Is Zone 2 the optimal intensity for inducing mitochondrial adaptation?

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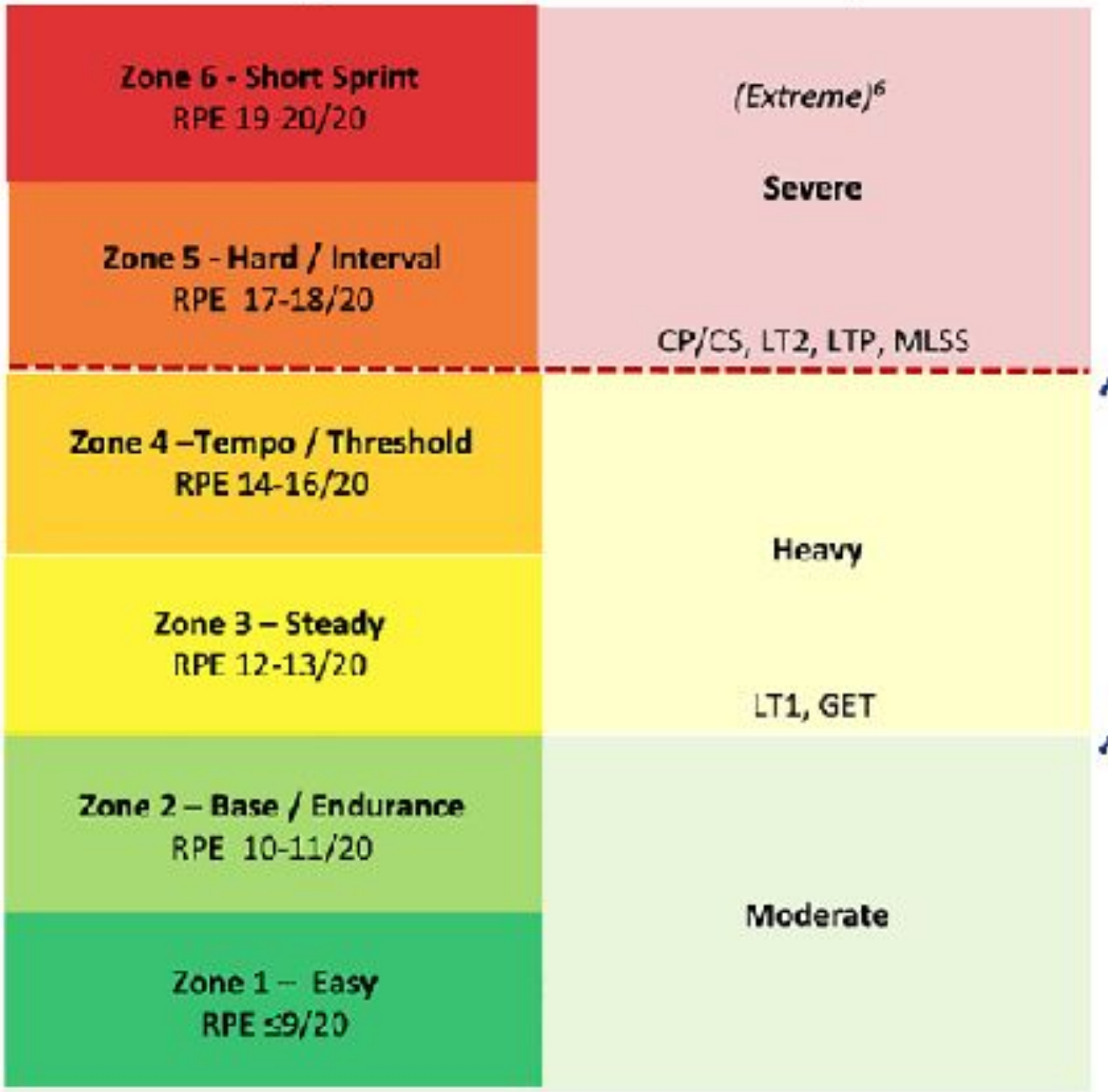


Zone 2 – Top of the moderate intensity domain

Characterized by high reliance on Fatty Acid Oxidation, low levels of AMP and ADP, low rates of glycogen and PCr (phosphocreatine) breakdown

Coates et al. (2023) *Sports Med* 53: 85

Theory – Do claims that Zone 2 is optimal for mitochondrial adaptation make sense?

1. Metabolic disturbance (AMP and ADP) and glycogen breakdown

Metabolic disturbance and glycogen breakdown

- As Exercise intently increases so too does the rate of muscle glycogen breakdown

