

The Physiology of Pacing

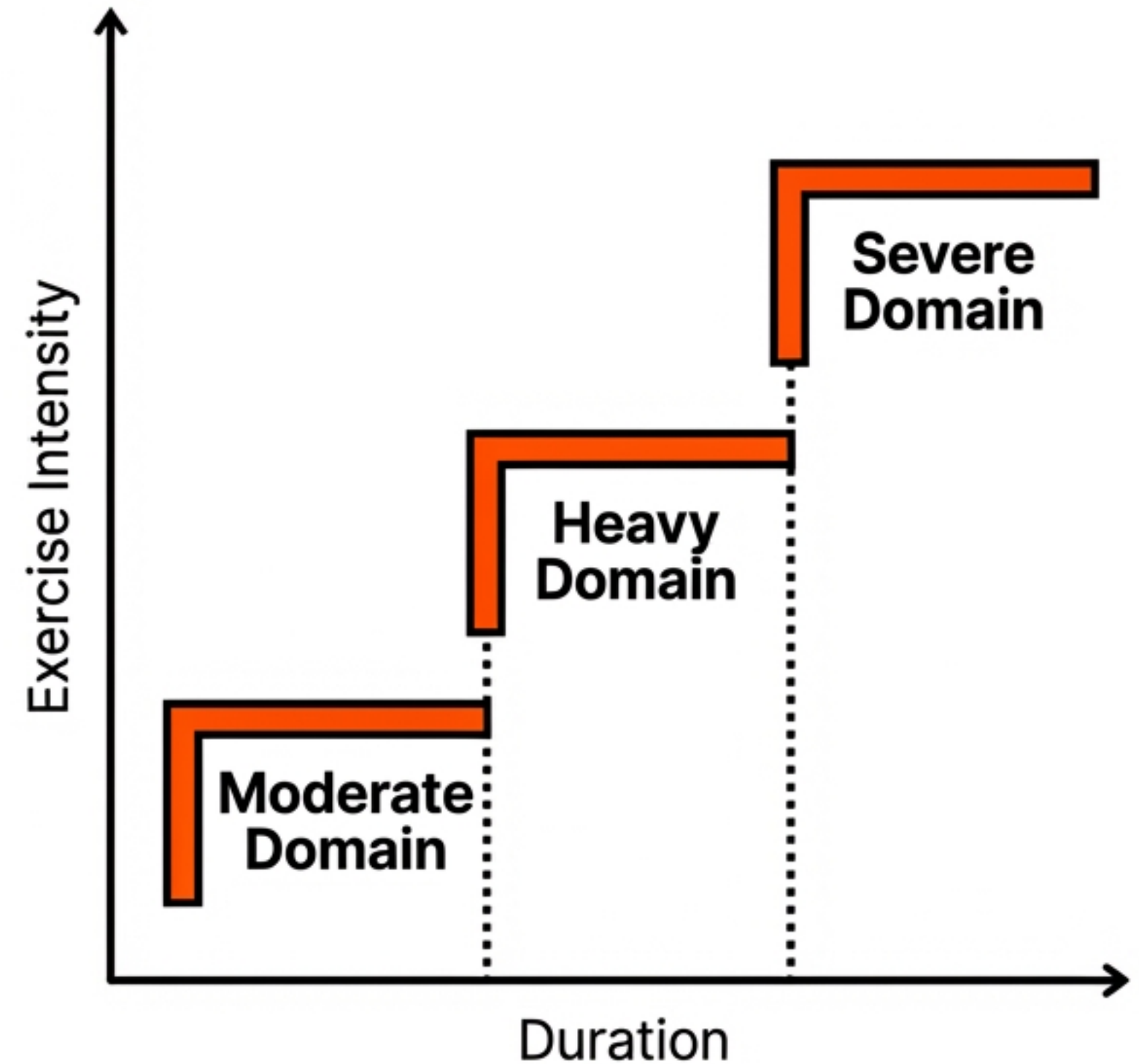
Fatigue Development in Self-Paced Endurance Exercise

Deconstructing the interplay between Central Fatigue, Peripheral Fatigue, and Perceived Exertion.



