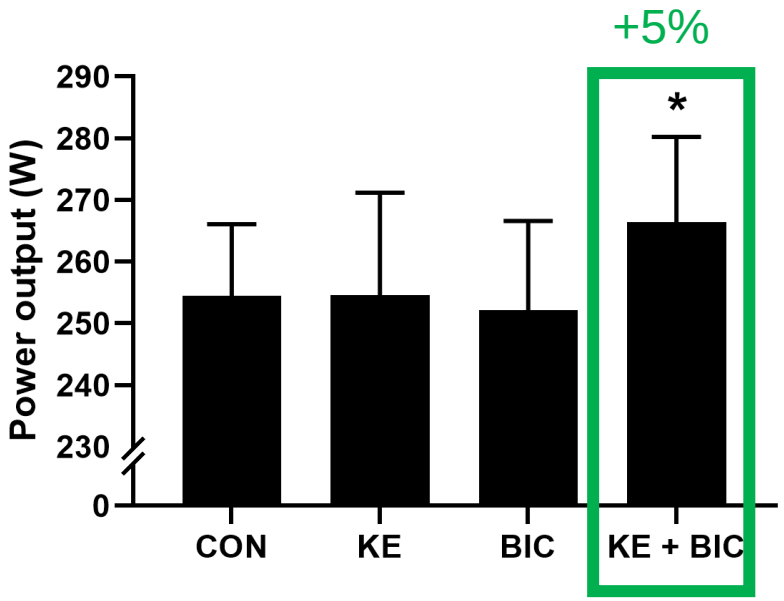




Poffé et al., MSSE (2021)

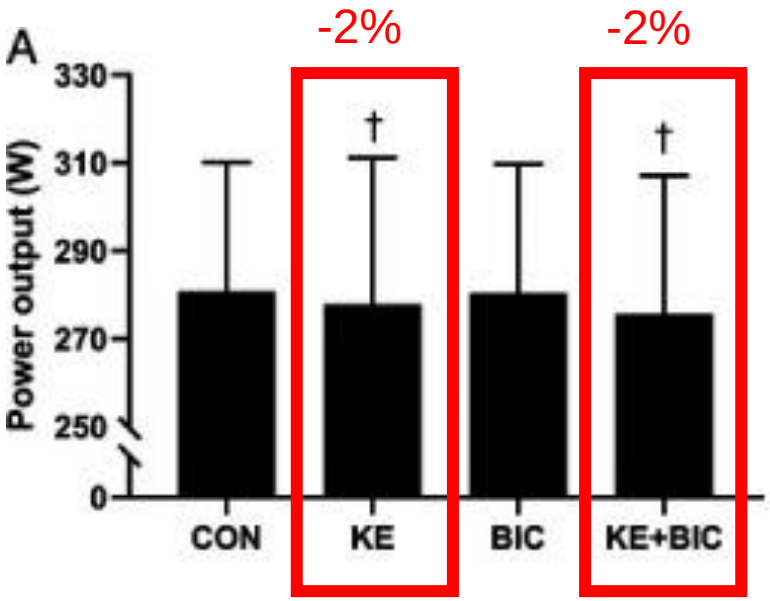
Ketone + bicarbonate: some evidence pro

3h + 15 min TT



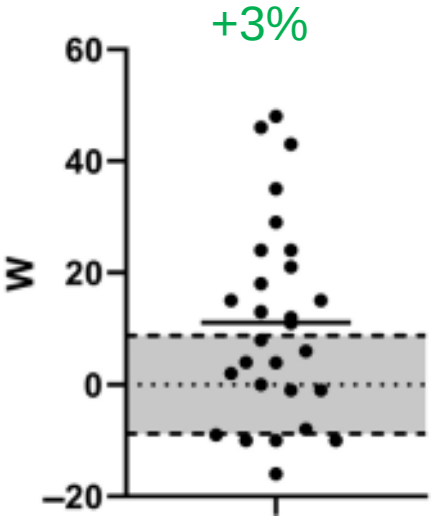
Poffé et al., MSSE (2021)

30 min TT



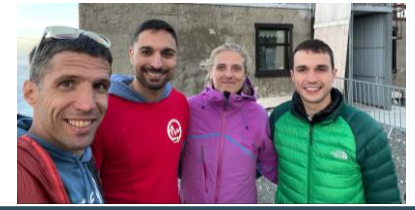
Poffé et al., MSSE (2021)

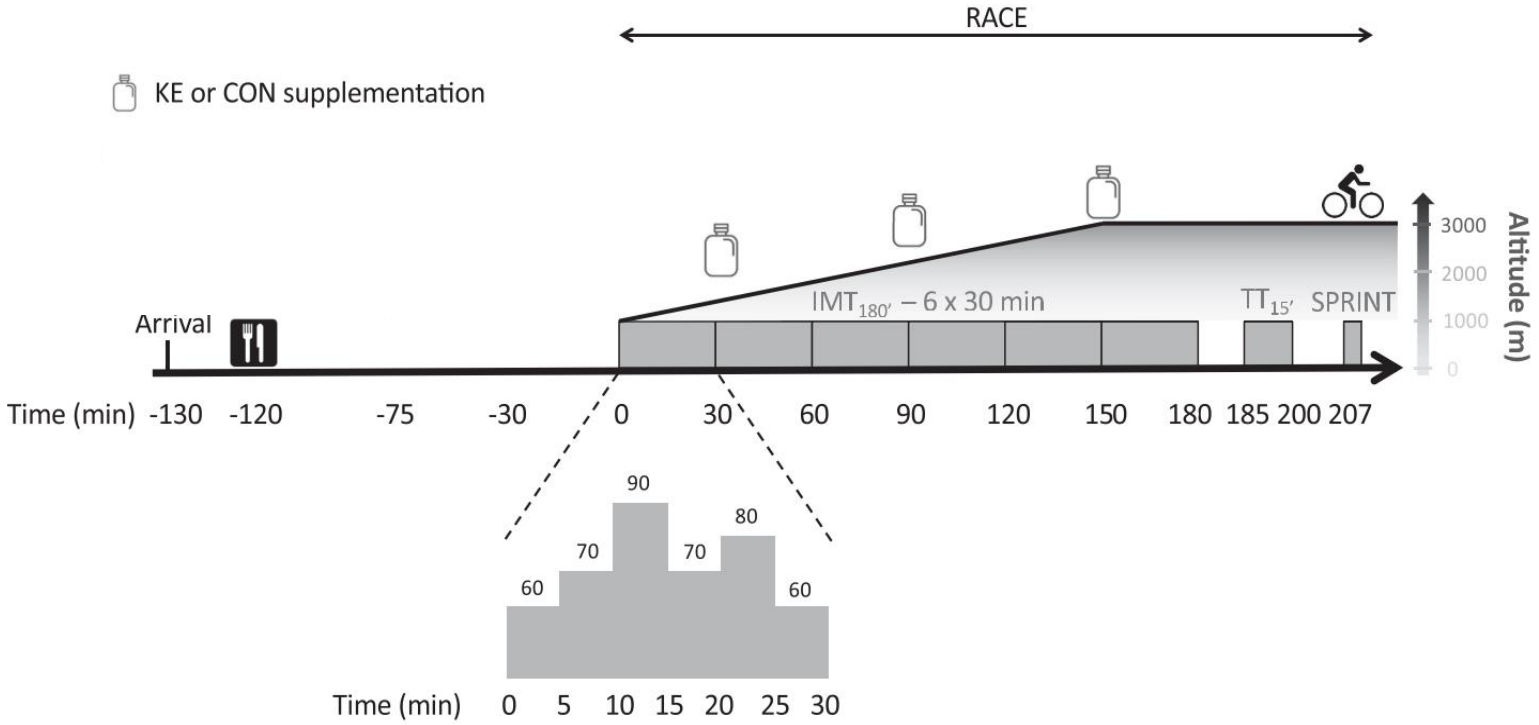
8 min TT
(WorldTour cyclists)



