supplysidesj.com

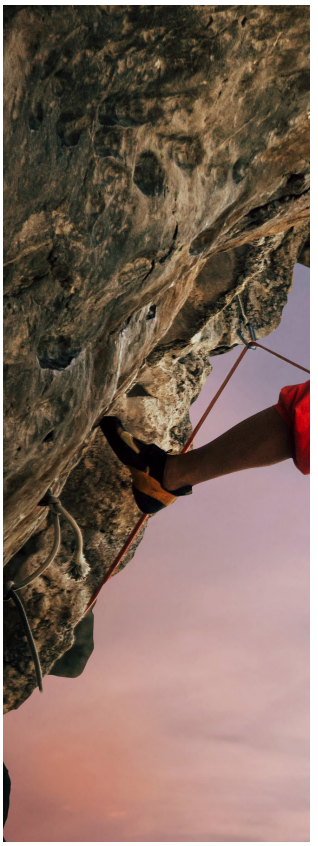
SupplySide®
Supplement Journal
September **2025**

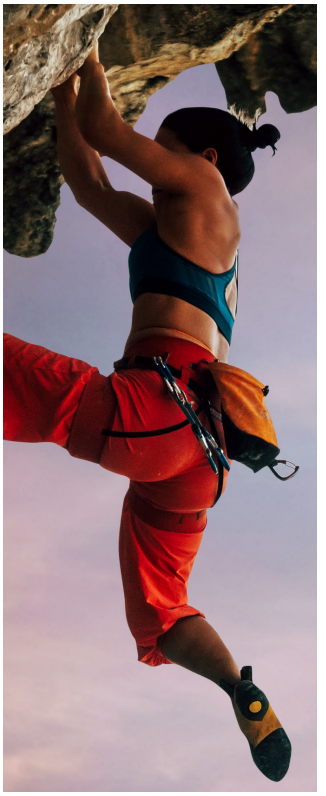
Precision performance

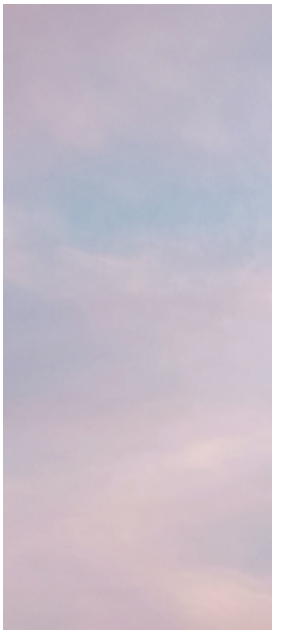
Pre-workouts, carbs, antioxidants

supplysidesj.com
Vol. 15, No. 8
September **2025**

CONTENTS







Guest viewpoint

Performance data is the new MVP in sports nutrition

by Susan M. Kleiner

The sports nutrition category has its roots in the 1950s, but the real emergence of the category as sports-specific supplementation took hold in the 1970s and '80s. In the early 1980s, all of my strength-training and bodybuilding clients used a mix of protein, carbohydrate and mass-building macronutrient powders. Gatorade was certainly on the scene and used by team athletes, as well as competitive runners and cyclists. Market growth really took off in the 1990s, and a handful of brands identified themselves as "performance nutrition" supplements for athletes and bodybuilders.

As fitness consciousness expanded in the U.S. in the early 2000s, so did the sports nutrition market. Sports nutrition evolved as a scientific discipline, and new evidence-based ingredients like creatine, beta-alanine, caffeine and others created explosive growth in the category, with many products and ingredients making performance-enhancement claims. More recently, the wellness/health promotion category has piggybacked onto the sports nutrition category with the "active nutrition" moniker. While there can be an overlap in ingredients between the two categories, the goals of the athlete/sports nutrition consumer are distinctive from the needs of the active nutrition consumer. The difference between the two consumers is, plainly, athletic performance.

To plant your flag in the sports nutrition space, performance data is king. It's nice to see changes in blood levels and metabolites, but that doesn't necessarily transfer to enhanced performance. Do research subjects run faster, jump higher, increase time to exhaustion, lift more weight, or increase focus in stressful situations to benefit end-of-match play? These are the scientific tests that will set a brand apart from those brands that don't test live performance.

Today there are dozens of bonafide research labs in the U.S. doing physical and mental performance studies to test ingredients and products. Brands that invest in science to support enhanced performance claims are leading the industry and creating a win-win for their athlete-customers and their brand. Don't get left in the dust!

Susan M. Kleiner

Susan M. Kleiner, Ph.D., RD, CNS-E, FACN, FISSN, is owner of consultancy High Performance Nutrition LLC.

Prepping for performance success

Pre-workout products provide the competitive edge serious athletes are pursuing.

by Lisa Schofield

Athletes of all ilks have come to appreciate the potential benefits offered by pre-workout supplements; however, for elite competitors, these formulations are often a must.

This year, the global fitness industry is growing at a rate of 5.6% per year — expected to rake in approximately $257 billion. According to Grand View Research data from December 2024, the pre-workout product market holds a respectable chunk of that, anticipated to reach approximately $20 billion in 2025, increasing at a compound annual growth rate (CAGR) of almost 6%. The data predicted this segment will surpass $28 billion by 2030.

