

**Review Article**

Dietary Supplements for Swimming Performance: A Critical Review of Performance Effects and Safety

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The use of performance-enhancing sport supplements among competitive swimmers has increased substantially in recent years, with growing adoption observed even at young ages. This trend appears to be driven in part by social media exposure, marketing strategies, and influence from peers, coaches, and online personalities, often preceding a clear understanding of supplement efficacy, safety, or regulatory status. Although many supplements are marketed to improve design and recovery, only a limited number are supported by scientific evidence and well-designed clinical trials. Furthermore, data regarding effectiveness in youth athletes, particularly swimmers, remain particularly sparse. Given these concerns, a critical evaluation of supplement use in competitive swimming is warranted. The objective of this review is to review the existing literature on commonly used supplements in swimming and evaluate their effect on swimming performance, as well as considerations related to safety and appropriateness for younger athletes. The purpose of this review is to provide an update to athletes, coaches, parents, and healthcare professionals about the efficacy and potential risks associated with sports supplement use in competitive swimming.

Introduction

Interest in the use of dietary supplements among competitive swimmers has grown substantially in recent decades. Evidence among competitive swimmers shows that there has not only been increased use but also increased reliance on multiple supplements over time. For example, Shaw et al. reported that elite Australian swimmers used more supplements in 2009 compared with 1998 (9.2 ± 3.7 vs. 5.9 ± 2.9 ; $p = 0.001$), with 97% of athletes reporting some form of supplementation (Shaw, Slater et al. 2016). Furthermore, Knapik, et al. estimated that supplement use among athletes ranges from 37% to 89%, with the highest prevalence observed in elite level athletes (Knapik, Steelman et al. 2016). These findings indicate the increased normalization of supplement use in competitive swimming and suggest the need for critical evaluation of their efficacy and safety.

Position statements from the American Academy of Pediatrics and the American College of Sports Medicine (ACSM) indicate that dietary supplement use is growing more frequently among adolescents. Frequently used products include protein powders

which are used by approximately 54.5% of youth athletes, caffeine, and creatine which is used by 25-40% of athletes. Percentage of athletes using creatine has been seen growing significantly from 9th to 12th grade suggesting the increased normalization of supplementation in young athletic populations (Cote, Wilson et al. 2016, Putukian, Leclerc et al. 2026).

Dietary supplement use among athletes is largely shaped by external factors such as social media, peers, coaches, and commercial marketing. The ACSM has stated that athletes often have limited amounts of knowledge regarding the efficacy and safety of supplements and often have to rely on informal sources such as coaches, teammates, friends, and the internet rather than qualified health professionals. Similarly, joint position statements from the ACSM, the Academy of Nutrition and Dietetics (AND), and Dietitians of Canada (DC) emphasized that supplementation practices are frequently driven by non-expert advice and retailer or marketing claims (Putukian, Leclerc et al. 2026).

Despite widespread use, only a limited number of supplements are supported by robust scientific evidence for performance

enhancement. The International Olympic Committee's statement identifies a small group of supplements including caffeine, creatine, certain buffering agents, and dietary nitrate, as ones that have consistent evidence of improving performance in certain contexts (Maughan, Burke et al. 2018). However, there still remains a lack of extensive evidence for aquatic sports, with only potential benefits for creatine, caffeine, and buffering agents in certain scenarios (Derave and Tipton 2014).

Data and evidence in youth athletes, particularly in swimmers, is limited despite the susceptibility of this population to social media and commercial marketing. This poses the risk of further amplifying the adoption of supplements without evidence or professional guidance. The American Academy of Pediatrics (AAP) highlights the lack of safety data for commonly used supplements such as creatine in adolescent populations. Evidence for caffeine use in young swimmers is also limited and inconclusive, with at least one study in late-adolescent competitive swimmers showing no improvement in short-distance performance (Newbury, Saunders et al. 2022). The limited amount of supplement research in swimming, particularly in adolescents represents a critical gap in knowledge of the safety and efficacy of supplementation.