Ramos-Campo et al., IJSNEM (2023)

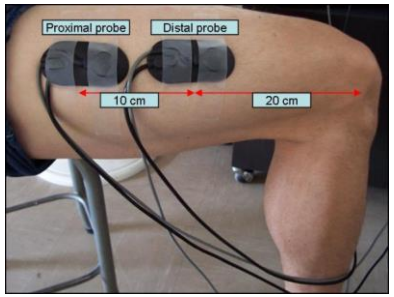
Effect during cycling in hypoxia?

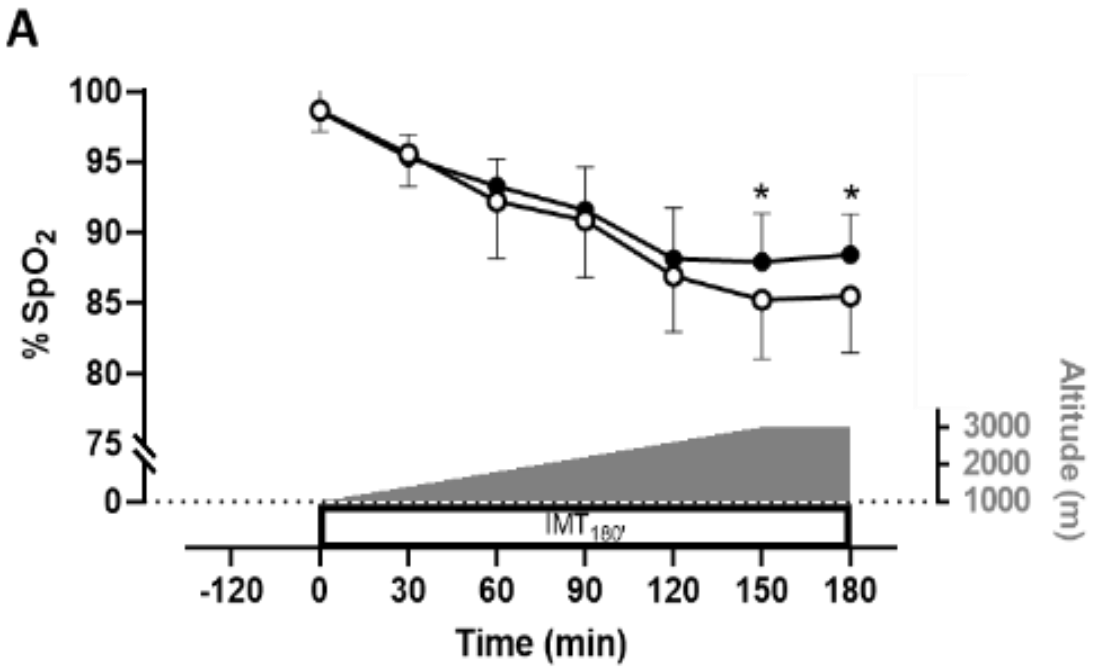


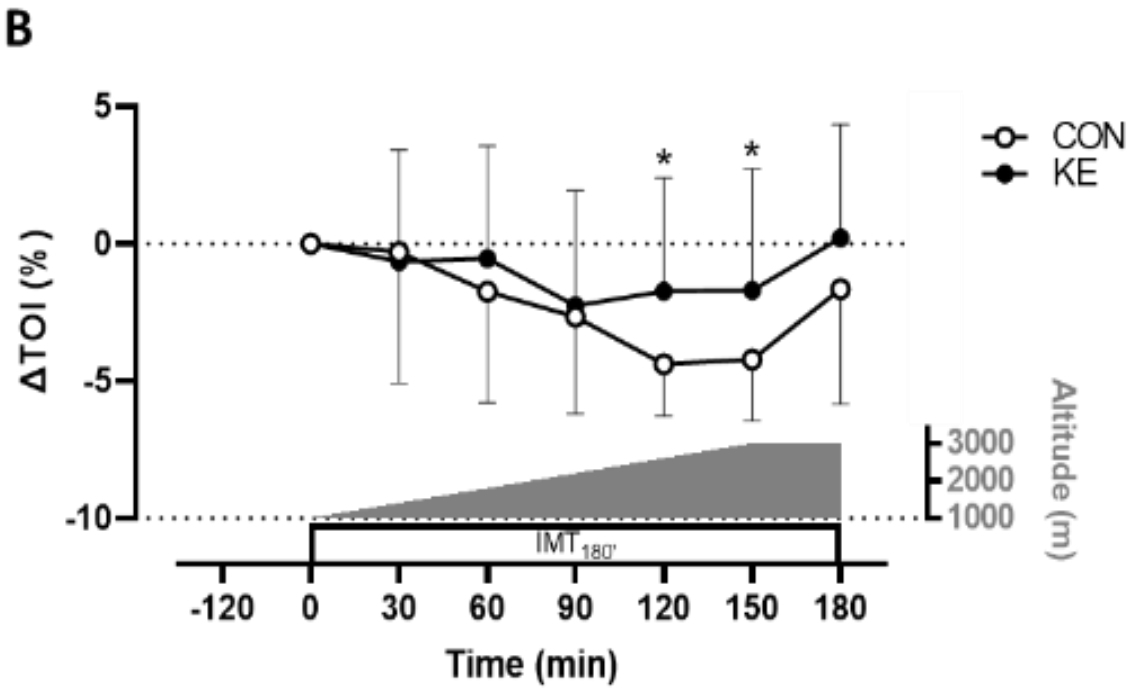


Poffé et al., *AJP – Reg Integr Comp* (2021)

KE attenuates oxygen desaturation during submax exercise

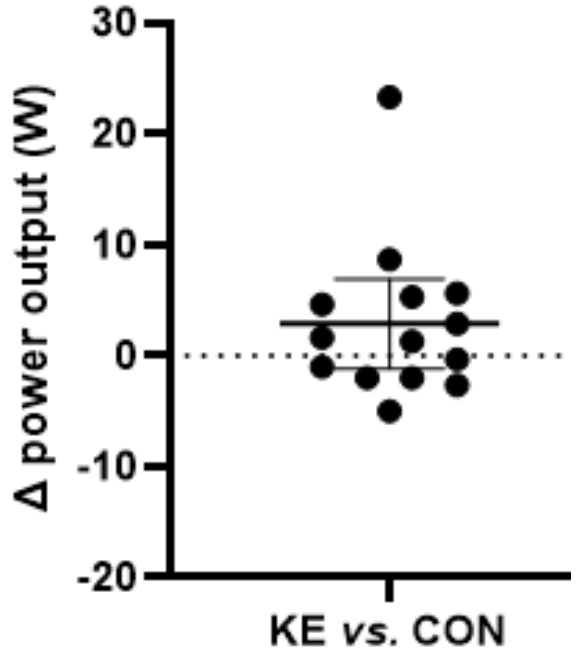






But does not improve performance

15 min TT



Beneficial effect on high-altitude sickness?