The Laboratory Trap: Constant-Load Exercise

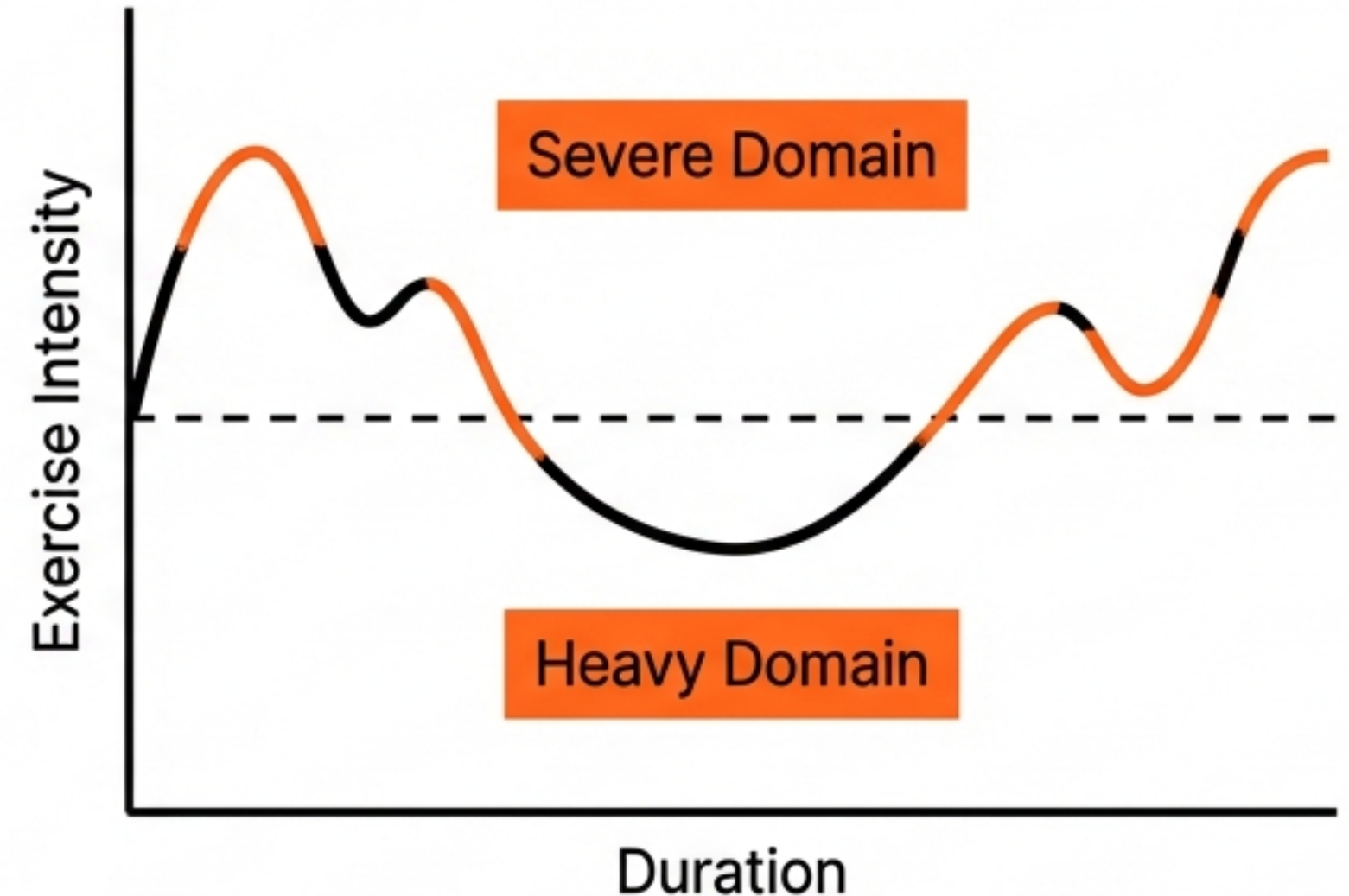
- **The Setup:** Fixed, pre-determined work rate until failure.
- **The Domains:** Moderate, Heavy, and Severe.
- **The Outcome:** Inevitable failure due to maximal metabolite accumulation.
- **Fatigue Profile:** Progressive linear development.