Methods

A narrative literature review was conducted to evaluate dietary supplements used in competitive swimming. Searching was performed in PubMed, Scopus, and Google Scholar. Articles published in English through March 2026 were considered. Keywords included "swimming," "dietary supplements," "ergogenic aids," "creatine," "caffeine," "beta-alanine," and "sodium bicarbonate." Additional terms were used as needed to capture swimmer-specific evidence.

Peer-reviewed randomized controlled trials, systematic reviews, meta-analyses, and consensus statements were included. Priority was given to swimmer-specific studies and major sports nutrition guidelines, including those from the International Society of Sports Nutrition and related organizations. Studies were synthesized narratively. This was due to heterogeneity in populations, dosing protocols, and performance outcomes. No meta-analysis was performed.

Results

Evidence-Based Supplements with Strong Support

Creatine Monohydrate

Creatine monohydrate is one of the most extensively studied performance enhancing supplements. Three decades of research and more than 500 peer-referenced publications have supported its role in improving exercise performance, recovery, and health (Antonio, Candow et al. 2021, Kerksick, Gonzalez et al. 2026), findings that are supported by the International Society of Sport Nutrition (ISSN) (Kreider, Kalman et al. 2017).

The performance enhancing effects of creatine supplementation are explained by increasing intramuscular creatine and phosphocreatine concentrations, which support faster ATP resynthesis during high-intensity efforts. However, additional supplementation in individuals who have already reached near-maximal baseline levels (≈ 20 g/kg dry muscle mass) show no additional benefit in phosphocreatine stores, ATP resynthesis, performance, or uptake (Casey and Greenhaff 2000, Terjung, Clarkson et al. 2000). Traditional supplementation of creatine involves a loading phase of ~ 20 g/day for 5-7 days followed by a maintenance of 3-5g/day, however, ACSM data show that daily intakes of ~ 3 g can achieve similar saturation over time (Terjung, Clarkson et al. 2000). Recent studies support consumption of ~ 0.1 g/kg/day.

Although evidence for creatine's effect on swimming performance is mixed, swimmer-specific studies suggest benefits in certain contexts. In competitive junior swimmers (mean age 16.4), four weeks of supplementation did not improve single 50-m or 100-m freestyle sprint times, though it did increase performance in a bench test (Dawson, Vladich et al. 2002). In trained swimmers (mean age 19), six days of creatine loading phase improved performance in repeated 50m sprints, reducing the decline of speed and diminished increase in heart rate when compared with placebo (Dabidi Roshan, Babaei et al. 2013). Similarly, in elite male swimmers, 5 days of 9 g/day creatine supplementation reduced performance dropoff during repeated sprints (8x50 yards) from 5.5% in control groups to 2.5% with supplementation (Hopwood, Graham et al. 2006). These findings indicate that creatine does not enhance performance in a single sprint but may improve fatigue resistance during repeated high-intensity sets (Hopwood, Graham et al. 2006) (Table 1).

Supplement	Dose & Timing	Mechanism of Action	Performance Improvement Area	Potential Risks
Creatine monohydrate	*Loading (optional): 20 g/day (5–7 days); maintenance: 3–5 g/day (~0.1 g/kg/day); timing flexible	Increases phosphocreatine stores → enhances ATP resynthesis during high-intensity exercise	Strength, power, repeated short bursts (anaerobic)	Water retention, weight gain, mild GI discomfort; caution in renal/hepatic conditions
Caffeine	3–6 mg/kg ~60 min pre-exercise; lower doses (~2 mg/kg) effective; gum: ~10 min prior	Adenosine receptor antagonism → ↑ CNS stimulation, ↓ perceived effort/pain; enhances neuromuscular function	Aerobic endurance, alertness, strength, power, sprint performance (broad effects)	Insomnia, jitteriness, GI discomfort; dose-dependent; individual variability
Beta-alanine	4–6 g/day in divided into multiple doses for ≥2–4 weeks (optimal 4–8 weeks); maintenance ~1.2 g/day	Increases muscle carnosine → intracellular pH buffering; delays acidosis and improves muscle function	High-intensity efforts (1–4 min), repeated sprints, fatigue resistance	Paresthesia (tingling), dose-related; minimized with divided dosing
Sodium bicarbonate	0.2–0.3 g/kg 60–90 min pre-exercise	Increases blood bicarbonate and pH → enhances H ⁺ efflux and delays acidosis	High-intensity efforts (45 sec–8 min), especially middle-distance performance	Gastrointestinal distress (common) may require dosing strategies to tolerate

Table 1: Common Supplements used by Swimmers.

