The Body’s Two Engines: Understanding Fuel Depletion and Repletion for Peak Performance

A Scientific Deep Dive into
into the Phosphagen and
Glycogen Systems

Performance Isn't Limitless. Fatigue is Often a Fuel Problem.

Core Insight: **The fatigue experienced during many activities is frequently and directly associated with the depletion of two key energy substrates: Phosphagens and Glycogen.**

Supporting Context: While other molecules like free fatty acids, lactate, and amino acids are used for energy, their depletion typically does not occur to an extent that limits performance. Therefore, understanding the depletion and repletion patterns of phosphagens and glycogen is critical.

Meet Your Engines: The Nitrous Boost vs. The Primary Fuel Tank

The Nitrous Boost (Phosphagens: ATP & CP)

Provides immediate, explosive energy for maximal intensity efforts lasting only a few seconds. A small tank that burns fast and refills quickly.

The Primary Fuel Tank (Glycogen)

Powers sustained, high-level performance. A much larger reserve that fuels longer durations of effort but takes significant time and resources to replenish.

PART I: THE PHOSPHAGEN SYSTEM

Fueling the Explosion: How the Body Powers Maximal Effort

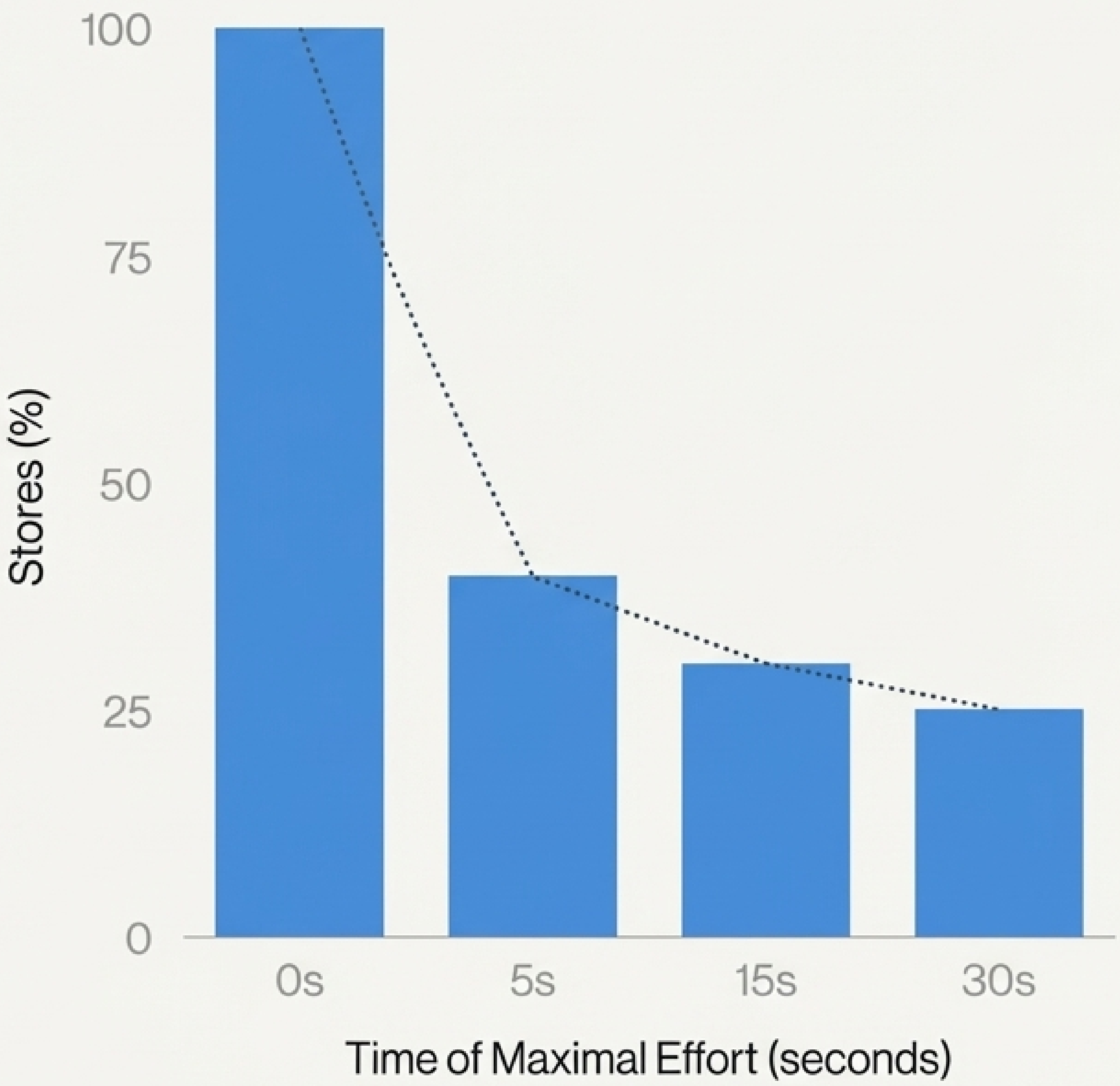
Phosphagen Stores Deplete Dramatically Within Seconds of High-Intensity Effort