Acute Mountain Sickness
(AMS)

2500m : ~25% of individuals

4000m: ~50% of individuals

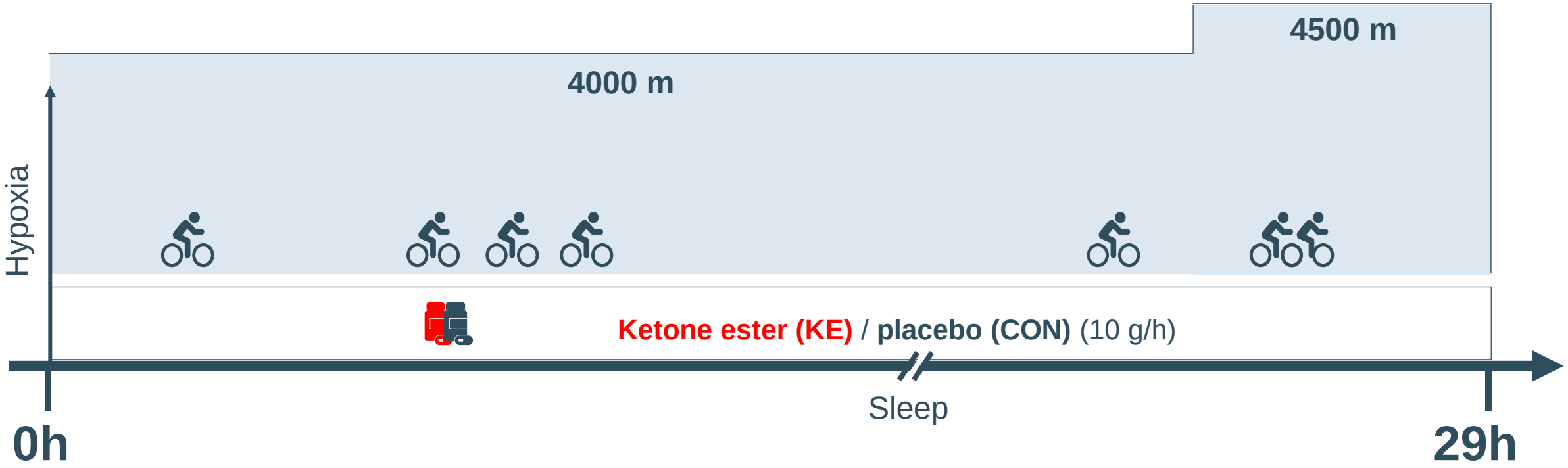
Headache

Nausea

Dizziness

Fatigue

n = 14
18-35 years old, male
Cross-over design

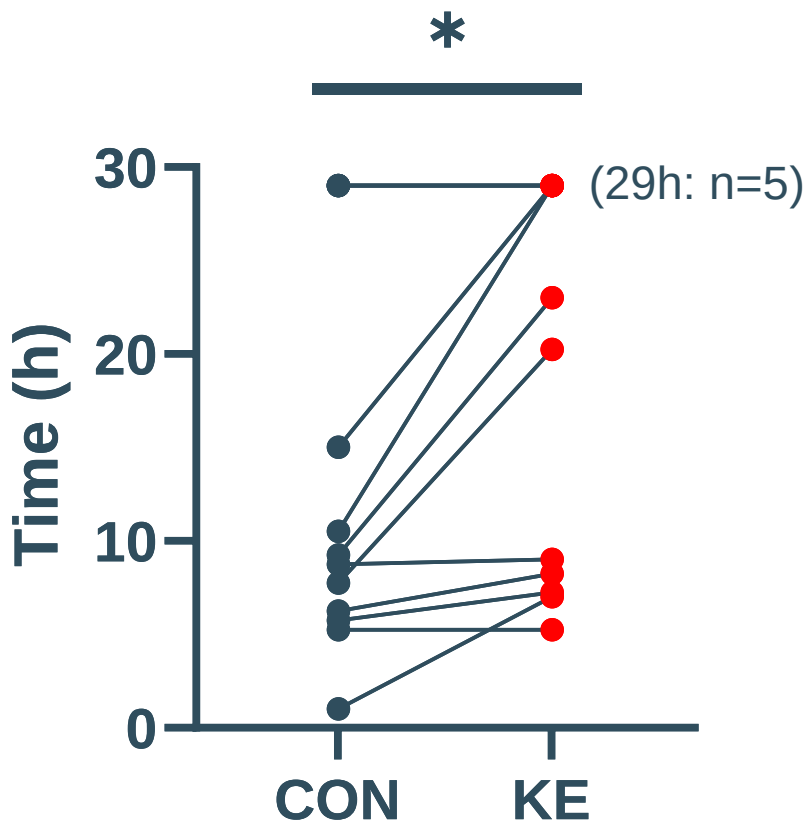


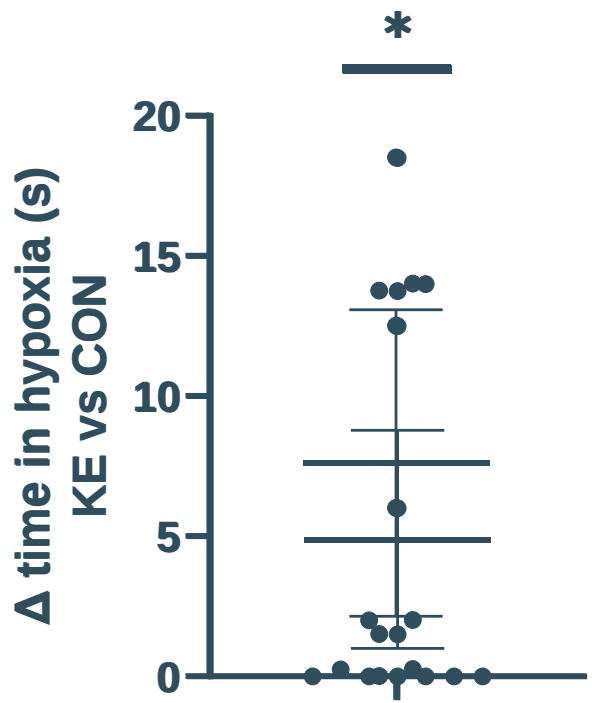
Stalmans et al., *medRxiv* (2023)