Generally, creatine is well tolerated in adults with research showing no increase of adverse side effects than placebo and evidence supporting the safety of long-term use at doses of up to 30 g/day for as long as five years. Although water-related weight gain in early phases of supplementation and gastrointestinal discomfort are common (Kreider, Kalman et al. 2017, Antonio, Candow et al. 2021). Concerns about dehydration, muscle injury, and kidney damage are merely anecdotal and aren't backed by controlled studies (Poortmans and Francaux 2000). Furthermore, the American Academy of Pediatrics take a more cautious position for adolescents, citing that creatine has not been formally studied for safety in youth raising concerns about kidney stress from creatine metabolites (Kreider, Kalman et al. 2017, Antonio, Candow et al. 2021).

Caffeine

Caffeine is one of the most well-studied performance enhancing substances, with research showing reliable performance benefits across many different types of exercise. According to the ISSN, certain levels of caffeine intake produce small to moderate improvements in muscular endurance, strength, and explosiveness in various activities (Guest, VanDusseldorp et al. 2021).

Caffeine's primary mechanism for performance enhancement involves blocking adenosine receptors in the central nervous system which results in a set of physiological reactions that increase focus while reducing perception of effort and pain (Barreto, Grecco et al. 2021). Additionally, benefits may include enhanced calcium release from the sarcoplasmic reticulum as well

as neuromuscular function (Guest, VanDusseldorp et al. 2021). Performance benefits are consistently observed with doses of ~3-6 mg/kg body mass (Southward, Rutherford-Markwick et al. 2018, Guest, VanDusseldorp et al. 2021) with doses as low as 2mg/kg also resulting in effective responses. Very high intakes (≥9 mg/kg) may result in adverse side effects without improving performance (Guest, VanDusseldorp et al. 2021). Optimal timing depends on the source of caffeine: with capsules needing to be taken around 60 minutes before exercise while caffeine gums can act within about 10 minutes (Grgic 2021). Various delivery methods have also been shown to be effective, particularly in aerobic exercise (Guest, VanDusseldorp et al. 2021). Although there has been research on the impact genetic variants such as CYP1A2, ADORA2A, and HTR2A on individual responses to caffeine but inconsistent findings restrict the use of genotyping to guide performance-based caffeine intake (Pickering and Kiely 2018, Barreto, Grecco et al. 2021).

Evidence for caffeine's effect on swimming has been mixed: a 2025 systematic review and meta-analysis of 10 randomized trials (n=121 swimmers) found no significant improvements in short-distance swim times, swimming velocity or power after acute caffeine intake, though these results were considered preliminary due to the small samples and heterogeneity of the subjects (Huang, Huang et al. 2025). In contrast, individual studies report benefits in sprint contexts: elite male swimmers that were given 3 mg/kg caffeine improved mean sprint performance by ~1.3% across six 75-m freestyle sprints with most of the improvement coming mid-set (Goods, Landers et al. 2017), and sprint swimmers showed

improvement of ~0.3 s in the 50m and greater power after the same 3mg/kg dose (Lara, Ruiz-Vicente et al. 2015). The ISSN has stated that caffeine in that dosage range is beneficial to endurance and may be beneficial to sprint performance as well. However, studies in adolescent athletes have shown that improved performance is more prevalent at the higher doses (6mg/kg) which includes aerobic endurance, strength, and jump performance (Spineli, Pinto et al. 2020, Dos Santos, Spineli et al. 2023). The American Academy of Pediatrics notes that caffeine at 1-3 mg/kg enhances performance in endurance activity showing 4% improved knee extensor strength, 14% in muscular endurance and a 10-20% improvement in time to exhaustion (LaBotz, Griesemer et al. 2016) (Table 1).