The Real World: Self-Paced Regulation

- **The Reality:** Continuous regulation of work rate.
- **The Domain Shift:** Oscillating between Severe and Heavy domains.
- **Mechanism:** Intensity drops allow partial recovery of intramuscular disturbances.
- **Goal:** Avoid premature failure; maximize exhaustion at the finish line.

Physiological & fatigue responses
based on self-paced endurance
exercise characteristics



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Central and peripheral fatigue assessment

The Two Antagonists: Defining Fatigue



Peripheral Fatigue (The Muscle)

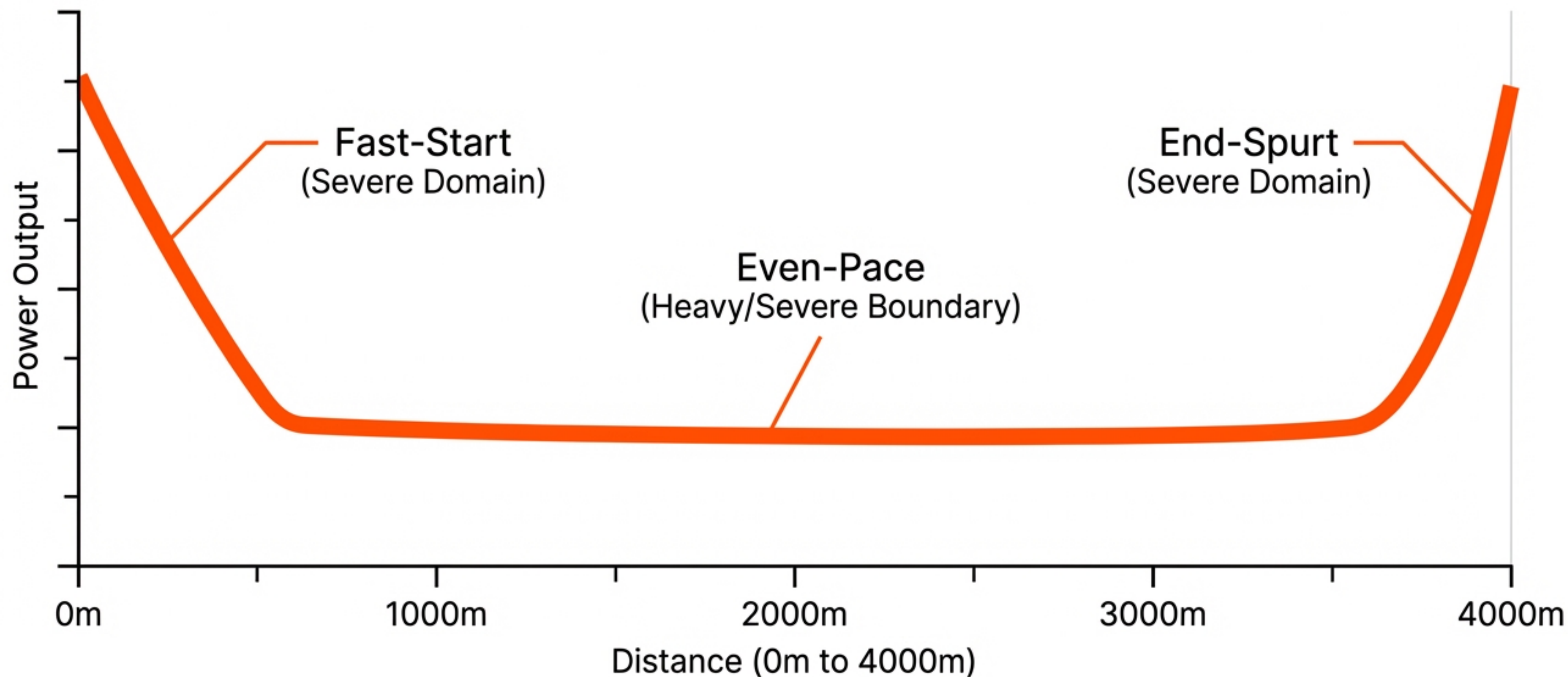
- **Definition:** Exercise-induced reduction in contractile function.
- **Marker:** Drop in evoked muscle torque (Q_{tw}).
- **Causes:** Accumulation of Pi, H⁺, and K⁺ ions.