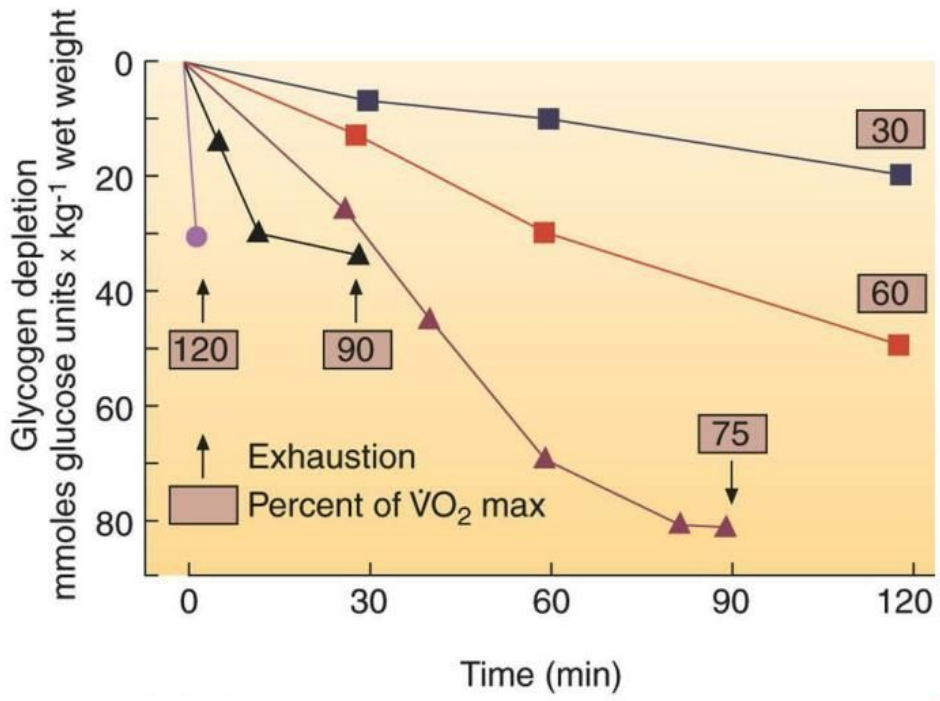
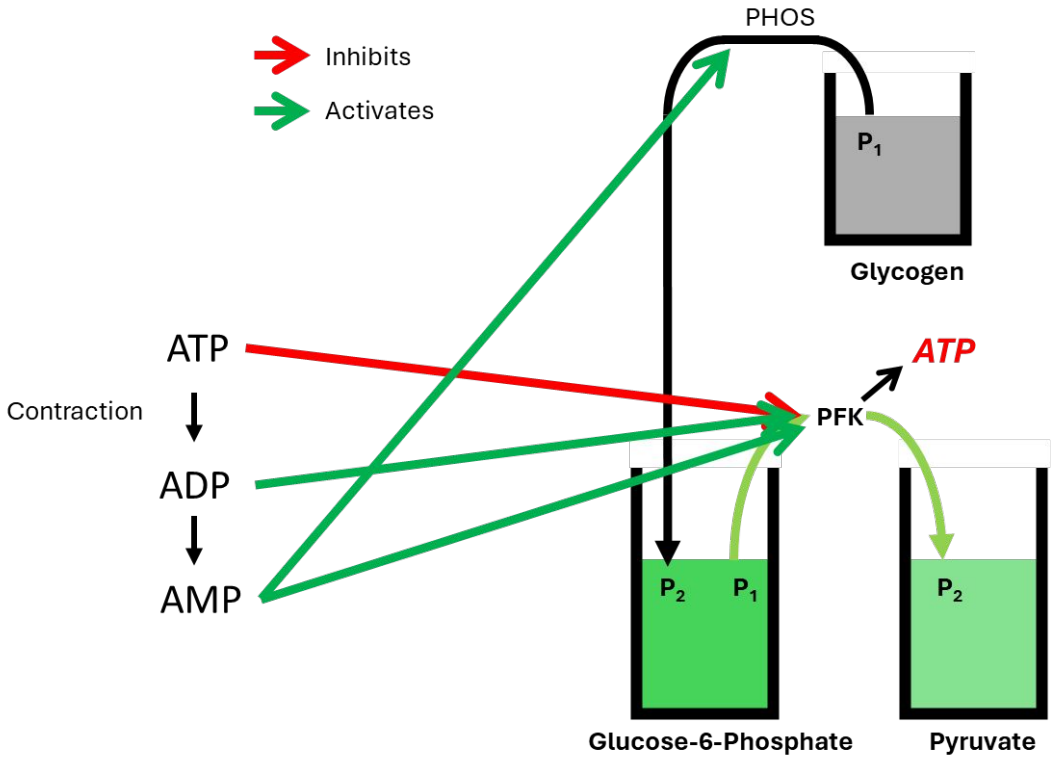


Figure 5.13

Saltin and Karlsson (1971)

Metabolic disturbance and glycogen breakdown

- As exercise intensity increases AMP and ADP accumulate (biproducts of ATP breakdown)
- AMP and ADP activate enzymes involved in glycogen breakdown and glycolysis thereby increasing glycogen breakdown and carbohydrate metabolism



Theory – Do claims that Zone 2 is optimal for mitochondrial adaptation make sense?