> Creatine Phosphate (CP) is the most rapidly depleted substrate during high-intensity anaerobic exercise.

- **5-30 seconds of high-intensity exercise:** CP can decrease by 50-70%.
- **Maximal exercise to exhaustion:** CP can be almost completely depleted.

Muscle ATP levels are largely sustained, decreasing only slightly or up to 50-60%, because CP is used to rapidly regenerate it.

Creatine Phosphate Depletion



The Body's 'Nitrous Boost' Refills Remarkably Fast

Post-exercise phosphagen repletion is a rapid process, primarily accomplished through aerobic metabolism.

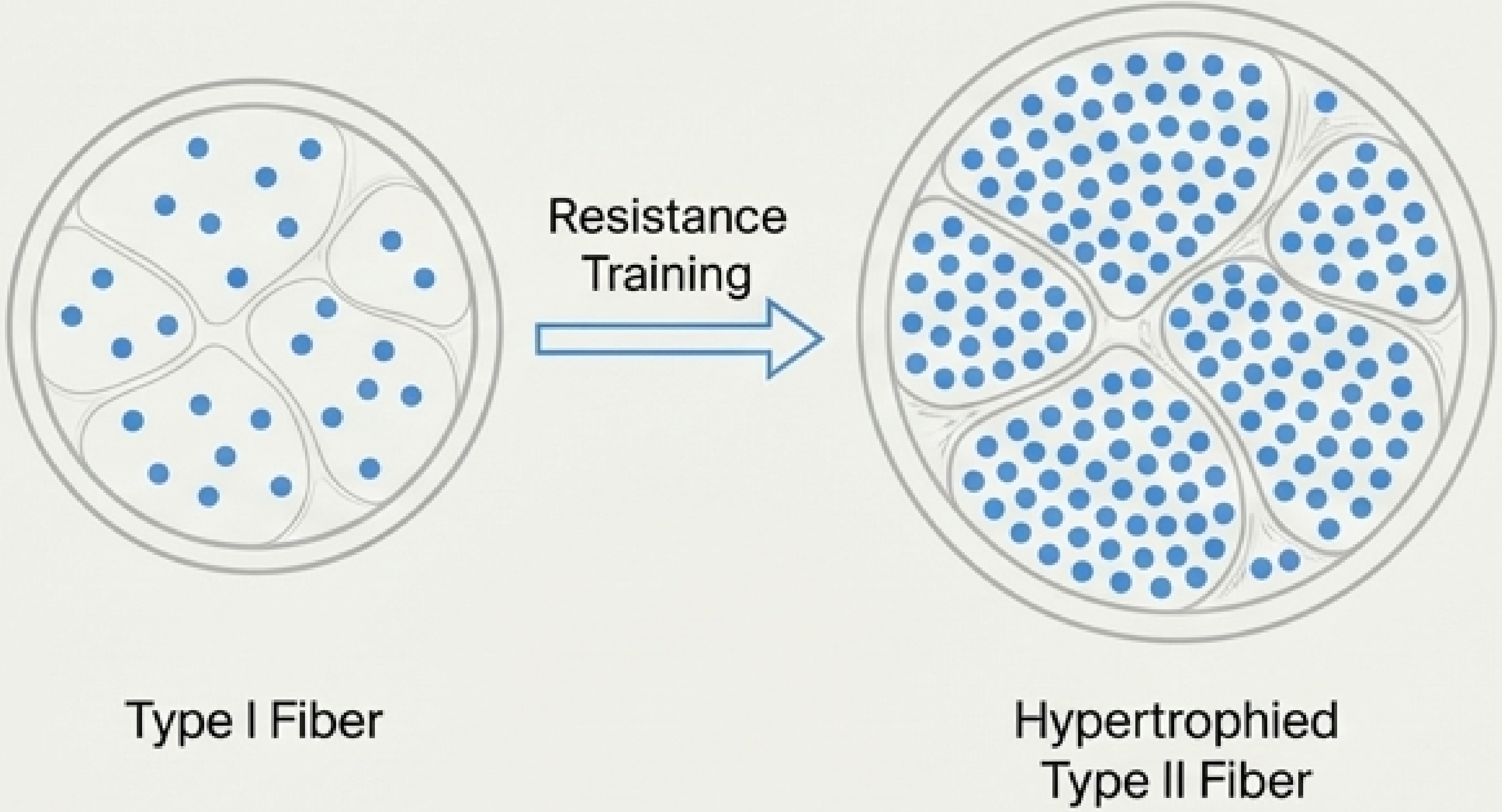
While primarily aerobic, glycolysis can contribute to recovery after very high-intensity exercise.