Safety concerns in adolescents are significant however: potential adverse effects include cardiac arrhythmias, increased blood pressure, headaches, irritability, sleep disruption, and gastric irritation (LaBotz, Griesemer et al. 2016). In 2011, energy drink consumption led to almost 1500 emergency department visits in the 12-17 age group, and pure powdered caffeine has been responsible for at least two deaths in young people. (LaBotz, Griesemer et al. 2016), While moderate caffeine consumption (<400 mg) appears to be relatively safe in adolescents, higher doses can cause physiological, psychological, and behavioral harm, particularly in those with outstanding psychiatric or cardiac conditions.

Beta-Alanine

Beta-alanine supplementation improves high-intensity exercise performance by increasing muscle carnosine content, which enhances intracellular buffering capacity and delays fatigue (Artioli, Gualano et al. 2010, Trexler, Smith-Ryan et al. 2015, Saunders, Elliott-Sale et al. 2017). Benefits are observed in efforts lasting 1–10 minutes, with the most pronounced effects in exercise capacity tests (e.g., time-to-exhaustion) lasting 1–4 minutes (Saunders, Elliott-Sale et al. 2017).

Beta-alanine is the rate limiting precursor in carnosine synthesis in skeletal muscle (Artioli, Gualano et al. 2010, Matthews, Artioli et al. 2019). Carnosine functions primarily as an intracellular pH buffer, neutralizing hydrogen ions generated during high-intensity exercise, thus reducing intramuscular acidosis which is a key contributor to fatigue (Artioli, Gualano et al. 2010, Matthews, Artioli et al. 2019). Additional potential mechanisms include scavenging of reactive oxygen species and acting as a cytoplasmic calcium-hydrogen exchanger (Matthews, Artioli et al. 2019). A 2025 systematic review reported that daily beta-alanine intakes of 3.0-6.4 g for a minimum of 4 weeks, particularly when divided into smaller doses (eg, 1g taken multiple times per day) were more likely to enhance strength and power (Trexler, Smith-Ryan et al. 2015). In addition, higher daily doses (5.6–6.4 g/day) appear to produce greater performance enhancing effects, with a reported effect size of 0.35 (Georgiou, Antoniou et al. 2024). After the

initial loading phase, a maintenance dose of ~1.2 g/day is enough to sustain concentrations of carnosine concentrations of 30-50% above baseline over prolonged periods (Stegen, Bex et al. 2014). Beta-alanine supplementation is most impactful during training phases characterized by high metabolic stress such as high-volume training with short rest (Ong, Chen et al. 2025).

Beta-alanine supplementation shows strong evidence for improving swimming performance in young adults, particularly in the 100m and 200m events, with trials showing performance improvements of 1.5-2.1% in competitive swimmers (Painelli Vde, Roschel et al. 2013, Brisola and Zagatto 2019). A study in 16 competitive swimmers after 5 weeks of supplementation (3.2 g/day for week 1, then 6.4 g/day for 4 weeks) demonstrated 2.1% improvement in 100m and 2.0% improvement in 200m time-trial performance (Painelli Vde, Roschel et al. 2013). A meta-analysis specifically examining trained adult males (ages 18-40) found a significant overall effect size of 0.39 (95% CI 0.09-0.69, $p = 0.01$) for maximal intensity exercise that lasted 0.5-10 minutes, with optimal effects at 4 weeks of supplementation using higher doses of 5.6-6.4 g/day (Georgiou, Antoniou et al. 2024). The recommended dosage for young adult swimmers is 6.4g/day divided into multiple doses for at least 4-5 weeks before competition with additional supplementation of sodium bicarbonate potentially providing additional benefits (78.5% probability of positive effect for 200m events) (Painelli Vde, Roschel et al. 2013, Lancha Junior, Painelli Vde et al. 2015).

Beta-alanine appears safe in young athletes, with the only reported side effects being paresthesia (tingling) when a single dose exceeds 800mg which can be prevented with smaller doses of ≤ 1.6 g (Artioli, Gualano et al. 2010, Dolan, Swinton et al. 2019).