1. Metabolic disturbance (AMP and ADP) and glycogen breakdown

2. Metabolic disturbance (AMP and ADP) and mitochondrial biogenesis

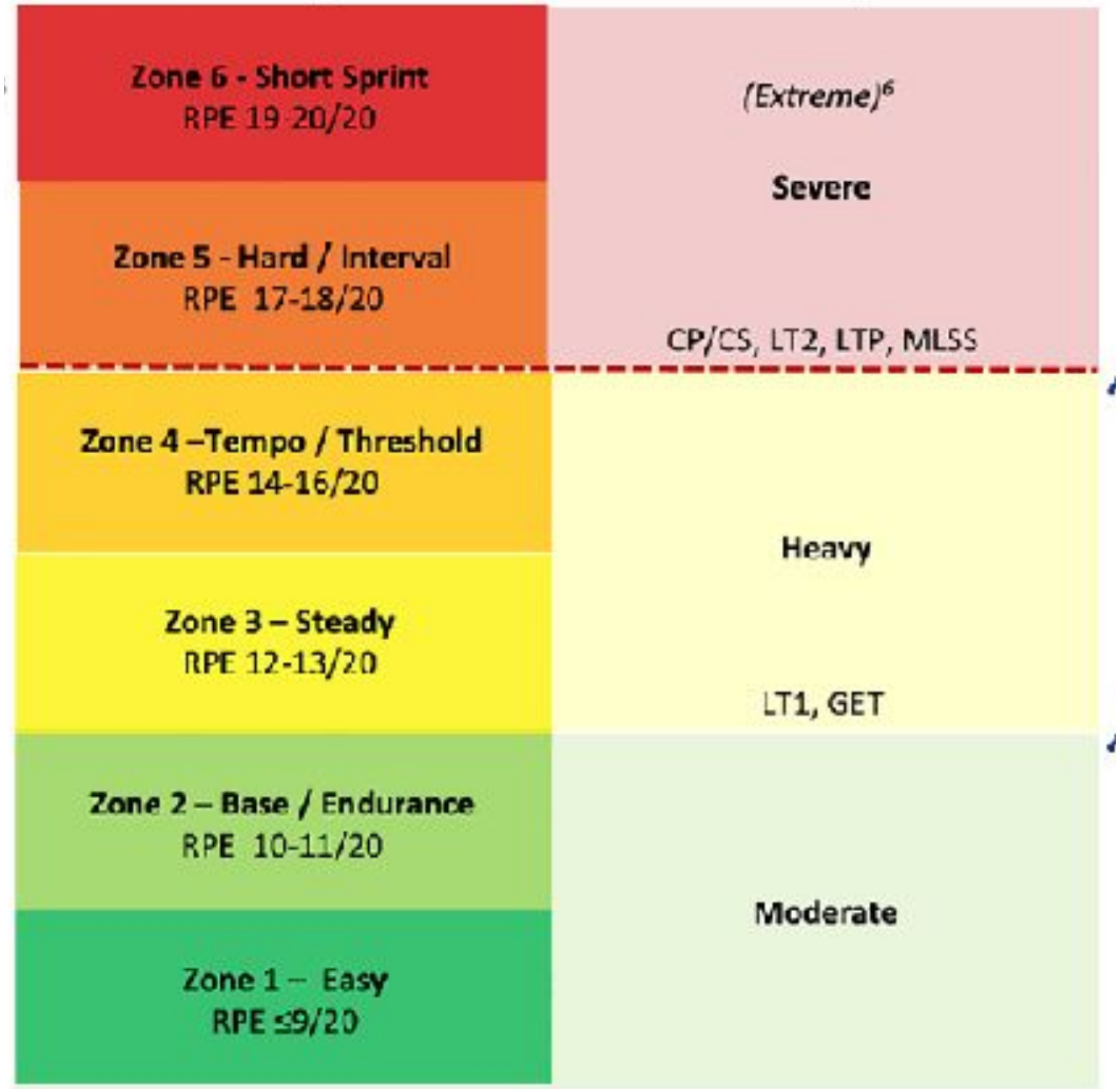
Metabolic disturbance and mitochondrial biogenesis

- As exercise intensity increases AMP and ADP accumulate (biproducts of ATP breakdown)

- AMP and ADP activate PGC-1α, the master regulator of mitochondrial biogenesis

Reviewed in Gurd (2022) *Sem Cell Dev Bio* 143: 17-27

Protocols that induce greater metabolic disturbances (AMP and ADP) should result in greater mitochondrial biogenesis (mitochondrial adaptation)!



Increasing Intensity Increases:
Metabolic Disturbance (AMP and ADP)
Glycogen Metabolism
Mitochondrial Biogenesis

Based on this theory Zone 2 should be the WORST intensity for inducing mitochondrial adaptations!

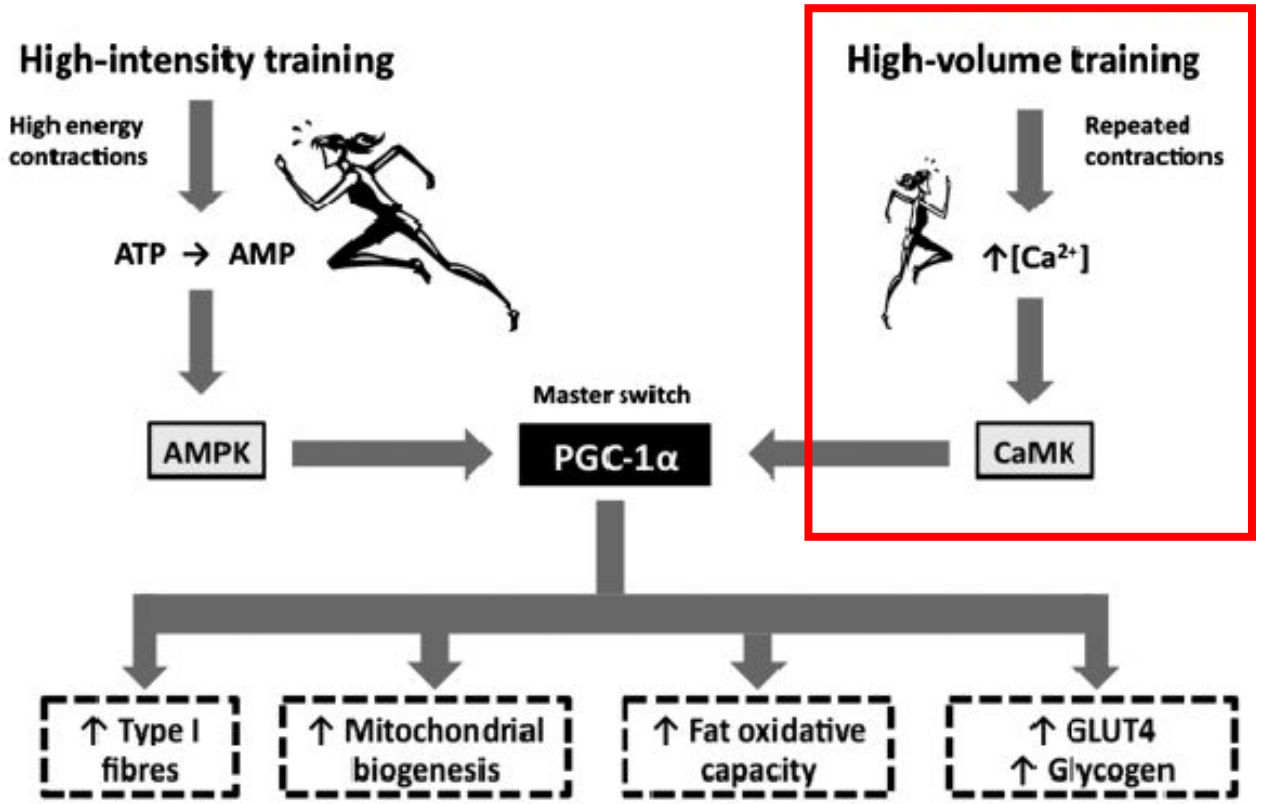
Theory – Do claims that Zone 2 is optimal for mitochondrial adaptation make sense?