KE increases hypoxic tolerance

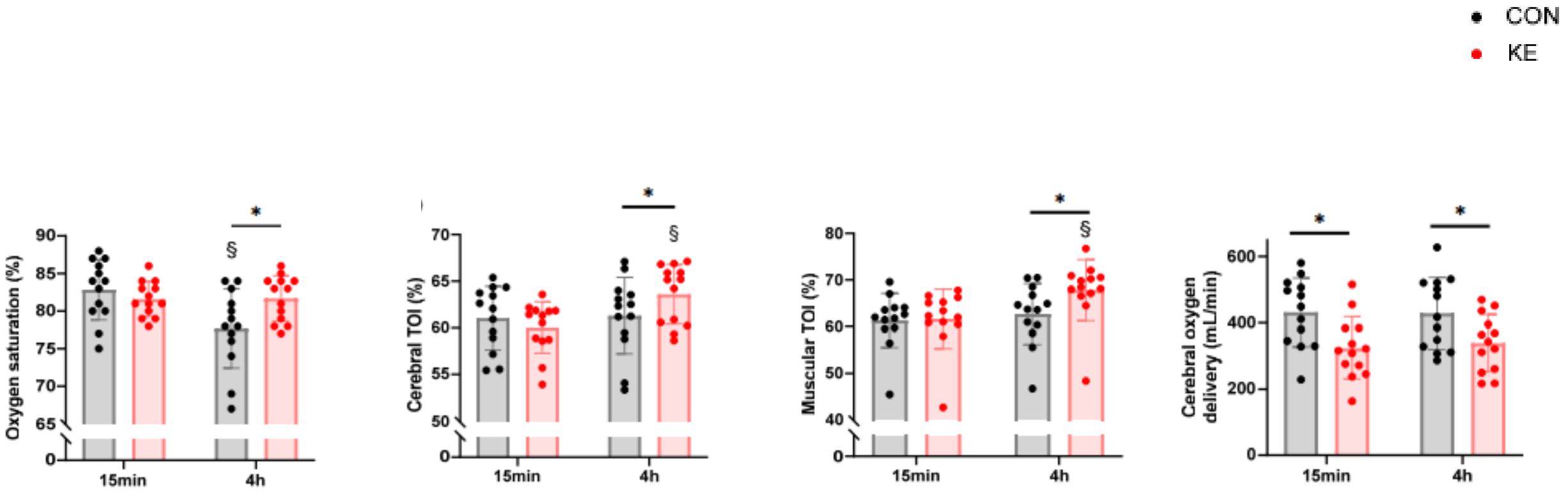
All participants: **+32%**

AMS sensitive participants: **+99%**





KE attenuates arterial, cerebral and SkM oxygen desaturation

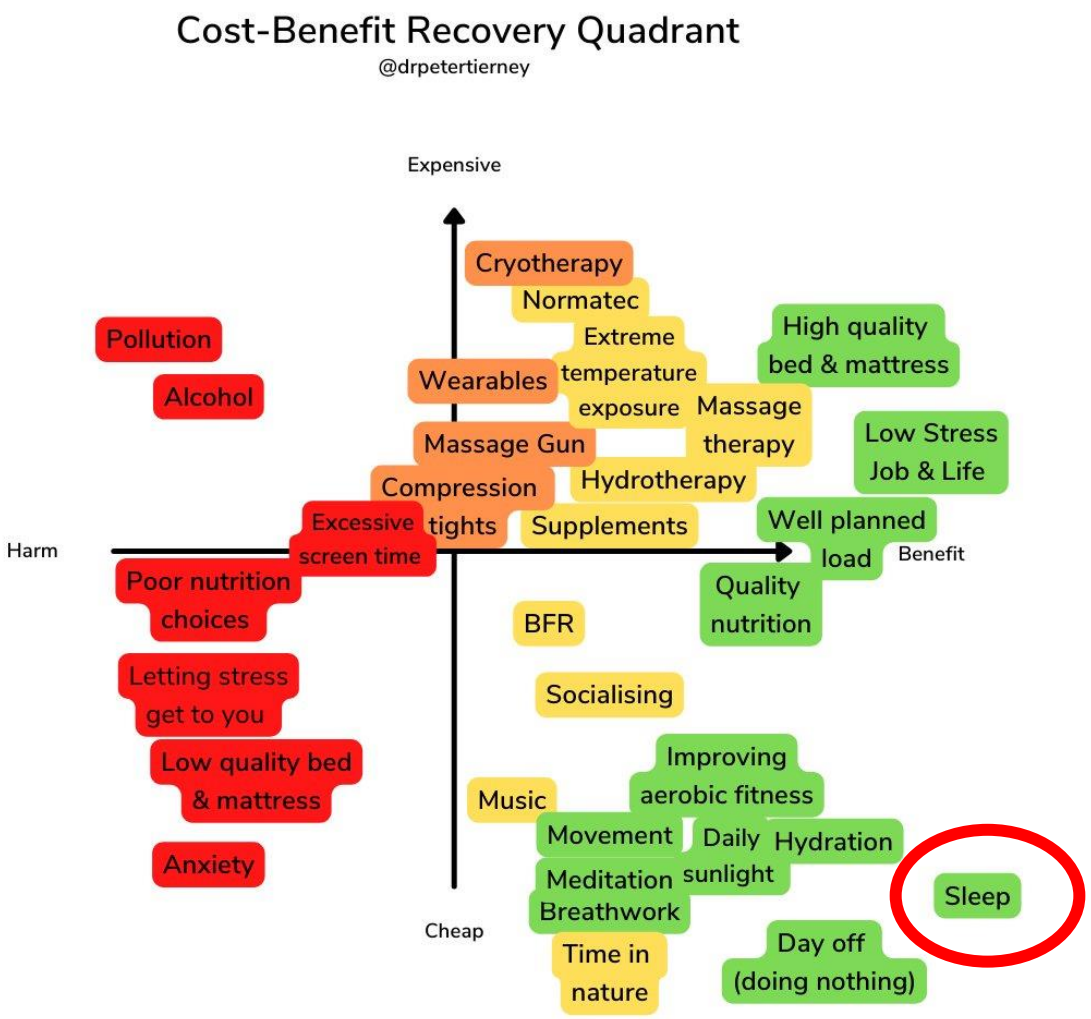


How to use ketones to improve performance?