A small increase in alanine aminotransferase was observed with supplementation (effect size: 0.274), though the mean values remained well within clinical reference ranges (Dolan, Swinton et al. 2019). Additionally, research has shown no effect on skeletal muscle taurine or histidine concentrations in humans at typical doses and dropout rates were similar with the placebo groups, showing good tolerability (Dolan, Swinton et al. 2019). The ISSN has concluded that beta-alanine supplementation appears to be safe in healthy populations at dosages of 4-6g daily (Trexler, Smith-Ryan et al. 2015) (Table 1).

Sodium Bicarbonate

Sodium bicarbonate supplementation improves performance in high-intensity exercise lasting from 30 seconds to 12 minutes (Grgic, Pedisic et al. 2021). A meta-analysis of 189 studies with 2019 total participants found an overall effect size of 0.17 for exercise capacity and performance, greatest effects were shown for exercise durations 0.5–10 min and >10 min (de Oliveira, Dolan et al. 2022).

Sodium bicarbonate when taken in dosages of 0.3 g/kg enhances high-intensity exercise performance by increase bicarbonate concentration in blood (~5 mmol/L), creating a stronger pH gradient that facilitates H⁺ and lactate efflux from working muscles through monocarboxylate transporters and sodium/hydrogen exchangers (de Oliveira, Dolan et al. 2022, Thomas, Delfour-Peyrethon et al. 2023). During intense exercise, intracellular pH drops from ~7.0 to as low as 6.2 in fast-twitch fibers which impairs muscle function by reducing Ca²⁺ sensitivity and peak power (~22%) (Cairns and Lindinger 2025). This extracellular buffering mechanism complements beta-alanine's intracellular buffering via carnosine, potentially producing additional performance enhancing effects when taken together (Lancha Junior, Painelli Vde et al. 2015). The ISSN recommends taking sodium bicarbonate 60-180 minutes before exercise, with the peak blood bicarbonate concentration occurring around 60 minutes for doses of 0.3 g/kg (Grgic, Pedisic et al. 2021). While doses of 0.2g/kg are best taken 40-50 minutes before exercise (Siegler, Midgley et al. 2010). To minimize gastrointestinal side effects, sodium bicarbonate is best taken with a high carbohydrate-meal, use of enteric-coated capsules, or extending timing to ~180 minutes before exercise may be beneficial (Grgic, Pedisic et al. 2021).

Sodium bicarbonate demonstrates performance enhancing effects for young adult swimmers, especially in repeated sprint swimming rather than single time-trial events. In regionally trained male swimmers, sodium bicarbonate taken 60 minutes before exercise improved performance in sprints 5-8 of an 8x50m sprint interval workout with effect sizes increasing progressively from 0.26 to 0.79 (Gough, Newbury et al. 2023). In competitive swimmers showed a 2% decrease in total swim time during an 8x25m sprint workout with sodium bicarbonate supplement (Siegler and Gleadall-Siddall 2010). However, in well-trained young swimmers (mean age 22 ± 3 years), individualized timing of sodium bicarbonate intake did not improve 200-m or 400-m freestyle time-trial performance, though it did reduce perceived exertion and increased post-exercise blood lactate, pointing to enhanced lactate efflux (Gurton, Dabin et al. 2025). The ISSN recommends ingestion 60–180 minutes before swimming events lasting 30 seconds to 12 minutes, with benefits most significantly seen in repeated-bout swimming such as interval training or multiple heats (Grgic, Pedisic et al. 2021). Wever, in adolescent swimmers (mean age 15.9 years), time to peak blood bicarbonate concentration was approximately 130 ± 35 minutes, showing that in younger swimmers individualized intake timing may be helpful (Newbury, Cole et al. 2021).

Common side effects of sodium bicarbonate are gastrointestinal disturbances, including bloating, nausea, vomiting, abdominal pain, and diarrhea, occurring in approximately 30% of athletes versus 3% with placebo (Miller, Bhattacharyya et al. 2025). Strategies to minimize side effects include using lower doses (0.2–0.3 g/kg),

extending timing to ~180 minutes pre-exercise, co-ingesting with a high-carbohydrate meal, using enteric-coated capsules (which reduce symptom severity from 7.0 to 2.8 arbitrary units (Hilton, Leach et al. 2020), or employing multiple-day loading protocols (Grgic, Pedisic et al. 2021) (Table 1).