1. Metabolic disturbance (AMP and ADP) and glycogen breakdown

2. Metabolic disturbance (AMP and ADP) and mitochondrial biogenesis

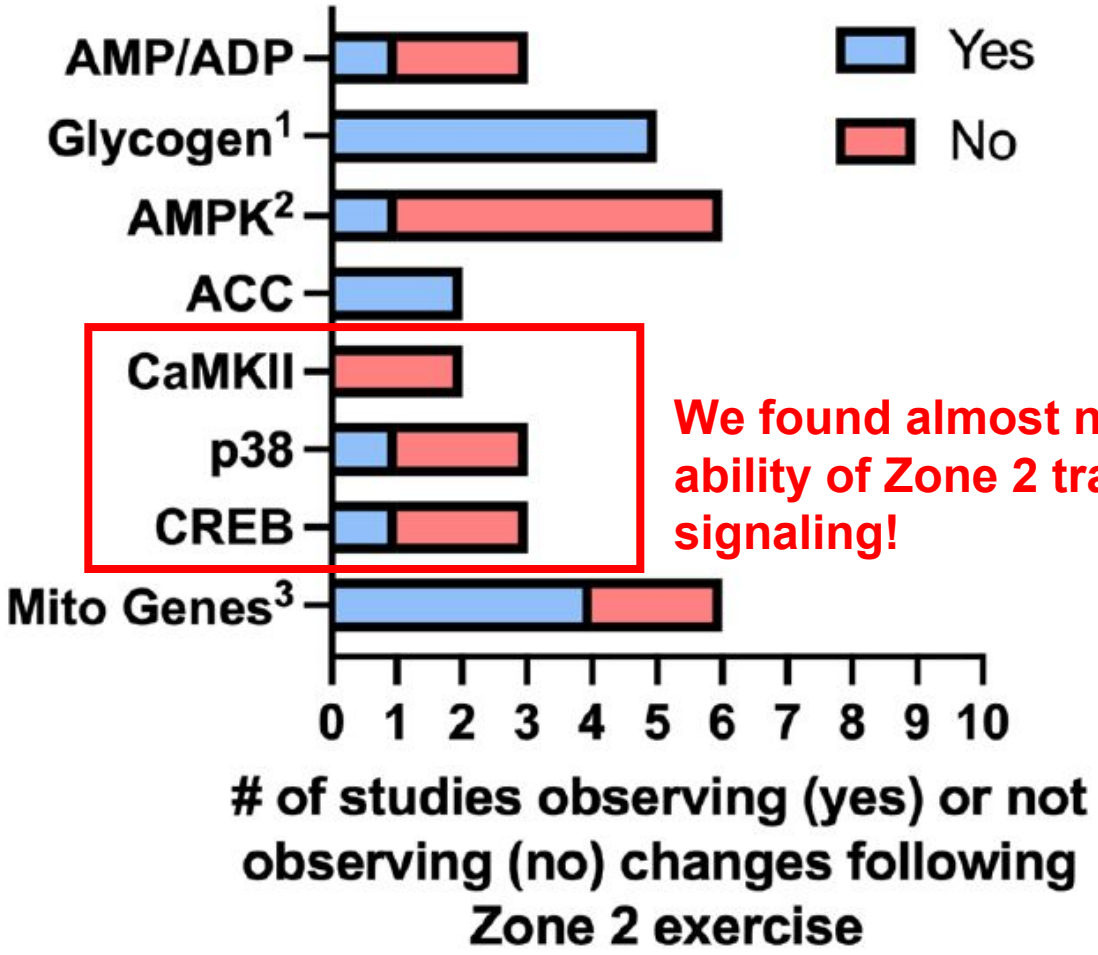
3. Maybe Zone 2 induces mitochondrial biogenesis through a different (calcium mediated) pathway?

Does Zone 2 act through a calcium mediated pathway



Zone 2 mediated Signalling?

Laursen (2010) *Scand J Med Sci Sports* 20: 1



We found almost no data supporting the ability of Zone 2 training to activate calcium signaling!

Storoschuk et al. (2025) *Sprts Med* (ePub)

Zone 2 DOES NOT appear to act through a different (calcium mediated) pathway!

Theory – Do claims that Zone 2 is optimal for mitochondrial adaptation make sense?