Central Fatigue (The Nervous System)

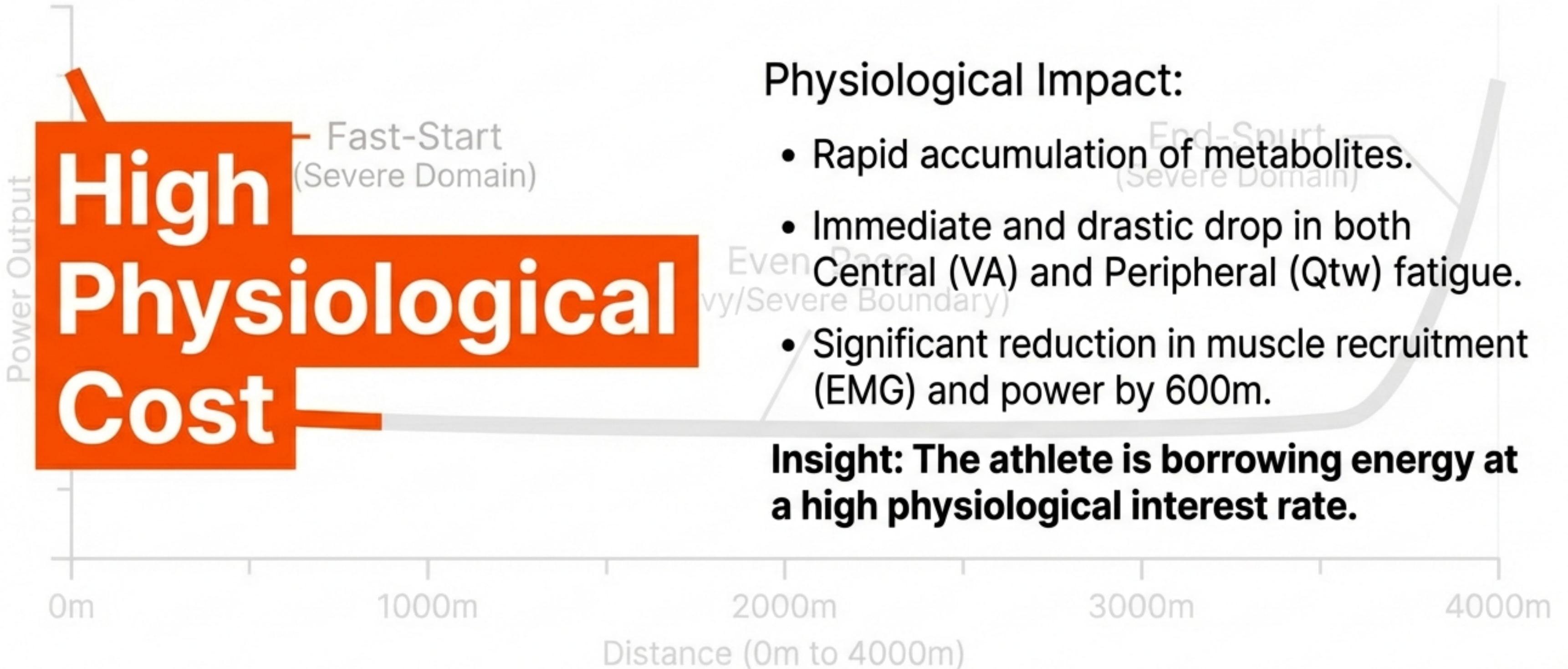
- **Definition:** Reduction in maximal neural drive.
- **Marker:** Decrease in Voluntary Activation (VA).
- **Causes:** Afferent feedback modifying CNS drive.