Leslie Gallo, president of nutraceutical provider Artemis International, concurred, "There is enormous potential in the pre-workout space."

Pre-performance, pre-covery

Formulator Shawn Wells, author of "The Energy Formula Book," noted, "The pre-workout category has evolved into what I'd now call pre-performance." That increased level of support has progressed from heart rate to enhanced readiness across physical, mental and emotional domains. Formula-wise, Wells has also observed a big shift in intention. "It's not just about the workout. It's about performance in life, and even what I call pre-covery." These formulas include ingredients like salidroside (a bioactive compound found in *Rhodiola rosea*), as well as amino acids L-BAIBA (beta-aminoisobutyric acid) and ergothioneine, which have shown to support performance and recovery cascades. He added that the rise of nootropics in pre-workout products includes ingredients to support neurotransmitters, neuroplasticity and blood-brain barrier penetration.

Also pointing to the mental factor in physical performance is Mariko Hill — director of scientific affairs for Asia-Pacific, Europe, the Middle East and Africa — at ingredient supplier

click to go!

IN THIS ISSUE | Table of contents p.2 | Trends p.11 | Ingredient adaptation p.16

Hardcore female athletes are often drawn to using pre-workouts as they tend to view these products not just for achieving satisfying workouts, but **for the day ahead.**

Gencor. She commented, “With the ever-evolving market and need for products that enhance cognition, memory and energy, we are seeing pre-workout brands innovating with different format offerings.” For example, new pre-workout formulas for the gym have been repositioned as ready-to-drink (RTD) beverages to enhance cognitive function and boost energy for everyday wellness. These products feature actives such as natural caffeine, yerba mate (*Ilex paraguariensis*), vitamin B complex, creatine, beta-alanine and nootropics.

Hardcore female athletes are often drawn to using pre-workouts as they tend to view these products not just for achieving satisfying workouts, but for the day ahead. Keely Johnson, VP of sales and marketing at plant-based extract provider Arjuna Natural, noted, “This is reflected in the rise of women-focused sports nutrition lines, particularly in areas like endurance, recovery and hormonal health.”

Energy revisited

Wells suggested one of the most significant challenges in the evolution of pre-workout formulas is what he labeled “stim fatigue.” Many times, the use of experiential products can result in a burnout from a growing intolerance or repulsion to the side effects. “Consumers are no longer chasing just the buzz of caffeine or exotic stimulants. They’re realizing there’s a cost to sleep, anxiety, heart rate variability, recovery and even emotional regulation,” he observed.

click to go!

watch

The hottest supplement trends in 2024 – video

The supplement sectors best positioned for future success are included in this must-watch.

OmniActive ingredients perform on every level

From pre-workout energy to post-workout recovery, we deliver clinically backed solutions for every stage of performance.

As a category leader in active and sports nutrition, our branded ingredients are trusted by top formulators to power products with benefits targeting thermogenesis, mental energy, focus, mobility, and recovery. Whether you're formulating for athletes, gamers, or weekend warriors, OmniActive gives you the versatility to create standouts in every performance category.

FORMULATE POWERFUL PRODUCTS WITH VERSATILE INGREDIENTS

Capsimax Next
Multi-dimensional efficacy for weight management*

Muvz
Mobility and flexibility for active recovery*

Curcuwin Ultra+
Joint health and mobility benefits*

enXtra
Jitter-free mental energy*

Lutemax 2020
Visual and cognitive performance*

Sleeproot
Restful recovery, naturally*

OmniActive

»LEARN MORE

*These statements have not been evaluated by the Food and Drug Administration This product is not intended to diagnose, treat, cure or prevent any disease.

He added that most high-performance athletes understand the distinction between being overstimulated and being in flow, which has led formulators to develop toward cleaner, more sustainable energy generation through novel nootropics, adaptogens and precision compounds like paraxanthine, which he noted is "a superior, more euphoric alternative to caffeine."

But caffeine has also progressed tremendously. Nutriventia Ltd. has engineered a caffeine that the company maintained retains its benefits while losing its "negatives." Made from 100% natural caffeine, CaffXtend provides sustained energy and focus for up to 12 hours through a controlled-release profile that also reduces perceived fatigue, according to Rajat Shah, co-founder and executive director. She said the ingredient "meets a real, previously unmet need in sports nutrition: sustained, crash-free energy that lasts beyond the workout." She also pointed out, "Traditional caffeine wears off quickly, leading to mid-session fatigue, crashes or overuse."

Another way to generate energy pre-workout is through the nitric oxide (NO) pathway. Annie Eng, CEO of HP Ingredients, a provider of nutraceutical herbal extracts, explained, "L-arginine levels become depleted during exercise, leading to less-than-ideal nitric oxide levels and higher lactic acid build up, fatigue and slow recovery times." Research demonstrated that when the NO amount in muscle was increased, both endurance and performance also increased.

N.O.Max is HP Ingredients' patent-pending blend with a 2:1 ratio of L-citrulline to BPF Gold *Citrus bergamia* Risso fruit extract. N.O.Max was shown to increase the production of endothelium NO while providing excellent antioxidant protection to reduce the harmful effects of free radicals in sustained and aerobic exercise.