Protocols that induce greater metabolic disturbances (AMP and ADP) should result in greater mitochondrial biogenesis (mitochondrial adaptation)!

Zone 2 DOES NOT appear to act through a different (calcium mediated) pathway!

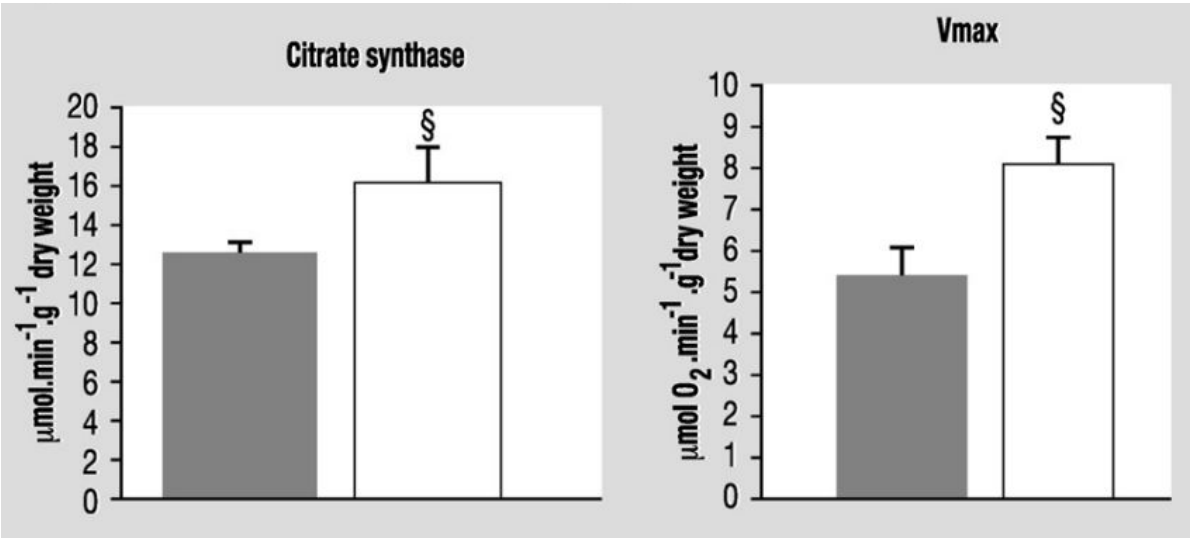
Theory does not support Zone 2 being the optimal intensity for inducing mitochondrial adaptations

Practice – What does evidence from training study say?

Few studies have explicitly investigated the impact of Zone 2 training on mitochondrial outcomes, and the available evidence is mixed… but:

1. Zone 2 training can induce mitochondrial adaptations

Zone 2 training can induce mitochondrial adaptations



- Type 2 Diabetics
- 10 Weeks of training at Lipid Oxidation Max (~Zone 2)
- Citrate Syntase (mitochondrial content) and Vmax (mitochondrial function) both increased

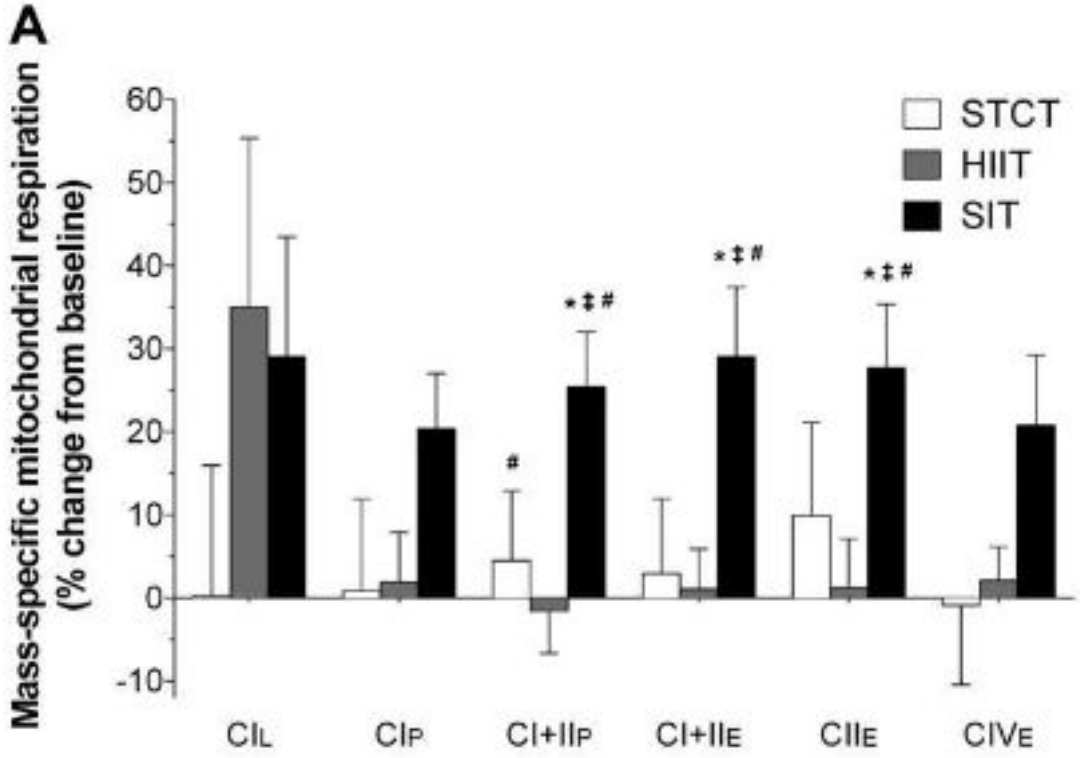
Bordenave et al. (2008) *Diabetes Metab* 34: 627

Practice – What does evidence from training study say?