During exercise
to improve
endurance exercise performance

After exercise
to improve
training adaptation and recovery

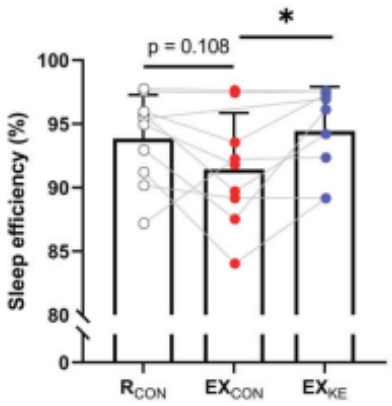
Sleep as a central aspect of exercise recovery

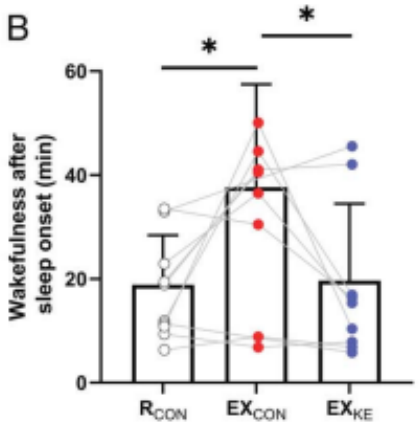


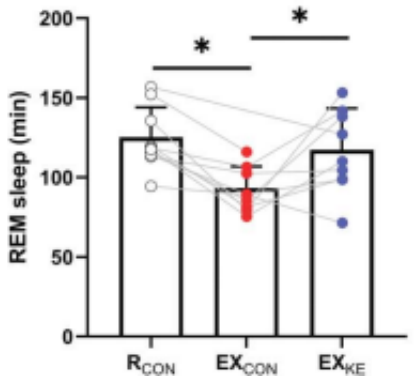
Sleep is disturbed by

- → Intensified training period
- → Late evening exercise
- → High altitude (>1600m)

Ketone ester: more sleep, less awakenings







Ketone ester as a recovery drink during a ‘Tour de France’

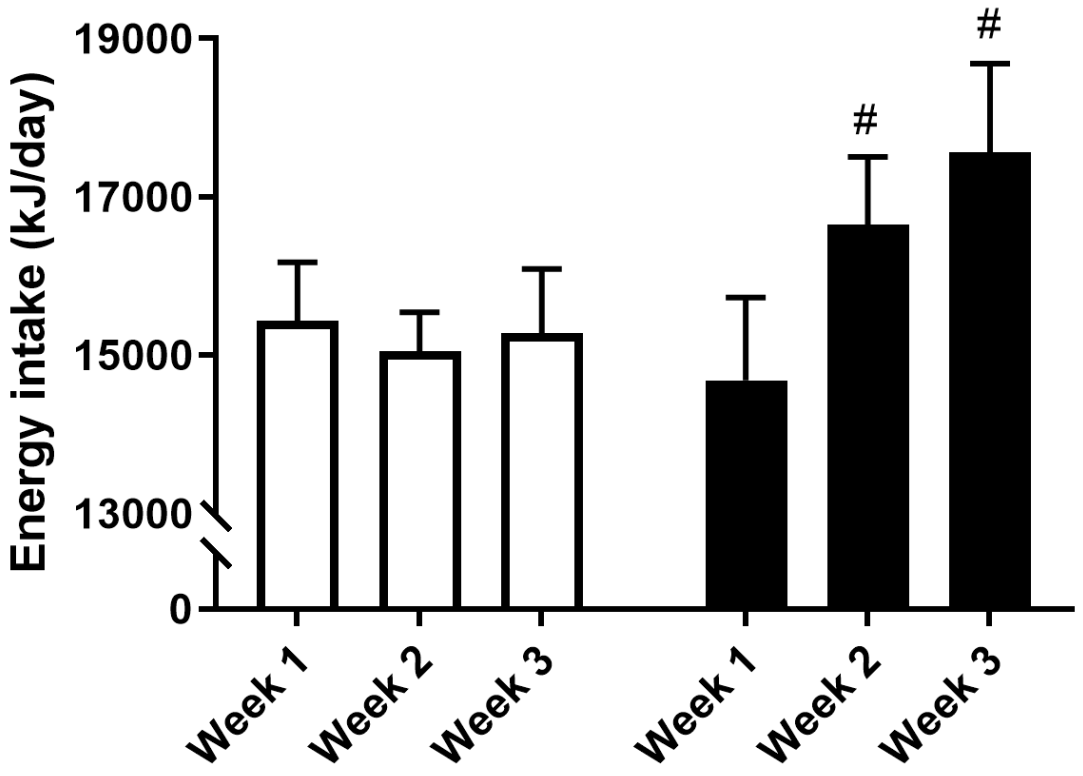
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Week 1	AM	70 min **IMT** 100/55%	Rest	30 min **HIIT**	70 min **IMT** 100/55%	30 min **HIIT**	70 min **IMT** 100/55%	***Test Wk1***
	PM	Rest	Rest	60 min **ET** 70%	60 min **ET** 70%	60 min **ET** 70%	60 min **ET** 70%	60 min **ET** 77.5%
Week 2	AM	70 min **IMT** 100/65%	Rest	30 min **HIIT**	70 min **IMT** 105/65%	30 min **HIIT**	70 min **IMT** 110/80%	***Test Wk2***
	PM	Rest	Rest	90 min **ET** 77.5%	60 min **ET** 85%	90 min **ET** 80%	60 min **ET** 90%	90 min **ET** 85%
Week 3	AM	120 min **HIIT & ET** 85%	Rest	70 min **IMT** 110/80%	120 min **ET-TT$_{30min}$** 85% - 30’ all-out	70 min **IMT** 110/80%	70 min **IMT** 110/85%	***Posttest Test Wk3***
	PM	Rest	Rest	90 min **ET** 90%	Rest	120 min **ET** 95%	150 min **HIIT & ET** 92.5%	Rest