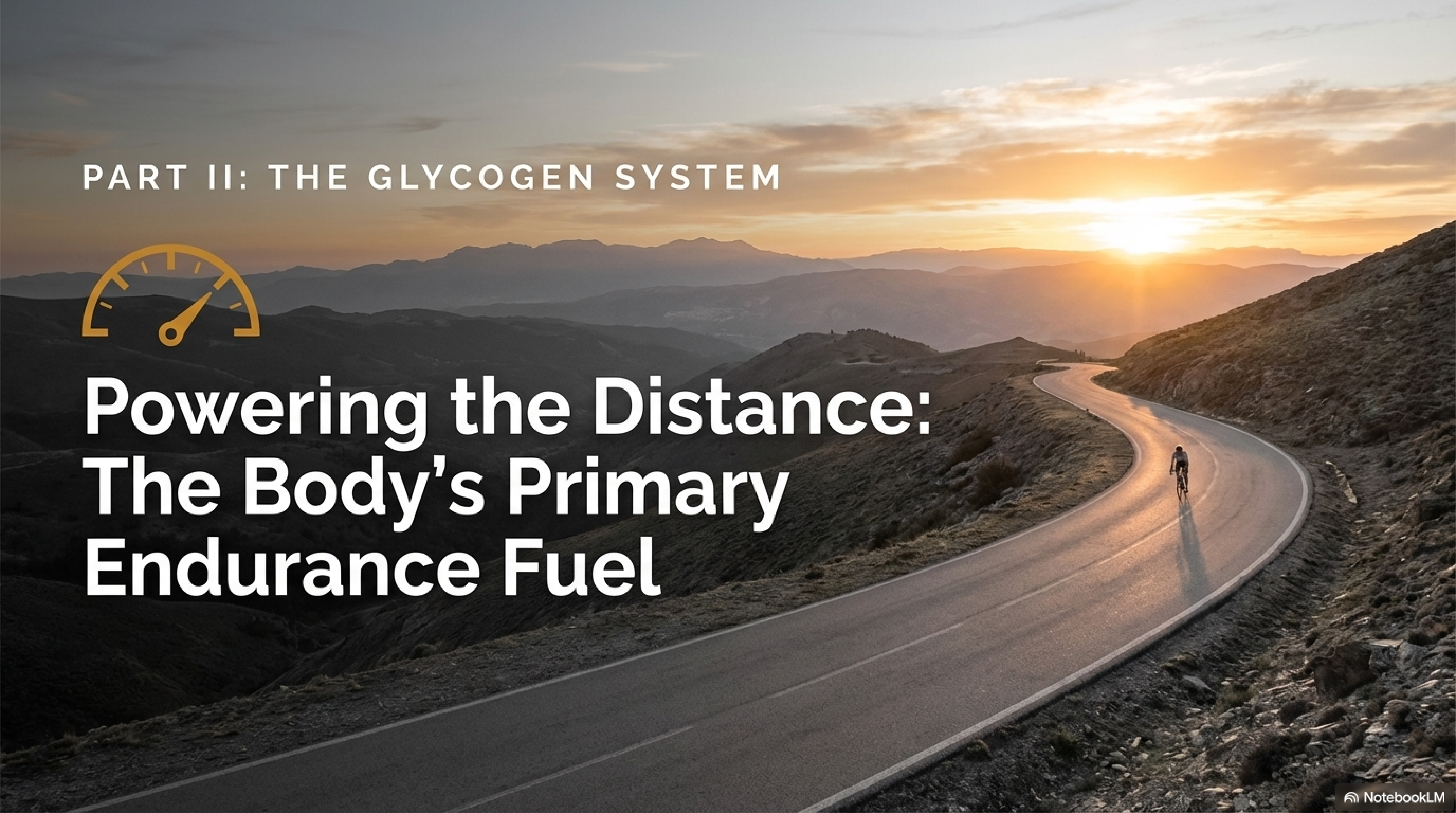
Upgrading the System: How Training Impacts Phosphagen Stores