Few studies have explicitly investigated the impact of Zone 2 training on mitochondrial outcomes, and the available evidence is mixed…

1. Zone 2 training can induce mitochondrial adaptations
2. But it doesn't always

Zone 2 training can induce mitochondrial adaptations… but it doesn't always



- Healthy men
- 4 weeks of Zone 2 (STCT), HIIT, or SIT training
- Only SIT improved mitochondrial function

Granata et al. (2016) *FASEB J* 30: 959

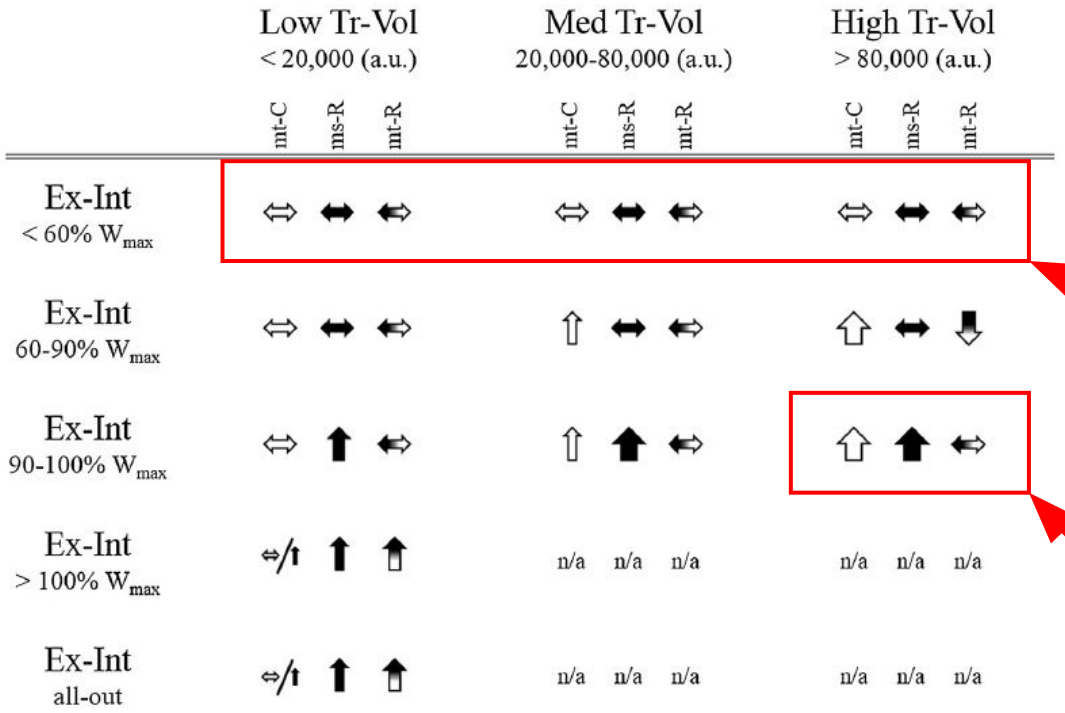
Practice – What does evidence from training study say?

Few studies have explicitly investigated the impact of Zone 2 training on mitochondrial outcomes, and the available evidence is mixed…

1. Zone 2 training can induce mitochondrial adaptations
2. But it doesn't always

3. Zone 2 is not optimal for inducing mitochondrial adaptation

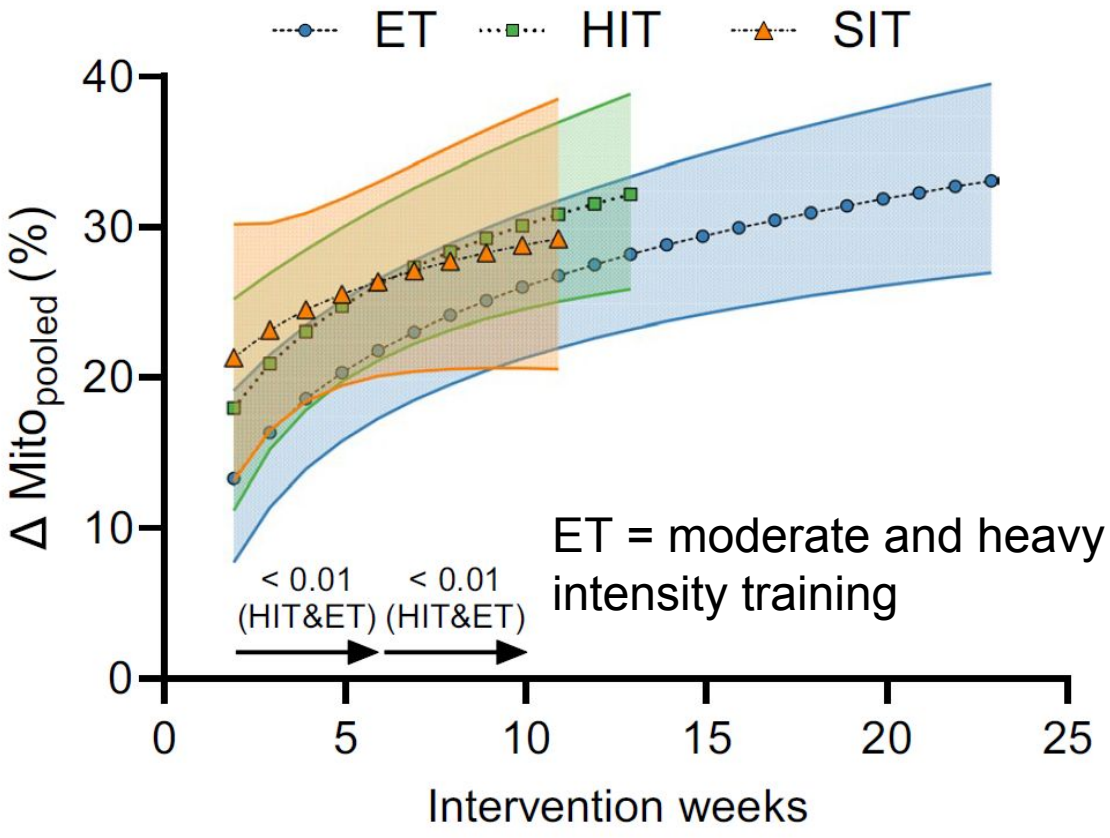
Zone 2 is not optimal for inducing mitochondrial adaptation