As an NO boost alternative, VasoDrive-AP is a proprietary casein-derived milk protein hydrolysate from branded ingredients supplier Maypro that supports cardiovascular function and athletic performance through a unique mechanism of action, according to Lauren Clardy, senior director. "VasoDrive-AP is shown to promote vasodilation through ACE (angiotensin-converting enzyme) inhibition — an underutilized target in sports nutrition," she contended. "By helping maintain arterial elasticity and healthy blood flow, VasoDrive-

AP facilitates more efficient delivery of oxygen and nutrients to working muscles. The result is improved exercise performance, greater muscle pumps and enhanced recovery."

As pre-workout formulations continue to evolve beyond mere stimulation toward comprehensive performance support, another standout ingredient is Balchem's VitaCholine, which is positioned as a key player in the sports nutrition market — highlighting the critical mind-body connection in athletic performance. Notably, Balchem recently formed a partnership with the NFL's New York Jets, underscoring VitaCholine's clinically proven support for muscle control accuracy.

Added pre-workout benefits

Gallo believes that "to make a pre-workout product stand out beyond the classic boosters, another approach to a pre-workout strategy involves the inclusion of ingredients that will support endurance and recovery by modulating the negative effects of extreme exercise." Artemis' CherryCraft tart cherry extracts, she said, can offer this additional layer of support due to their ability to support against inflammation, oxidative stress, muscle soreness and strength loss that can occur from intense workouts. Another meta-analysis showed that tart cherry had a significant benefit on endurance exercise performance.

Other ingredients have been clinically demonstrated to extend energy while also providing muscle recovery, nootropic and stress-reduction benefits. For example, ingredient supplier AIDP's Gremin, a blend of green coffee bean extract and curcumin (*Curcuma longa*), has been shown to enhance stamina and endurance as well as improve post-exercise muscle recovery and modulate inflammatory response, according to Angel Aponte, director of food, beverage and pet ingredients. And Gencor's Levagen+, a cold-water dispersible, bioavailable form of palmitoylethanolamide (PEA), may help manage discomfort, enhance sports performance and support cognitive function. Similarly, Arjuna's Showden ashwagandha (*Withania somnifera*) improved endurance performance in the KU Leuven Crossover Trial; and in another clinical study, participants experienced stress reduction and anxiety relief in tandem with cortisol decrease, Johnson reported.

Adding recovery value

When athletes think of pre-workouts for energy, adding an ingredient to help muscle recovery and manage exercise-induced inflammation could be a bonus to tip the scales toward a purchase. As one example, a low but effective 250 mg dose of Nutriventia's TurmXTRA 60N showed in a study to help

Pre-workout is one of the **most versatile segments** in the sports and active nutrition categories.

reduce delayed onset muscle soreness (DOMS).

In another human study, researchers found that Maypro's PurpleForce Kenyan purple tea (*Camellia sinensis* var. assamica) extract not only improved the delivery of oxygen to the muscle — optimizing its use in energy production for exercise — it also reduced fatigue likely due to reducing excessive inflammation caused by exercise, according to Clardy.

As athletes increasingly seek products that deliver both immediate benefits and long-term physiological improvements, specialized collagen peptides also offer formulators unique opportunities to create differentiated products that support the entire athletic journey — from preparation through performance to recovery.

Gelita is a collagen peptide provider strategically positioning in the sports nutrition space. Gelita ingredients include BODYBALANCE, clinically proven to increase lean body mass and decrease fat mass when combined with resistance training, and PeptENDURE, shown to enhance endurance performance with participants experiencing a 14% increase in speed.

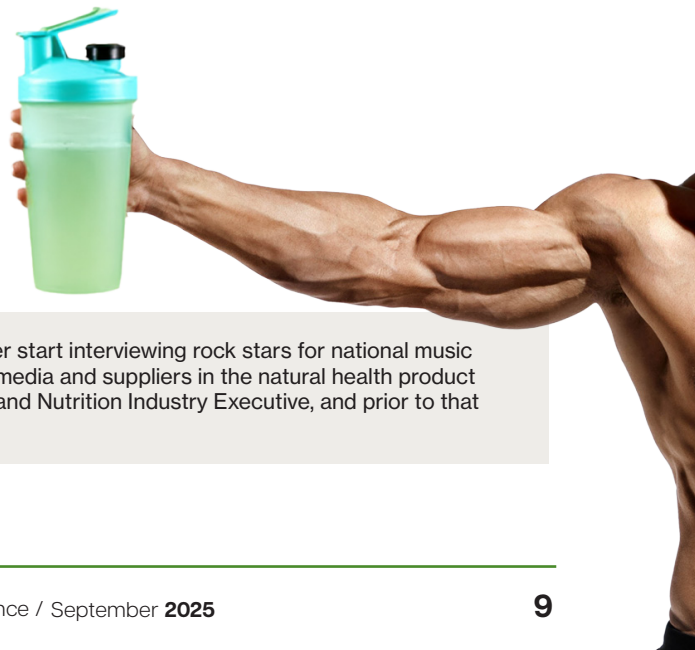
The future of pre-workouts

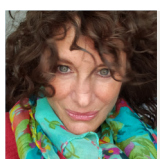
As previously noted, an energetic market is emerging in pre-workout products designed for women. According to research from Future Data Stats, this demographic is looking for formulas that "enhance stamina, improve workout focus, and assist in achieving training goals such as endurance fat loss or muscle toning."