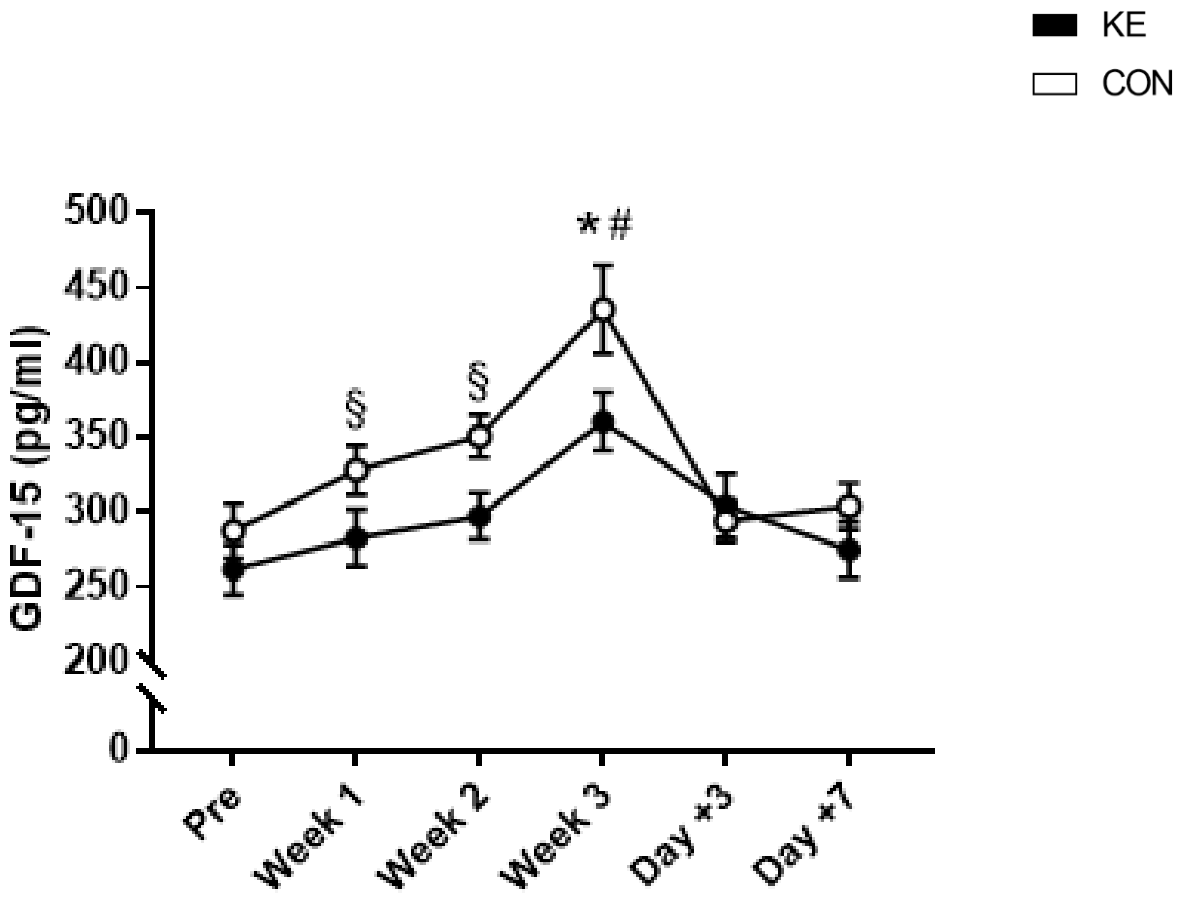
+ 25g KE/PL doses

2-3 * daily

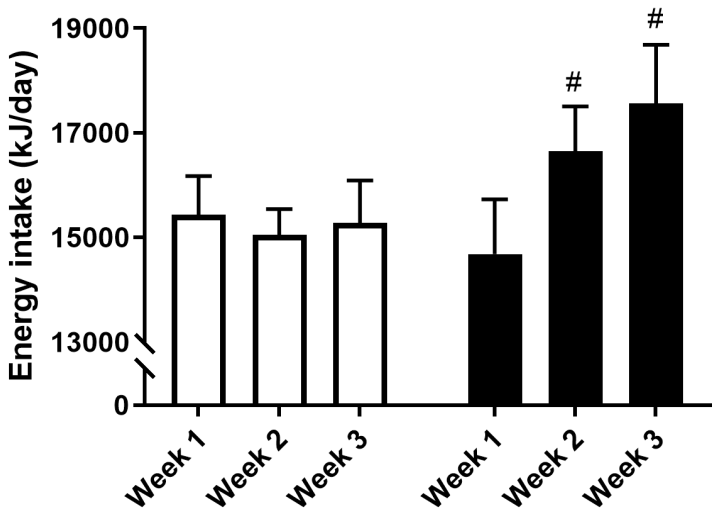
Poffé et al., *J Physiol* (2019)