- Meta-Analysis
- Low intensities expected to induce minimal adaptation
- High intensity, high volume best for improving mitochondrial content (mt-C) and function (ms-R)

Granata et al. (2018) *Sprts Med* 48: 1809

Zone 2 is not optimal for inducing mitochondrial adaptation

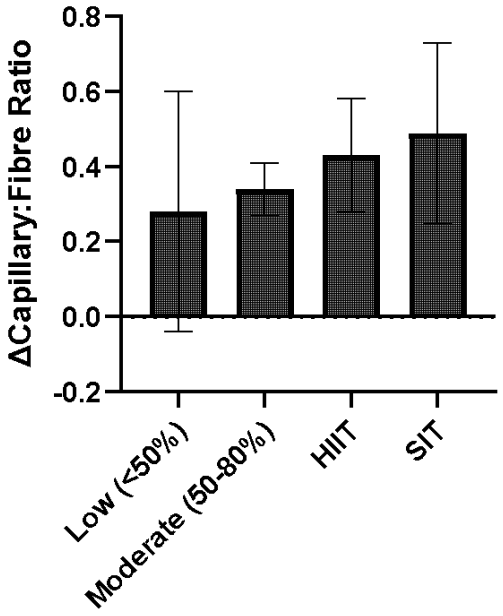


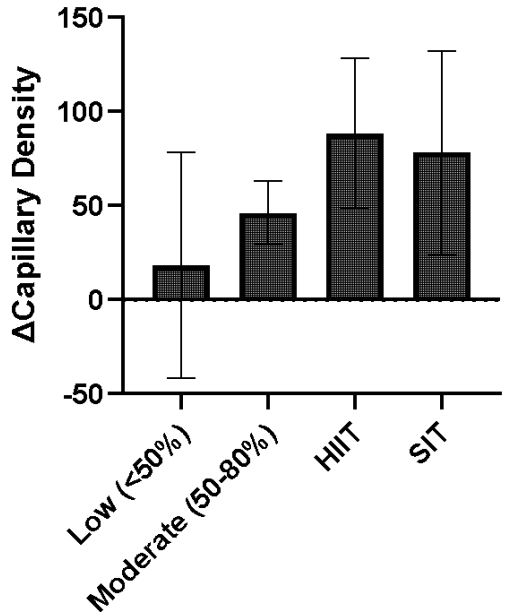
- Meta-Analysis
- Endurance training (ET) including BOTH Zone 2 and higher intensity continuous training induces smallest mitochondrial adaptations

Molmen et al. (2024) *Sprts Med 55*: 115

Zone 2 is NOT optimal for inducing mitochondrial adaptation!

Zone 2 is not optimal for inducing CAPILLARY adaptation

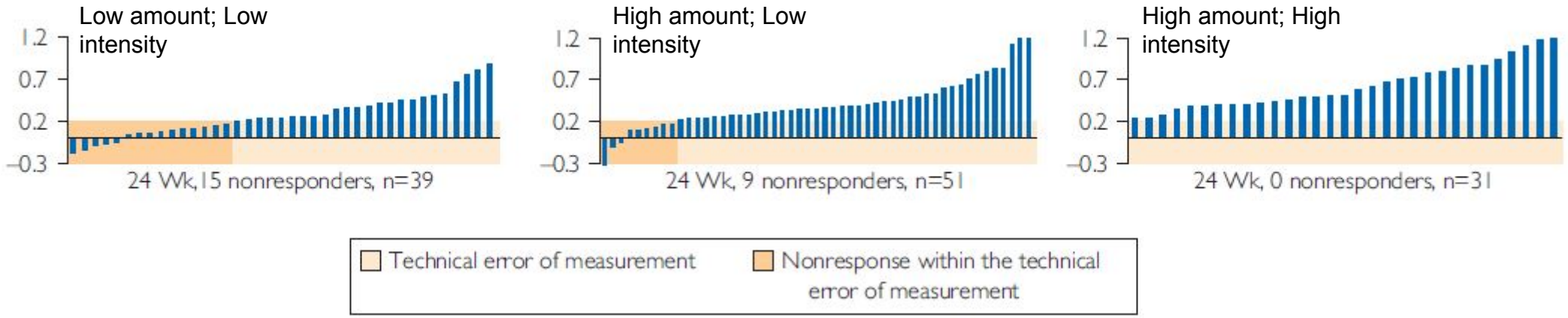




- Meta-Analysis
- Low and Moderate (Zone 2 and higher) intensities induce smaller improvements in capillary density than higher intensity training