The Anatomy of a 4km Time Trial



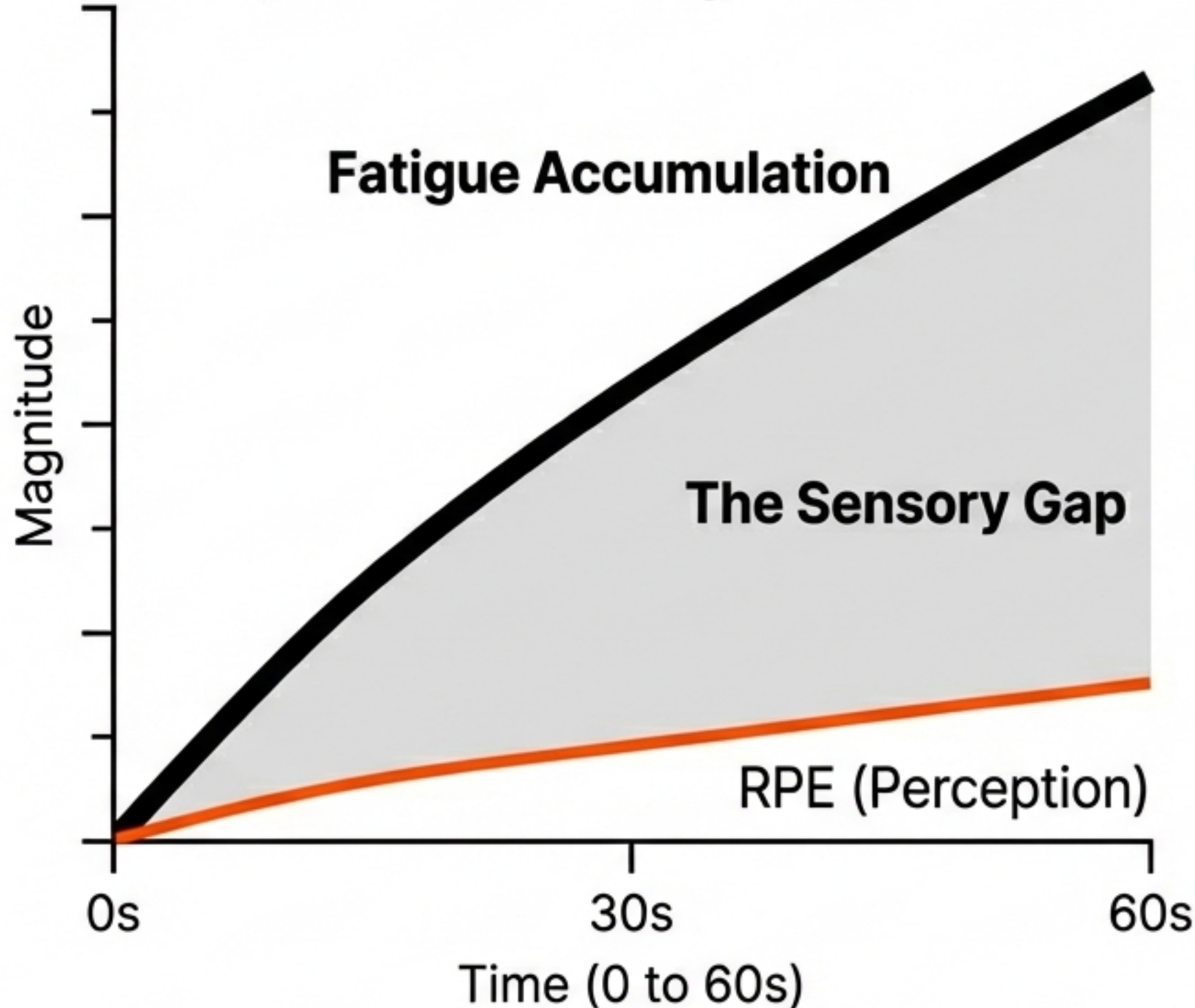
Phase I: The Fast-Start

~0 to 600m / Severe Domain



The Sensory Gap

A Temporal Misalignment



The Paradox: Fatigue is high, but **Perception** is low.

- Why? Delayed afferent feedback processing.
- Result: The athlete feels fine, but the damage is already done.