Gallo predicted the pre-workout segment will see a rise in targeted, personalized formulations tailored to individual needs, including gender, workout intensity and training type. She anticipates greater use of innovative delivery systems — such as sublingual and nanodelivery technologies — and next-gen multifunctional RTD formulas that blend ingredients for increased energy, focus, hydration and recovery in a single solution.

Clardy agreed, "Pre-workout is one of the most versatile segments in the sports and active nutrition categories, offering strong crossover potential into energy, cognitive performance and broader wellness."

Whether serious athletes are targeting a performance edge or looking for widespread benefits, pre-workout formulas can set the desired boost in motion before a contender ever crosses the starting line. ■





Lisa Schofield is a veteran writer and editor who got her start interviewing rock stars for national music magazines. She now writes and edits content for B2B media and suppliers in the natural health product industry. She has served as editor for Vitamin Retailer and Nutrition Industry Executive, and prior to that as associate editor for Whole Foods.

Unlock Your Daily PERFORMANCE POTENTIAL

elevATP

Increases your body's own ATP for improved cellular energy, muscle strength and power output.†

S7

Boosts your body's own nitric oxide and maintains elevated levels for optimal performance and recovery.†

CLINICALLY RESEARCHED · NON-STIMULANT · PLANT-BASED

cognatiQ

Supports a key neuroprotein for improved mental focus, attention, stamina and processing speed.†

FEATURED SOLUTIONS

Today's consumers seek solutions for all of life's active moments. Whether you're developing products for athletes, fitness enthusiasts or those simply looking for active lifestyle support, our clinically researched, low dose solutions activate the body from within so you can reach your full potential every day.

Are you ready to explore our full sports and active nutrition portfolio? *Let's Talk!*

FUTURECEUTICALS

futureceuticals.com

†These statements have not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure, or prevent any disease.

The carb comeback: New science and opportunities in sports fueling

by Nick Collias

A new wave of endurance research, personalization tools and performance insight is reshaping how athletes and brands think about carbohydrate supplementation.

There's a quiet renaissance happening in sports fueling. But if you're not tuned in to the world's most elite endurance events, you might've missed it. Long demonized in diet culture and ignored in mass-market supplement marketing, carbohydrates are once again being recognized as perhaps the most essential performance nutrient next to water.

Elite athletes are quietly leading the charge, consuming previously unthinkable quantities of carbs mid-race — while scientists, coaches and brands work behind the scenes to bring that performance insight to a broader audience. From gut training and blood sugar personalization to novel textures and cooling formats, the next generation of carbohydrate products is as much about delivery innovation and athlete education as it is about dosage.

Why carbs are trending ... again

Carbohydrates are having a comeback. But for sports nutrition veterans, it feels more like a restoration than a revelation.

"When I started in the 1980s, the only supplement that worked was carbohydrates," Susan Kleiner, Ph.D., a pioneering researcher and performance nutritionist, recalled. "But then the diet world went anti-carb, and the

click to go!

IN THIS ISSUE Table of contents **p.2** Formulation focus **p.4** Ingredient adaptation **p.16**

> A kind of **'carb renaissance'** is happening at elite levels.

sports world followed. It seemed like insanity, because we've never seen a study that shows that a low-carb carb diet enhances athletic performance."

The fallout? Years of underfueling, misplaced fear and suboptimal performance. But the backlash sparked something productive: a new wave of research, exploring not just whether carbs are necessary (they are), but how to dose and deliver them with surgical precision.

"It forced scientists to go back to the lab and prove what we thought we already knew," Kleiner stated. "We didn't just confirm the value of carbs. We started asking how much, when and for what type of session."

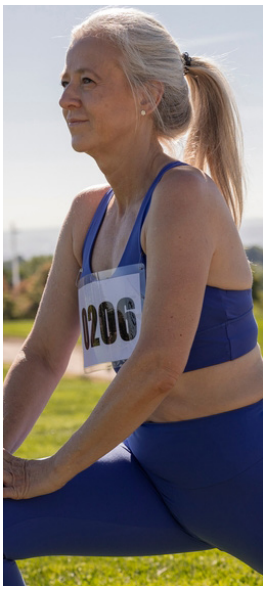
This shift opened the door to more personalized, goal-specific fueling strategies. Endurance athletes now think in terms of "grams per hour" and "burn rate" instead of generic advice. And at the elite level, those gram counts have ballooned. Sometimes, they're doubling what was considered acceptable just a decade ago.

The authors of the NBJ (Nutrition Business Journal) 2025 Supplement Business Report wrote, "We've often wondered why endurance athletes haven't received more attention from sports nutrition companies. But a kind of 'carb renaissance' is happening at elite levels. That suggests an opportunity to translate it for more casual athletes."