The effects of training are complex and depend on the training type, but adaptations are possible.

- **Aerobic Training:** May increase resting concentrations and slow depletion at a given *absolute* power output.
- **Sprint & Resistance Training:** While short-term studies show little change in concentration, *total* phosphagen content can increase due to gains in muscle mass.
- **The Key Mechanism:** Resistance training can increase resting phosphagen concentrations by causing **selective hypertrophy of Type II fibers,** which naturally contain higher concentrations than Type I fibers.

The Impact of Selective Hypertrophy





PART II: THE GLYCOGEN SYSTEM

Powering the Distance: The Body’s Primary Endurance Fuel

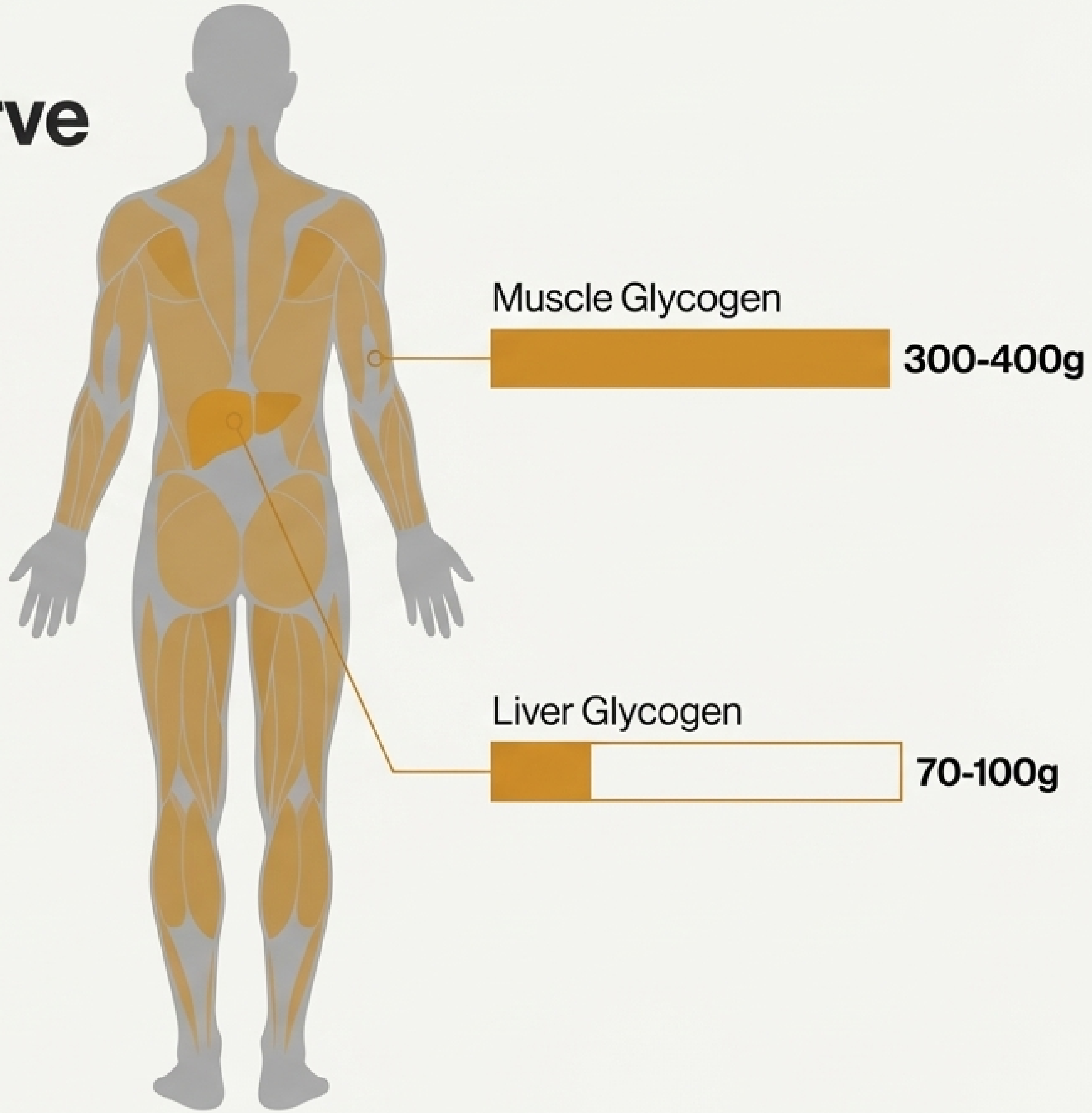
Glycogen is Our Onboard, High-Performance Fuel Reserve