Phase II: The Even-Pace

~600m to 3600m / Survival Mode

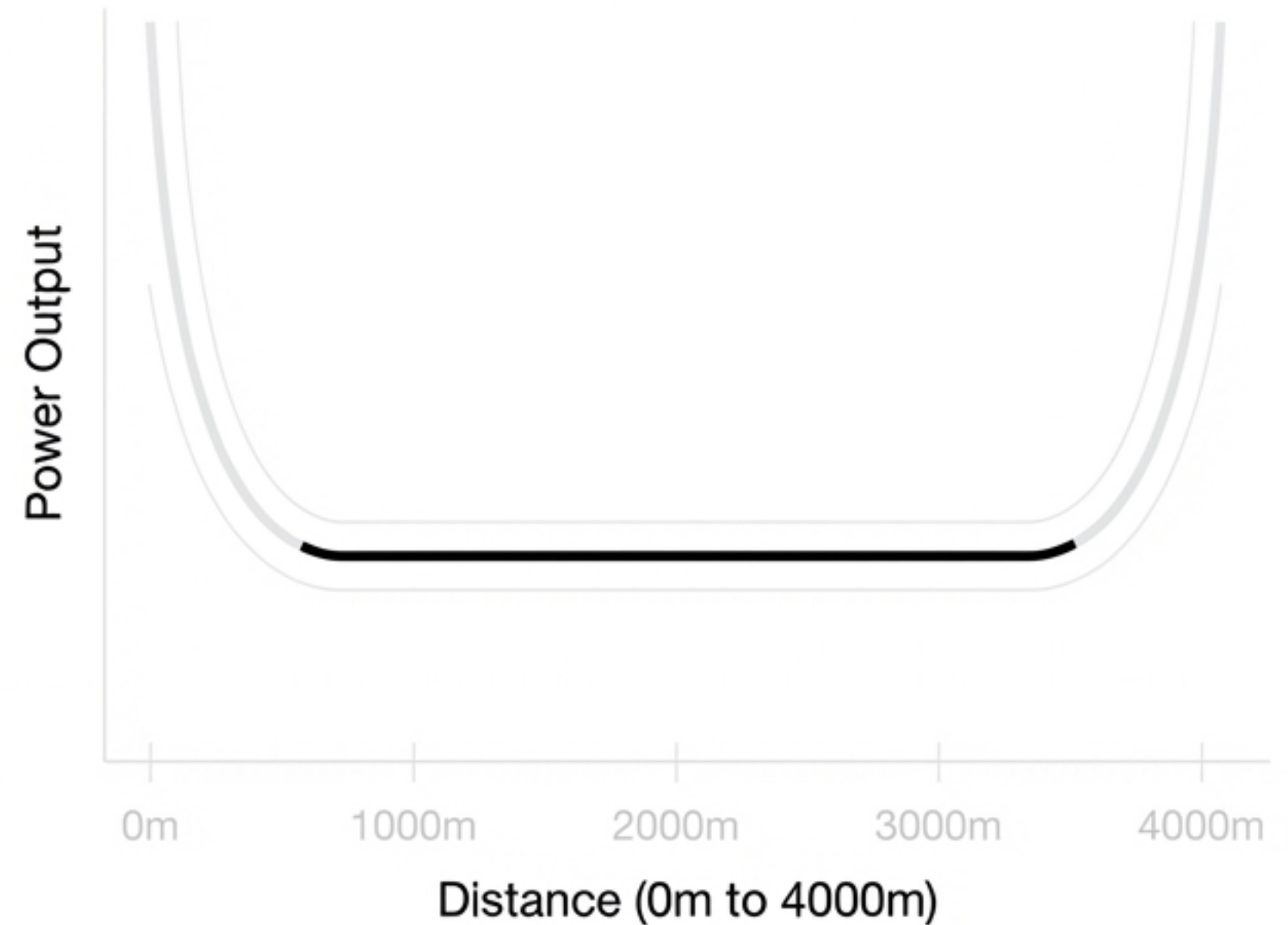
The Adjustment:

Power output drops to the boundary of Severe/Heavy domains.