KE stimulated spontaneous energy intake

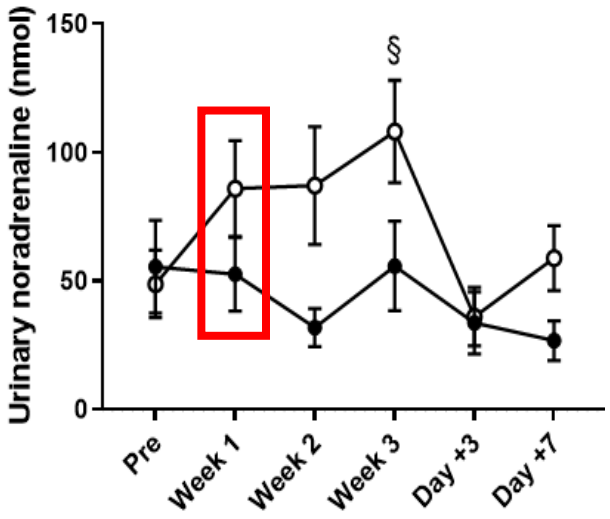




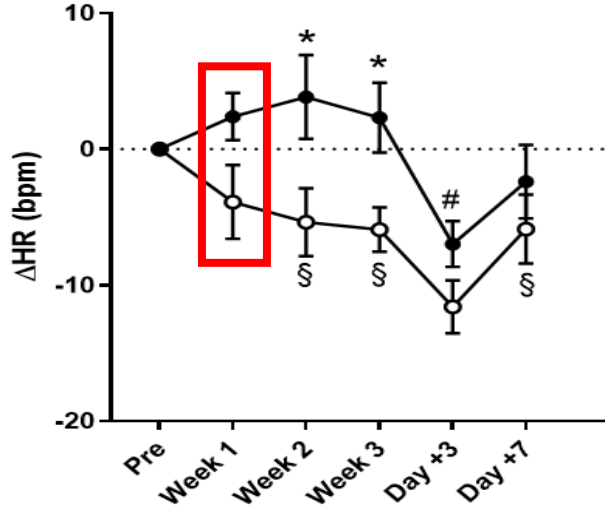
KE suppressed heart rate drop



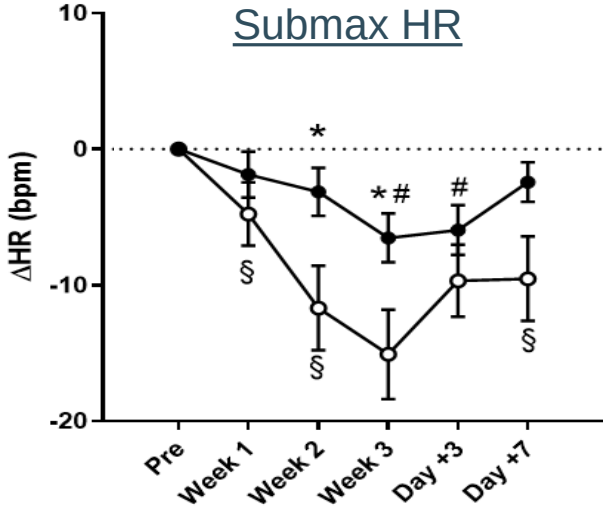
Nocturnal noradrenalin excretion



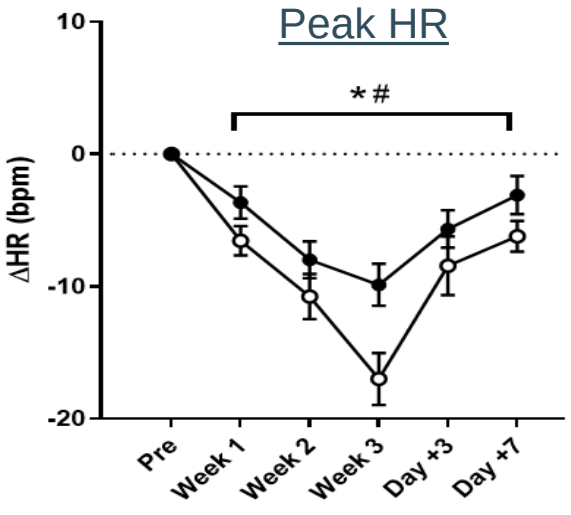
Resting HR



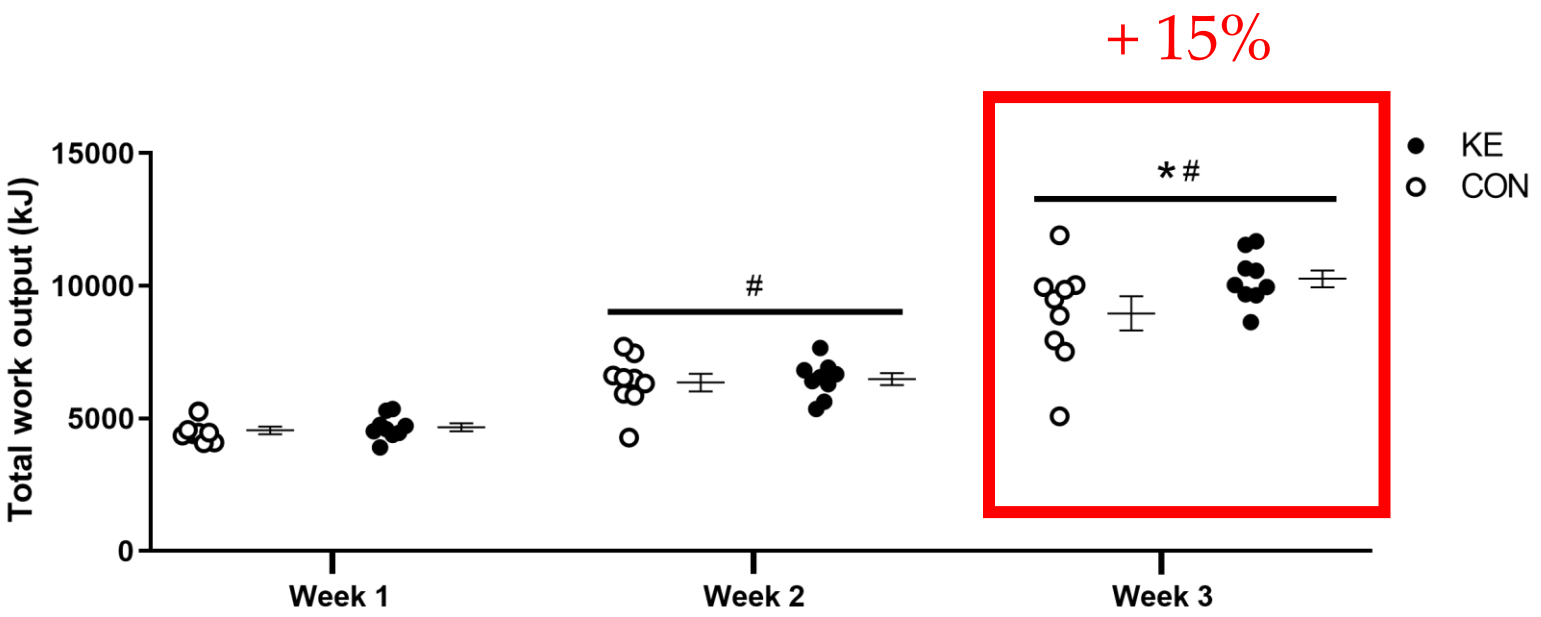
Submax HR

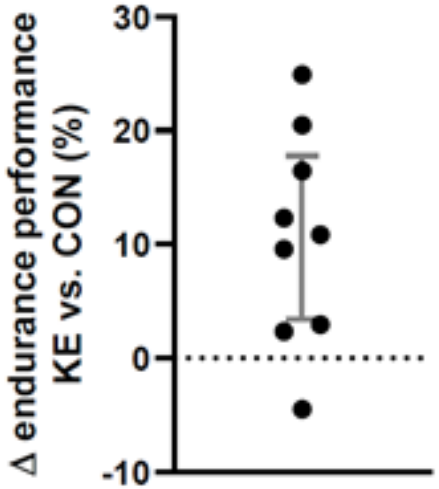


Peak HR



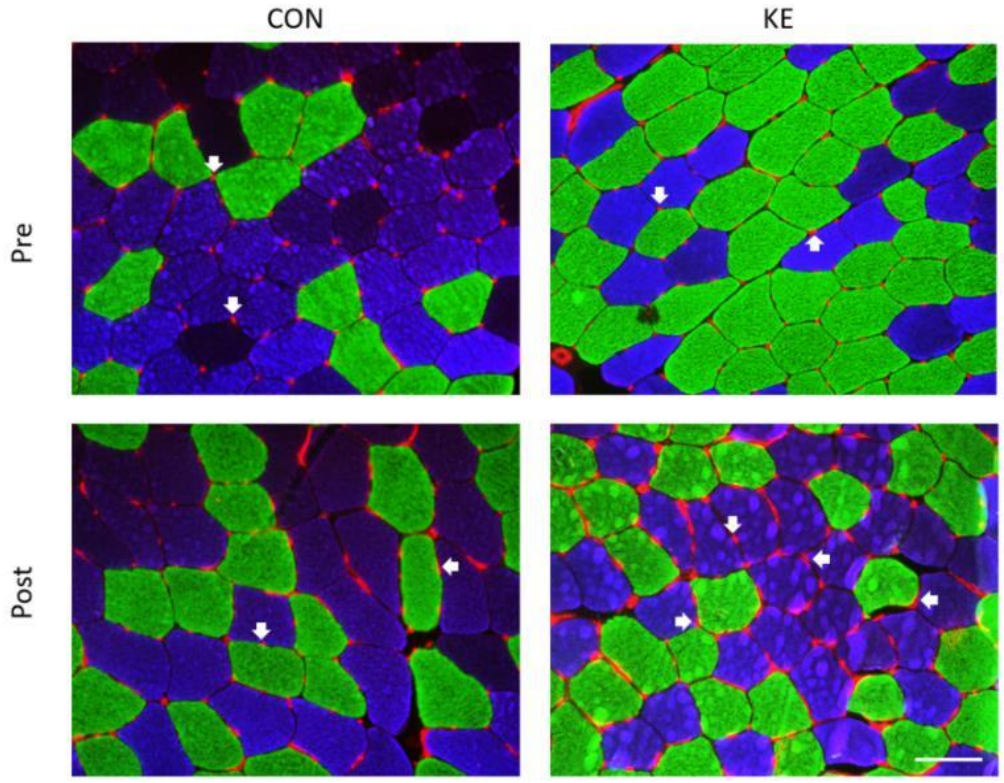
KE increased sustained training workload