The body maintains limited stores of glycogen in muscle and the liver, which can be influenced by training and nutrition.

Typical Resting Stores:

- **Total Muscle:** Approximately 300 to 400 g
- **Liver:** Approximately 70 to 100 g

Both anaerobic (sprinting, resistance) and aerobic endurance training can increase resting muscle glycogen concentration when paired with appropriate nutrition.



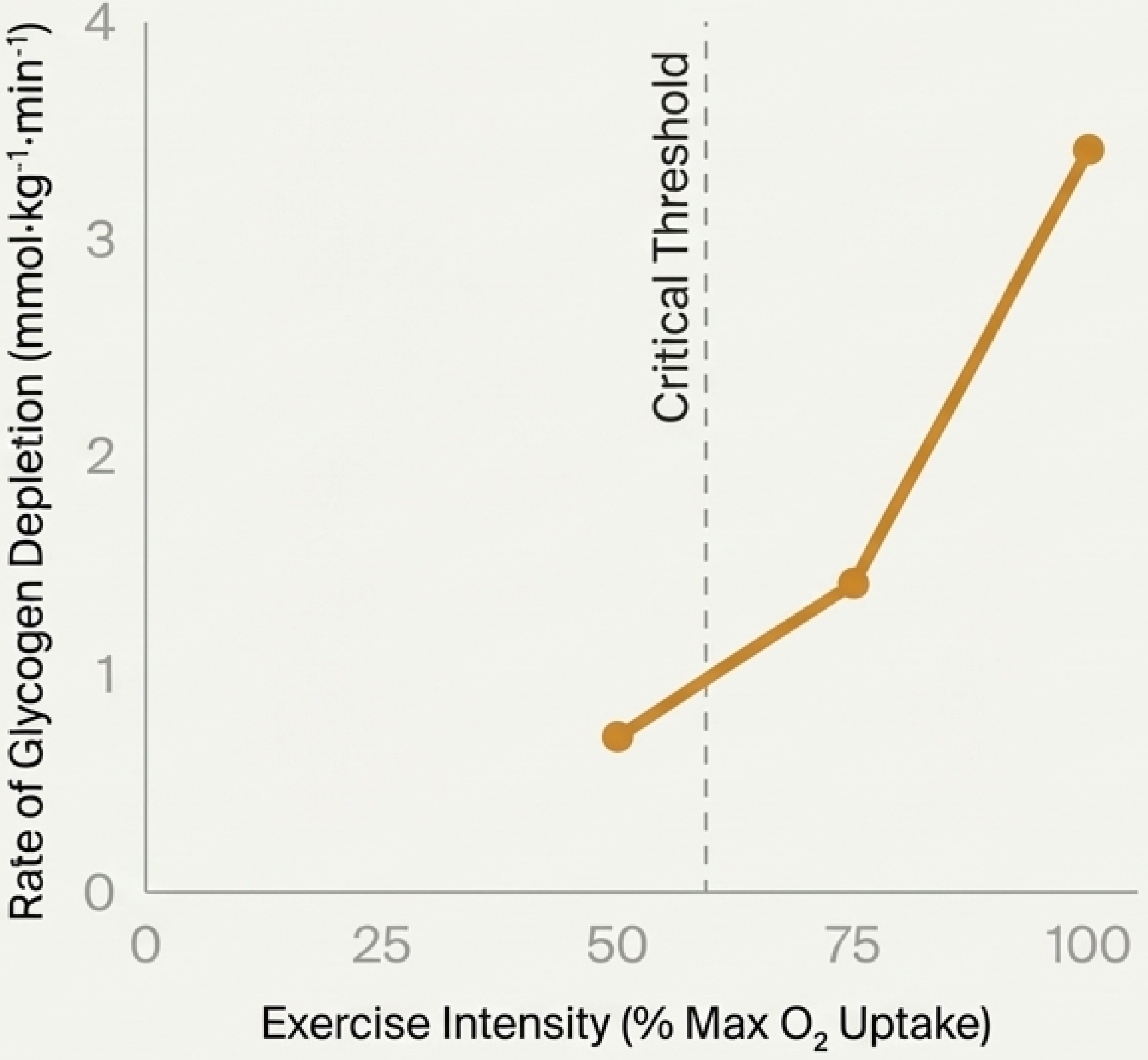
The Harder You Work, The Faster You Burn Through Muscle Glycogen

The rate of muscle glycogenolysis (the breakdown of glycogen) is directly related to exercise intensity.

50% Intensity: 0.7 $mmol \cdot kg^{-1} \cdot min^{-1}$
75% Intensity: 1.4 $mmol \cdot kg^{-1} \cdot min^{-1}$
100% Intensity: 3.4 $mmol \cdot kg^{-1} \cdot min^{-1}$

Above 60% of maximal oxygen uptake, muscle glycogen becomes an increasingly important energy substrate.