Tailoring for different athletes – especially women

One of the biggest evolutions in carbohydrate fueling isn't just about what the body uses. It's about who's using it and how. Researchers and coaches alike are moving away from universal recommendations and toward individualized strategies based on gender, exercise intensity and even hormonal cycles.

Kleiner championed the shift. "Carbohydrate utilization is not one-size-fits-all," she explained. "At high intensities, men and women are nearly identical. But at submaximal levels, women use more fat and less carbohydrate, and that can shift further depending on where they are in their menstrual cycle." This has major implications for event-day fueling and long-term training planning.



Researchers and coaches alike are moving away from universal recommendations and toward individualized strategies based on **gender, exercise intensity** and even **hormonal cycles.**

Professional ultra runner and bike racker Hillary Allen has seen this evolution firsthand. "There was a time when people wore 'low-carb' like a badge of honor," she mused. "But I've worked with athletes — especially women — who started training with more fuel and just got faster. They're not even elites, but they're logging elite-level hours. Even getting them to 30-40 grams per hour made a real difference."

That shift from "how little can I get away with" to "how much do I need" is what makes this moment different. It's not just about copying what the world's best do, but rather, about embracing what Allen called "the conversation" with every athlete.

Gut training and bio-adaptation

As athletes push higher carb loads during training and competition, their digestive systems have to keep up. That's where gut training — once a niche topic in elite competitive circles — is becoming mainstream.

For perspective, Kleiner offered, "It's just like hydration. People say, 'Oh, I can't drink while I exercise.' But in most cases, that's trainable. You're habituating the gut and ramping up the transport systems to handle more carbohydrate."

But even the perfect gut training protocol (if it existed) won't smooth out the individual differences between athletes. "Just because you have a mouth doesn't mean your gut is the same," Kleiner quipped. "Everyone's comfort level is different."

That variability has sparked renewed interest in slow-release and low-glycemic options like isomaltulose (branded as Palatinose), a once-popular carb derived from sugar beets. It has also led to an explosion of interest in the elite level into highly branched cyclic dextrin.

These options can offer smoother blood sugar curves, and fewer mid-race "bonks" or digestive surprises. But Kleiner said the ingredients have never received the marketing

balchem
HUMAN NUTRITION & HEALTH

From Mind to Muscle, **Stay Game-Ready with VitaCholine®**

Choline is an essential nutrient for brain, body and nervous system, promoting memory, mood, muscle control, and many other cellular functions.

VitaCholine® is the Gold Standard

- Safe, non-GMO, and naturally sourced L(+) tartaric acid form.
- Clinically-studied choline salts offer unsurpassed choline content and proven absorption.
- Demonstrated to enhance muscle control, visuomotor performance and precision.

Learn more about VitaCholine's plug-and-play solutions for RTDs, supplements, and beyond.

Meet us in Las Vegas at the **SupplySide Global 2025, Booth 5264.**

Let's connect — book your appointment today!

SupplySide Global

VitaCholine®

JETS

Official Partner of the New York Jets

vitacholine.com

and consumer education support needed to help them reach their full potential.

"We still need better tools to match gut tolerance with ingredient choice and delivery method," she added. "But we're getting closer."

Novel formats and flavors: Fighting palate fatigue

Carbohydrates are unique among supplements in that athletes often take them simultaneously in multiple forms: gels, chews, drinks, bars and whole foods. And that variety isn't just for convenience. It's a practical response to taste and texture fatigue when an athlete is exhausted.

What's the alternative? Allen knows it personally. "I've successfully done one marathon where I was at 70 grams of carbs per hour because I was pushing really hard the whole time," she recalled. "But I didn't even want to look at another gel for weeks afterward." And 70 g is far below what some elite racers are consuming.

That's why high-level athletes still often end up customizing their fuel in the kitchen. Allen, who races both trail and bike, said she's long experimented with homemade snacks and savory ingredients to get out of the sweetness feedback loop. And she suggested that one area ripe for innovation is temperature.

"One of my favorites is gels you can chill, like popsicles. Neversecond makes one of those (the IceGel)," she shared. "Honestly, I think it would be amazing if Otter Pop rebranded as a sports nutrition company."

Flavors like sour citrus and salty chocolate are slowly entering the market, but Allen believes there's room for more. "I already have decision fatigue as an athlete," she said. "But I'd still love better options."

Athletes can be an ally in innovation

In many ways, carbohydrate supplementation has come full circle: from pure sugar to purpose-built, scientifically dialed nutrition. Kleiner supported this notion: "When I started 40 years ago, it was just sugar. Now we have more options, better ingredients and a deeper understanding of what athletes actually need."

She added that the biggest shift may not be in the ingredients themselves, but in the athletes. Whether they're chasing a spot on the Olympic podium or just a personal best, today's athletes are more receptive to the idea that fueling well isn't a luxury for elites. It's a conversation for everyone. ■

Nick Collias is a writer and editor with over a decade of experience working in the health and fitness industry. From 2016 to 2021, he was the host of the Bodybuilding.com Podcast, interviewing elite athletes and training thought-leaders on a wide range of exercise, nutrition and lifestyle topics. Additionally, he has worked for the last 20 years as a longform print and online journalist, as well as a book author, ghostwriter and editor.