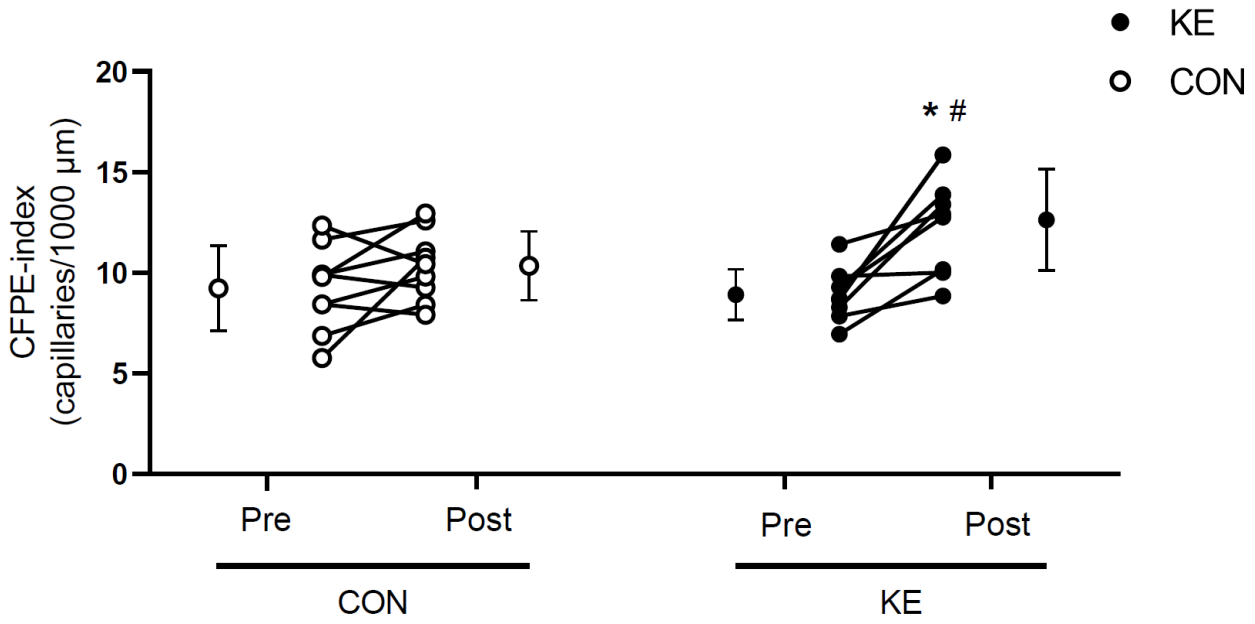


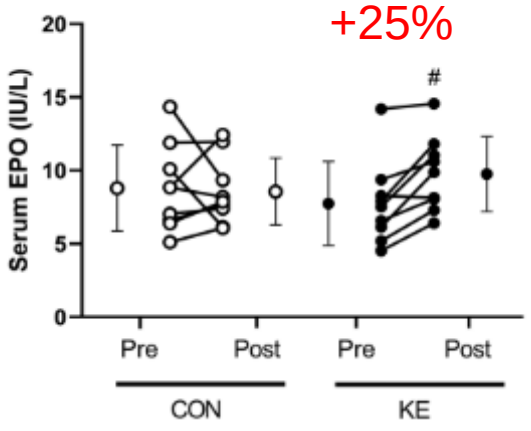


- Training workload
- 30 min TT
- 120 min training + 30 min TT

KE increased skeletal muscle capillarization







- Muscle angiogenesis
- Muscle oxidative capacity
- Hematopoiesis

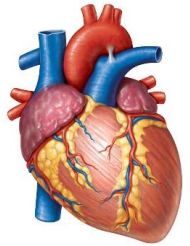
Poffé et al., *J Physiol* (2023)

Safety

8 weeks – 50-75g KE/day

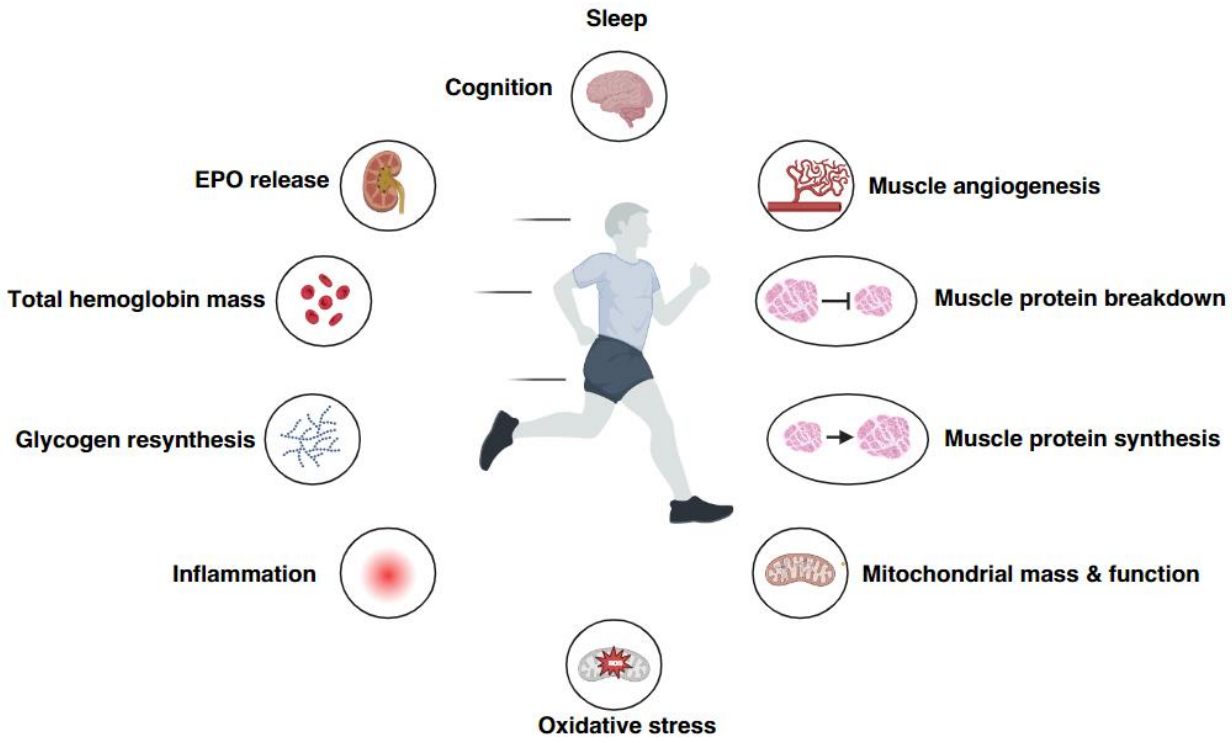
Echocardiography at rest
& during exercise

(Prof. Guido Claessen)



Stroke volume
Cardiac output
Left ventricular global longitudinal strain
Arrhythmias

Conclusion



~20-25g KE post-exercise & pre sleep

- Grand tours
- Training camps
- ↓ REM sleep
- (High-altitude)

Research Foundation Flanders
Opening new horizons

Exercise Physiology Research Group

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Drs. Wout Lauriks
Drs. Louise Engelbrecht

Prof. Katrien Koppo
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