Glycogen Depletion Rate Accelerates with Intensity

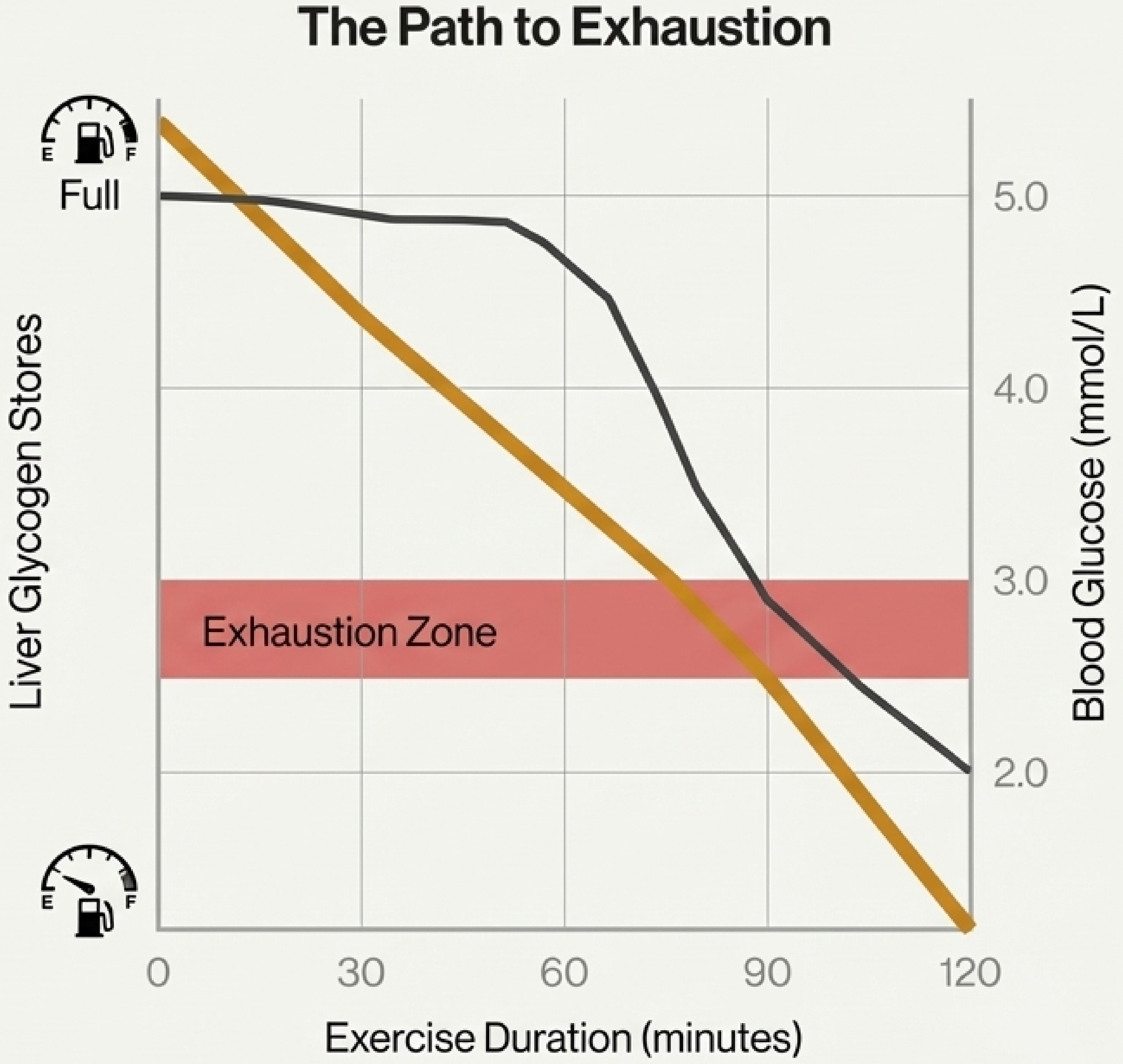


Running on Empty: How Glycogen Depletion Leads to Exhaustion

During prolonged exercise (>90 mins) at higher intensities (>50% max O_2 uptake), liver glycogen stores are depleted. This causes blood glucose concentrations to fall substantially.

The Performance Impact

- A decline in blood glucose to around 2.5 to 3.0 mmol/L results in reduced carbohydrate oxidation and eventual exhaustion.