Free radical thinking: Exploring the role of antioxidants in athletic performance

by Denis Faye

Friedrich Nietzsche famously wrote, "What doesn't kill me, makes me stronger." And while it may seem odd to associate a 19th century German philosopher with sports performance, this little aphorism tidily sums up one of athletic training's core concepts: adaptation.

A big reason athletes do hard workouts is because the exertion breaks down various systems in the body, allowing them to grow back stronger, faster or tougher. A classic example of adaptation is using a muscle to the point of failure, then allowing it to recover – which is thought to contribute to increased strength and/or size.

Key to adaption is a cellular process called redox homeostasis – a constant battle between oxygen-based molecules called reactive oxygen species (ROS) and antioxidants. ROS do the breaking down and antioxidants do the building up.

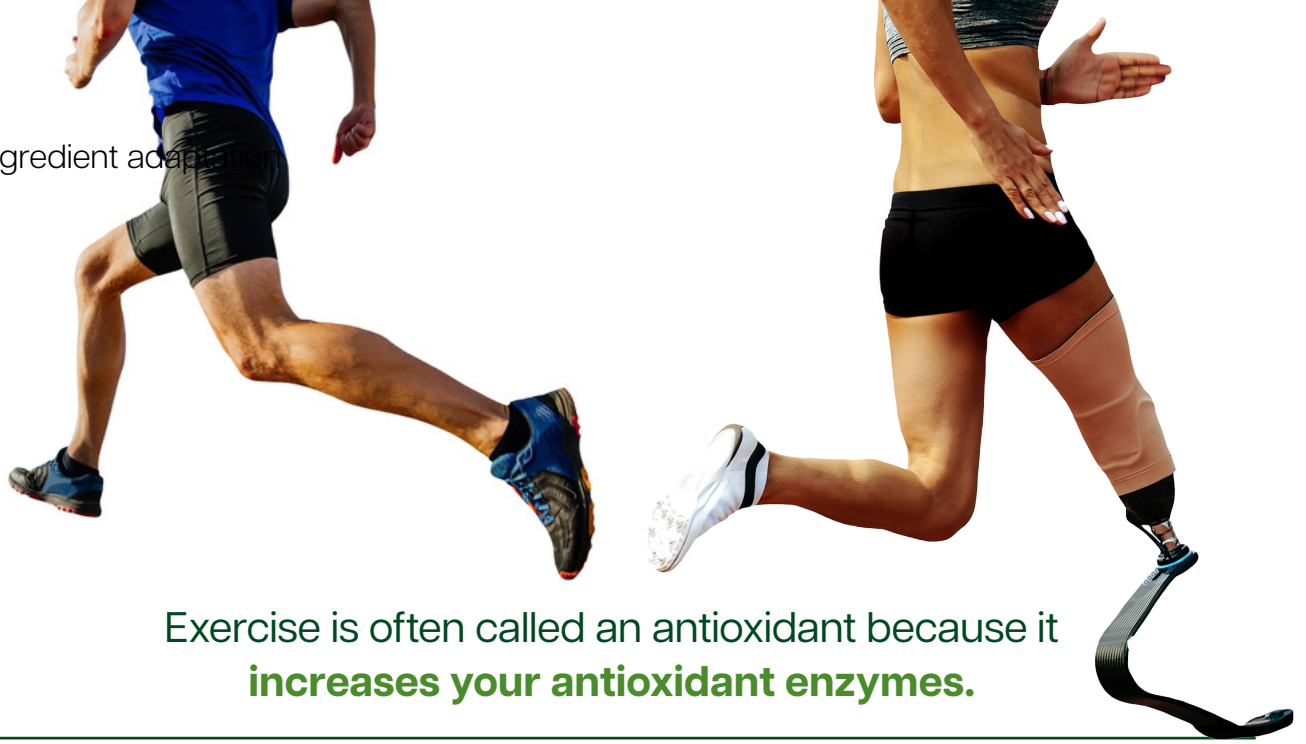
It's not hard to introduce ROS into a system; just add stress. Antioxidants are a little more complex. The body has its own internal endogenous antioxidants such as glutathione, coenzyme Q10 and alpha-lipoic acid. While the body makes these, they can also be supplemented.

Endogenous antioxidants receive backup from exogenous antioxidants – substances that the body doesn't make. Typically, they come from food and supplements. Sometimes sleep, exercise and other beneficial lifestyle practices are considered to foster antioxidant properties.

Common orally consumed antioxidants include micronutrients like vitamins C and E, as well as selenium and zinc. Polyphenols such as quercetin and resveratrol are also considered antioxidants. They all work differently in the body – and consuming them in a way that maximizes benefit can be complex, especially when dealing with the extremes that serious athletes go to.

click to go!

IN THIS ISSUE | Table of contents p.2 | Formulation focus p.4 | Trends p.11



Exercise is often called an antioxidant because it **increases your antioxidant enzymes.**

ROS and antioxidants in athletic training

ROS production increases naturally during any kind of stress — environmental stress like pollution, heat and UV (ultraviolet) exposure; psychological stress; and physical stress, which includes exercise — especially intense or prolonged efforts.