Liu et al. (2022) *Med Sci Sprt Ex* 54: 1714

Zone 2 is not optimal for inducing adaptation in FITNESS

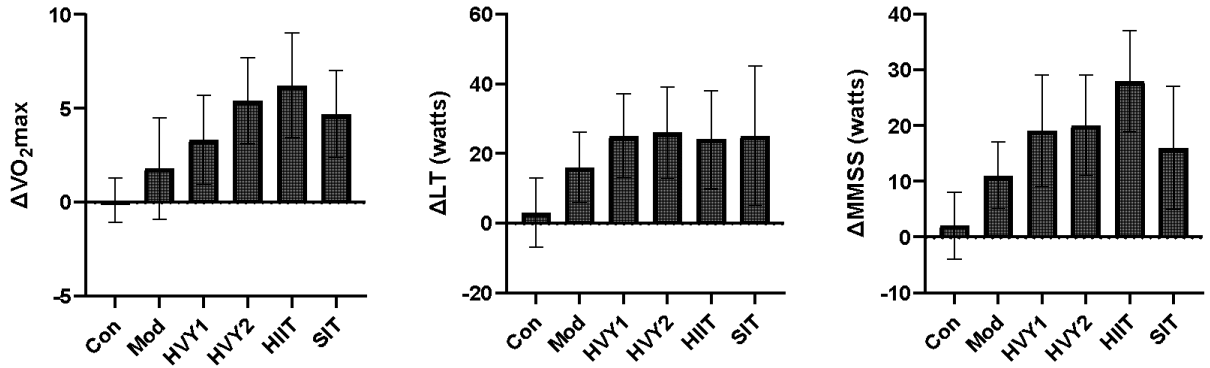


- Sedentary, middle aged, obese adults
- 24 weeks of training

- Vigorous training induced greater improvements in VO2max than moderate

Ross et al. (2015) *Mayo Clin Proc* 90: 1506

Zone 2 is not optimal for inducing adaptation in FITNESS AND PERFORMANCE



- Young healthy adults
- 6 weeks of training
- Moderate (Zone 2) training induced smallest improvements in VO2max, LT, and MLSS

Inglis et al. (2024) *Med Sci Sprt Ex* 56: 1307

Zone 2 is NOT optimal for inducing other training mediated adaptations!

Practice – What does evidence from training study say?

Few studies have explicitly investigated the impact of Zone 2 training on mitochondrial outcomes, and the available evidence is mixed…

Zone 2 training can but doesn't always induce mitochondrial adaptation

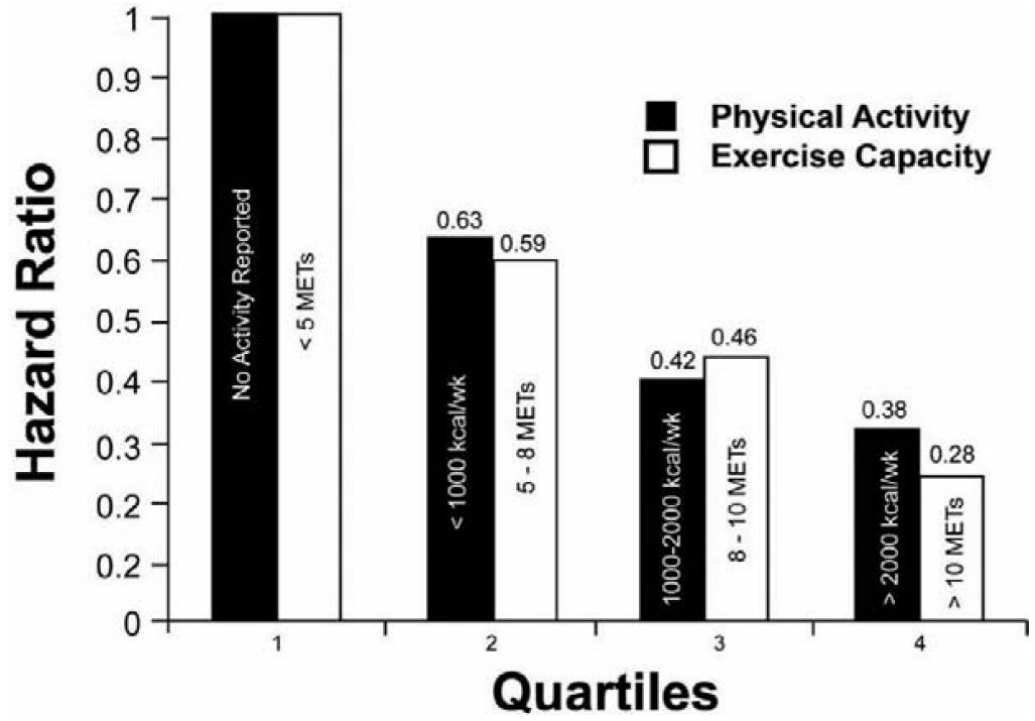
Zone 2 is NOT optimal for inducing mitochondrial adaptation!

Zone 2 is NOT optimal for inducing other training mediated adaptations!

Neither ***Theory*** nor ***Practice*** support Zone 2 as the optimal intensity for inducing mitochondrial adaptations

Anything (including Zone 2) is better than nothing...

Mortality Risk



- Prospective study examining predictive power of fitness and activity level
- Increases in both fitness and activity reduced risk of mortality (death)

Myers et al. (2024) *Am J Med* 117: 912

…but

Recommendations that the general population forgo higher intensity exercise in favour of Zone 2 appear to be largely based on unsubstantiated theory

If you are crunched for time and are trying to optimize fitness, performance, and/or health **Prioritize Intensity** over time in Zone 2!