- Hypoglycemic reactions can occur in some individuals with blood glucose values below 2.5 mmol/L.



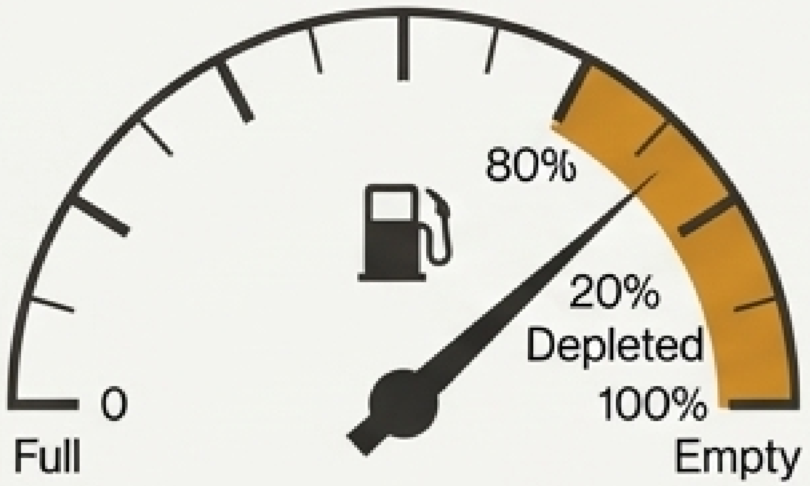
Glycogen is a Key Limiting Factor in High-Volume Strength Work

While phosphagens may limit a single high-resistance set, muscle glycogen depletion can become the limiting factor for resistance training involving many total sets.