To complicate matters, different kinds of ROS exist. While the ROS stemming from a sunburn or an abusive boss are generally destructive, ROS generated from exercise can be beneficial because they trigger the positive adaptation that Nietzsche mused about.

ROS are natural byproducts of oxygen metabolism. During exercise — particularly high-intensity or prolonged activity — muscles require more oxygen, prompting mitochondria to increase energy production. This heightened activity leads to a corresponding rise in ROS generation.

At reasonable levels, ROS act as signaling agents, allowing cells to tell each other what to do. They help regulate processes like mitochondrial creation, muscle building, glucose uptake and inflammatory response. In this sense, ROS are part of how the body senses stress and initiates growth and repair.

Still, they need to be managed. This is where antioxidants come in. As previously mentioned, there are several kinds of ROS. Without getting too deep into the chemistry, some ROS are free radicals, meaning they have unpaired electrons — which prompts them to "steal" electrons from molecules, including proteins and DNA. This can cause all kinds of damage. Others are nonradical but still chemically reactive.

Antioxidants neutralize free radical ROS by donating electrons, stabilizing them and stopping damage. For nonradical ROS, antioxidants break them down into harmless substances or prevent them from converting into more harmful radicals. This is sometimes done enzymatically.

Abhijeet Morde, divisional VP of in vitro biology, animal studies and clinicals at ingredient provider OmniActive Health Technologies, said: "In the context of athletic performance, antioxidants may assist in mitigating post-exercise muscle soreness, supporting tissue repair and reducing markers of muscle damage. These benefits contribute more directly to recovery, though sustained antioxidant support can also help preserve performance over time by protecting muscle cells and reducing fatigue-associated oxidative burden."

One interesting aspect of redox homeostasis as it relates to adaptation is that workouts

PeptENDURE®
Performance Peptides

Faster.
Farther.
Longer.

A Revolutionary Sports Performance Ingredient

- Enhances endurance performance
- Maximizes your trainings
- Improves energy metabolism

Trusted Science
BIOACTIVE COLLAGEN PEPTIDES®

GELITA USA Inc. · P.O. Box 927 · Sioux City, IA 51102 · USA · www.gelita.com

don't just create ROS, they help manage them. In other words, as Glenn Wadley, Ph.D., professor of exercise metabolism at Deakin University's School of Exercise and Nutrition Sciences in Australia, explained, "Exercise is often called an antioxidant because it increases your antioxidant enzymes."

Vicente Javier Clemente-Suárez, Ph.D., a professor at the European University of Madrid's Faculty of Medicine, Health and Sports, explained, "Highly trained athletes often have more robust endogenous antioxidant defenses. While extreme training does increase ROS production, trained individuals adapt by enhancing their antioxidant enzyme systems."

But antioxidant protection has its limits, even for elite athletes. There is such a thing as too much exercise. If ROS levels rise too high — in this case from overtraining — they can cause oxidative stress, which contributes to fatigue, inflammation, injury and slower recovery. "If training load exceeds recovery capacity, oxidative damage can accumulate," Clemente-Suárez continued. "Extreme adaptation is beneficial up to a point — beyond which chronic stress may outweigh the adaptive benefits, regardless of diet and rest."

What's on the antioxidant menu?

Given the role antioxidants play, it seems logical that loading them would have big benefits for athletes. But it's not that simple, for several reasons.

Because ROS can play a positive role, dousing them with excessive antioxidants or taking antioxidants for long periods of time can interfere with beneficial adaptations to training. "There is a threshold beyond which supplementation may blunt cellular signaling necessary for muscle growth, mitochondrial biogenesis and overall adaptation," Clemente-Suárez explained. "The key is balance, not suppression of all oxidative stress, which plays a physiological role in signaling and adaptation."

This is especially true for exogenous antioxidants. The body can manage endogenous antioxidants. It made them, so it knows what to do with them. Exogenous antioxidants are harder to wrangle.

The case for vitamin C

Exogenous antioxidants sometimes work as direct scavengers, which basically means they work independently of the body's endogenous antioxidants to manage ROS. Situations can occur where, if too many are consumed, they can potentially counter ROS before they have a chance to do their job.

"Vitamin C, especially in high doses — a gram a day or more — can blunt exercise-induced ROS signals that are essential for mitochondrial adaptations," Clemente-Suárez said. "This is because vitamin C directly scavenges ROS that act as secondary messengers in signaling pathways."

Still, vitamin C is essential because it's not synthesized by the body yet is required for many vital biological processes.

> Tour de France cyclists – who ride hard four to six hours a day for 21 days with only two rest days – **can benefit** from some **antioxidant help.**

Emily Fritz, Ph.D., director of business development at VDF FutureCeuticals, a provider of plant-based nutritional ingredients, said, "In the context of sports nutrition, there's a lot of conflicting evidence on the benefits of [vitamin C's] role as an antioxidant for performance and recovery. But there are likely downstream benefits that could support performance – like its role in supporting collagen synthesis and its ability to support a healthy immune function."

Acute, low-dose vitamin C supplementation (≤ 250 mg/day) may support immune function and reduce oxidative stress without impairing adaptations. This may be especially beneficial during prolonged efforts.