Physiological Stabilization:

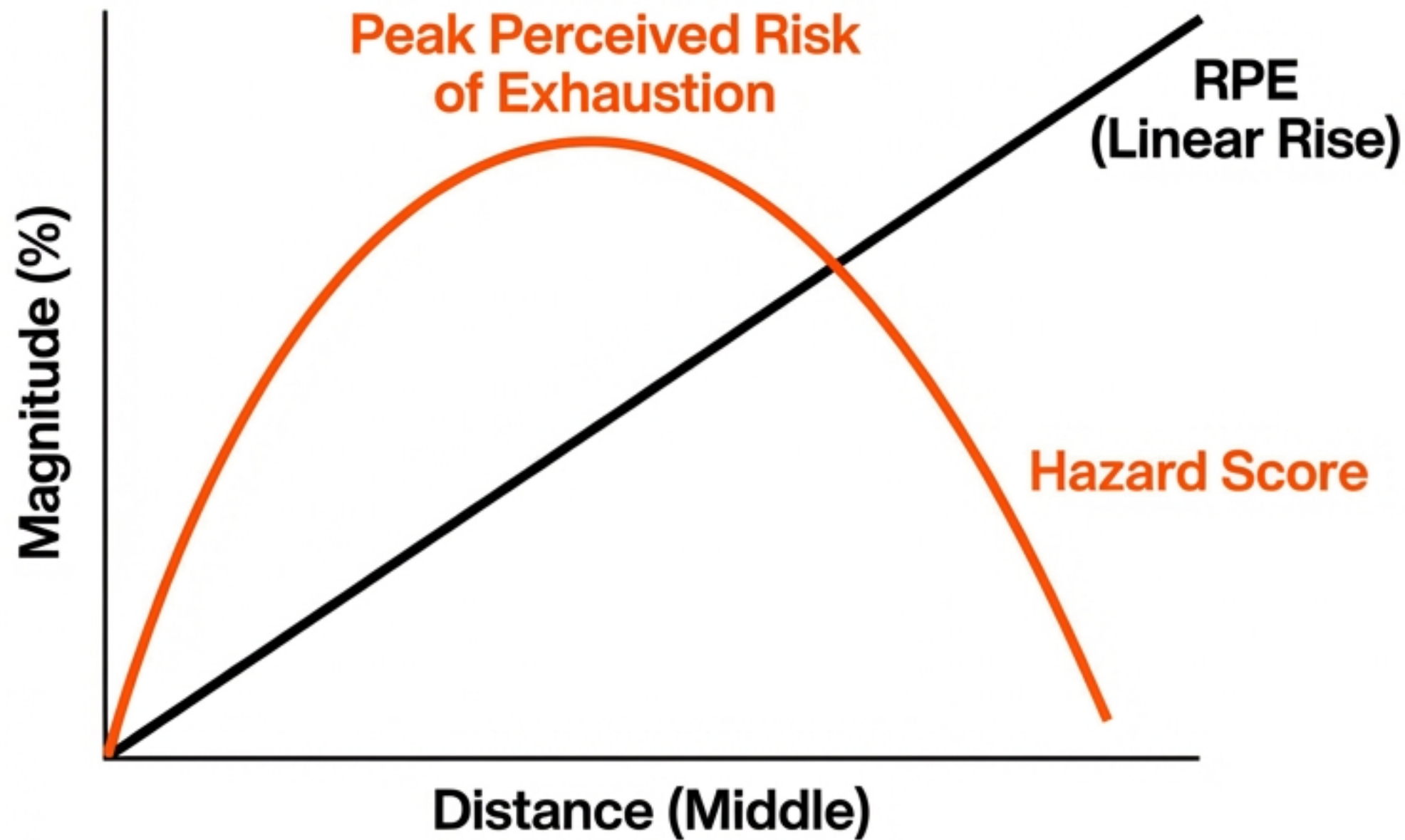
- Peripheral fatigue (Q_{tw}) stabilizes.
- Central fatigue (VA) plateaus.
- No new fatigue accumulation.

Mechanism: Downregulation of neural drive to prevent total system failure.



The Psychology of the Middle

The Hazard Score



The Conflict: Physiology is stable, but RPE rises linearly.

Calculation: Momentary RPE x Fraction of Distance Remaining.

The Brain asks: "Can I sustain this effort to the end?"

Phase III: The End-Spurt

Final 400m / The Override



The Phenomenon: Power output spikes back into the Severe Domain.

The Paradox: High intensity occurs despite maximal peripheral fatigue.

Mechanism: Teleoanticipation.