- High-intensity resistance training can cause substantial glycogen depletion (20% to 60%) with relatively low total workloads.
- This can lead to selective glycogen depletion in Type II fibers, limiting performance.
- An interesting finding: when total work performed is equal, the absolute amount of glycogen depleted is the same, regardless of training intensity.

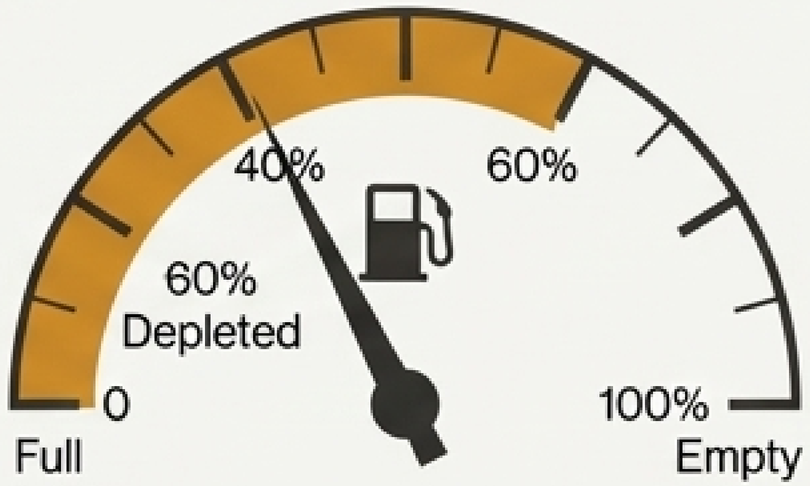
Total Work Dictates Depletion

Workout A: High Intensity, Low Volume



Total work in Workout B is greater, leading to more significant glycogen depletion.

Workout B: Moderate Intensity, High Volume



Refilling the Main Tank is a 24-Hour Process Driven by Carbohydrates

Repletion of muscle glycogen is related to post-exercise carbohydrate ingestion and takes a full day or more.

Optimal repletion strategy:

- **Amount:** Ingest **0.7 to 3.0 grams of carbohydrate per kilogram of body weight**.
- **Timing:** Consume this amount **every 2 hours** following exercise for the first 4-6 hours to maximize repletion rates.

With sufficient carbohydrate intake, muscle glycogen can be fully replenished within **24 hours**.
Important Caveat: If the workout had a high eccentric component (leading to muscle damage), complete repletion may take longer.

The Ultimate Comparison: Two Engines, Two Missions

Metric	Phosphagen System	Glycogen System
Primary Role	Immediate, max-intensity bursts (<30s)	Sustained high-intensity effort (>30s)
Depletion Speed	**Extremely Rapid** (50-70% in 5-30s)	Moderate to Rapid (Intensity-dependent)
Repletion Time	**Very Fast** (3-8 minutes)	**Slow** (24+ hours)
Key to Repletion	Rest & Aerobic Metabolism	**High Carbohydrate Intake**
Training Adaptation	Increase total stores via muscle mass & Type II hypertrophy	Increase resting storage capacity

Matching Your Fuel Strategy to Your Performance Goals

A deep understanding of these systems enables smarter decisions about training structure, nutrition, and recovery.

Strategic Application for Power/Sprint Athletes

- Prioritize adequate rest between maximal efforts (~8 minutes) to ensure near-complete phosphagen repletion.
- Focus on training that increases Type II muscle mass as a primary method for expanding this immediate fuel reserve.

Strategic Application for Endurance/High-Volume Athletes

- Make post-exercise carbohydrate intake (0.7-3.0g/kg every 2h) a non-negotiable part of recovery to ensure the 'tank' is full for the next session.
- For efforts over 90 minutes, plan intra-workout fueling to spare liver glycogen and maintain blood glucose levels.