For example, Tour de France cyclists – who ride hard four to six hours a day for 21 days with only two rest days – can benefit from some antioxidant help. Wadley suggested, "Their energy intake is 30,000 kilojoules a day or something, so they're eating a lot of not nutritionally dense but energy dense foods. It's very hard to get your vitamins and minerals in those sorts of foods. They probably want to take some sort of vitamin supplement, but they probably don't need a gram a day."

Polyphenols: The support players

Many phytonutrients have been shown to have antioxidant properties – including polyphenols. These plant-based compounds sometimes scavenge directly, but they also support endogenous antioxidants. Clemente-Suárez noted, "Polyphenols like quercetin or resveratrol tend to act more as modulators of signaling pathways, often enhancing mitochondrial biogenesis and improving blood flow without fully suppressing beneficial ROS signals. Their mechanisms – anti-inflammatory, vasodilatory and gene-regulatory – make them less likely to disrupt adaptation when used appropriately."

According to Fritz, "Continued daily supplementation with polyphenols can support mitochondrial health, maintain redox balance, and support vascular and endothelial health over time." This means that chronic use can possibly support increases in muscle strength and improvements in endurance.

However, the direct studies on acute performance benefits of polyphenols are mixed. The possible benefits of using polyphenols acutely for sport are more related to recovery. "Most of the studies use acute, damaging protocols that result in soreness and fatigue

and then look at markers of recovery like muscle soreness, biomarkers and muscle function 24 to 96 hours after the damaging exercise," Fritz proposed. "For athletes doing high level training that results in muscle soreness or extreme events — like marathons or ultras or century rides — these solutions could provide some noticeable benefits."

Clemente-Suárez added, "Polyphenol-rich foods like pomegranate juice, tart cherry and blueberries have demonstrated reductions in muscle soreness and oxidative damage after resistance and endurance exercise."

Other bioactive compounds are available that are not classical antioxidants but, like polyphenols, support the body's own antioxidant defenses. "Melatonin and L-carnitine have also shown potential in reducing biomarkers of muscle damage and improving recovery," Clemente-Suárez stated. "These substances act through multiple mechanisms and generally avoid over-suppressing ROS signaling."

The research dilemma

Plenty of positive research has been done regarding the benefits of antioxidants. Studies regarding elite athletic performance and recovery are rarer. Athletes' unique physiologies make them tricky research subjects.

On the one hand, Wadley shared, "Athletes are usually quite good at performance tests because they can replicate a time trial quite accurately and get consistency." On the other hand, he countered, "They also have a smaller room for improvement, which makes it harder to detect."

Jose A. L. Calbet, M.D., Ph.D., a professor at the University of Las Palmas de Gran Canaria's Department of Physical Education, explained further, "The problem when you are dealing with elite athletes is that they are at the limit of adaptation. They have already enhanced antioxidant capacity. When you want to study them, it's much more difficult because the potential effect of an antioxidant will be very small compared to a person not trained at all."

click to go!

read

Tangeretin plus whey protein helps athletes breathe better

A little-known citrus flavonoid was shown, when used with whey protein, to help athletes suffering from exercise-induced asthma.

Still, some research is out there. For example, a 2024 systemic review in the Journal of Functional Foods looked at athletic men and the effect of the antioxidant astaxanthin. The phytonutrient — found in some microalgae and the sea life that eats it — was shown to potentially improve cycling trial time and increase total antioxidant capacity.

Clemente-Suárez was the lead author on a 2023 article in the journal Nutrients. The piece cited an exhaustive range of studies regarding various antioxidants and their impact on athletes, concluding, "Micronutrients play an important role in counteracting free radicals, such as reactive oxygen species, which cause oxidative stress, and the effects of antioxidants on recovery, sports performance and strategies for using antioxidant supplements, such as vitamin C, vitamin E, resveratrol, coenzyme Q10, selenium and curcumin, to enhance physical and mental well-being."

An ideal strategy

An effective antioxidant protocol depends on an athlete's goals and needs. Obviously, exercise and rest will play a role, as will what the person consumes.

Wadley opined, "Call me old-fashioned, but I'd prefer to start with a really well-balanced diet. For the vast majority of people, including the vast majority of athletes, I think that would be sufficient — but there are probably a couple of extreme examples where they might benefit from some supplement as well."

That said, Fritz indicated the targeted nature of supplementation may offer some advantages. "Getting adequate fruits and vegetables certainly helps support health and well-being," she acknowledged, "but from an 'optimal dose' perspective, if you look at the doses of polyphenols that have shown to provide benefits for performance and recovery, the translation into whole fruit and vegetable intake would be difficult to achieve."

Calbet recommended an athlete could try antioxidants to see if they work, and then "make a decision depending on the outcome." But in general, he noted, "If there is an effect, it's going to be very small."

However, as any serious athlete knows, small effects matter. Sometimes, just five-thousands of a second can mean the difference between winning the silver or the gold. ■

Denis Faye is a nutrition communications consultant and committed competitive athlete who splits his time between writing, riding, running and raising his family. Occasionally, he sleeps.