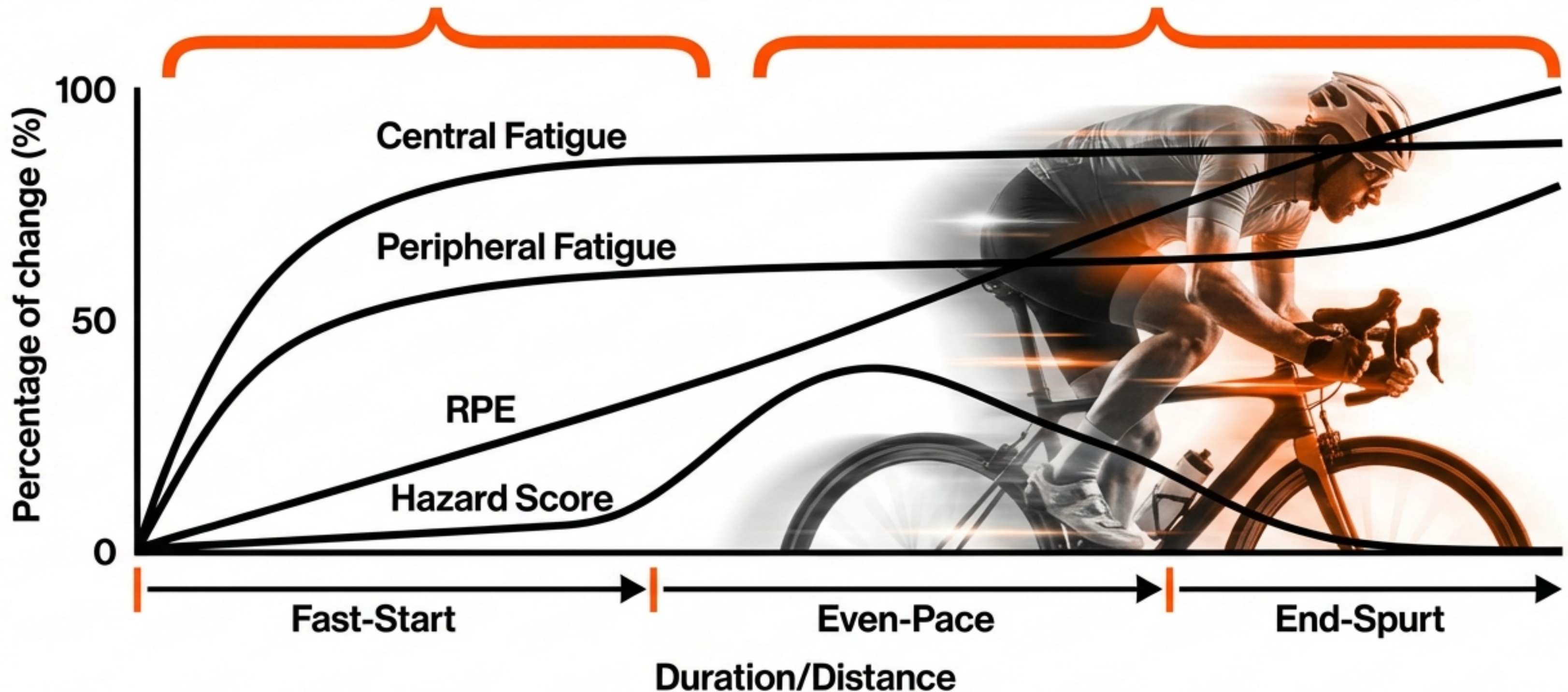
- Hazard Score drops to zero.
- Conscious decision to expend remaining W' .



The Integrated Fatigue Model

Driver: Neuromuscular Fatigue

Driver: Perceived Exertion



Constant-Load vs. Self-Paced

The Critical Differences

	Constant-Load (Lab)	Self-Paced (Race)
Fatigue Timing	Progressive. Max fatigue at failure.	Rapid early rise. Max fatigue maintained throughout.
RPE Relationship	Mirrors fatigue development.	Disconnected from fatigue (Sensory Gap).
Regulation Mode	Mechanical failure.	Behavioral regulation & Teleoanticipation.



The Future of Fatigue Research



The Gap: Moving beyond pre/post-exercise measurement.

The Goal: Assessing fatigue dynamically during competition.

The Truth: The athlete is a complex decision-making system, not just a biological machine.