Emerging Supplements with Promising Evidence

Royal Jelly Plus Coenzyme Q10

Royal jelly plus coenzyme Q10 (RJ+CoQ10) may improve performance in high intensity swimming in young adults by reducing oxidative stress and muscle damage. A randomized, double-blind trial of 20 high-levels young male swimmers, mean age 19.30, found that 10 days of supplementation with 400 mg of royal jelly along with 60mg of CoQ10 significantly improved performance in high-intensity interval swimmer performance, compared to the placebo group, with reduced lipid peroxidation and creatine kinase markers (Ovchinnikov, Paoli et al. 2022). On the other hand, supplementation of CoQ10 alone (300 mg/day for 14 days) in elite adolescent swimmers prevented adverse changes in antioxidant enzymes during heavy training (Emami, Tofighi et al. 2018). However, the effect of CoQ10 alone has limited evidence for increasing exercise performance (Deng, Song et al. 2025).

Bioactive Peptides

Bioactive peptides usually consist of 2-30 amino acids that are derived from food proteins through enzymatic hydrolysis including whey protein hydrolysates, collagen peptides, soy peptides, and animal-derived peptides like CMS001 from pig spleen. The potential mechanism through which they enhance sports performance is through improving muscle repair, anti-fatigue effects, and increased mitochondrial function. However, there is currently limited evidence relating the consumption of bioactive peptides to these effects. Whey protein hydrolysates reduced muscle soreness at 24 hours and increased anti-inflammatory IL-10 in adolescent swimmers (ages 11–17), however, no improvement in 200m swim was observed (McKinlay, Theocharidis et al. 2020). Collagen peptide when taken in doses of 5-15/day for ≥8 weeks improve tendon morphology, fat-free mass, and 48-hour recovery beneficial for repetitive shoulder movements in healthy adults (Bischof, Moitzi et al. 2024). CMS001 prolonged exhaustive swim time in mice by protecting mitochondria and enhancing antioxidant capacity (Wang, Zhang et al. 2008). Limitations of this type of supplementation include the low to moderate quality of evidence, the lack of studies involving elite swimmers, lack of swimmer-specific human trials, unclear optimal dosing protocols, and insufficient evidence that protein hydrolysates are superior to intact proteins for promoting muscle anabolism (Khatri, Naughton et al. 2021, Morgan and Breen 2021).

Glutamine

Glutamine, the most abundant amino acid in plasma and skeletal muscle, has limited evidence supporting supplementation improving athletic performance. However, it may benefit recovery and immune function. 2019 meta-analysis of 47 studies found no significant effect of glutamine supplementation on aerobic performance, VO₂max, body composition, or immune cell counts in athletes (Ramezani Ahmadi, Rayyani et al. 2019). Glutamine supplementation at 0.3 g/kg/day reduced muscle soreness at 24–72 hours post-exercise (Legault, Bagnall et al. 2015), decreased upper respiratory tract infection incidence, and improved testosterone/cortisol ratio in combat-sport athletes (Lu, Zheng et al. 2024). Glutamine supplementation does not directly improve swimming performance, though it may offer indirect support for recovery and immune health during intense training. The ACSM categorizes glutamine among supplements that “may perform as claimed but for which there is insufficient evidence”. Glutamine supplementation at doses up to 14 g/day has strong evidence of safety in healthy young adults, with acute intakes of 20–30 g appearing well tolerated in athletes and doses up to 0.65 g/kg body mass not resulting in abnormal plasma ammonia levels; adverse effects are generally limited to mild gastrointestinal symptoms, and no detrimental effects on renal function have been observed in individuals without underlying kidney disease (Shao and Hathcock 2008).

Branched-Chain Amino Acids (BCAAs)

BCAAs, including leucine, isoleucine, and valine, are essential amino acids that reduce muscle soreness and muscle damage markers but have limited evidence for improving direct athletic performance. 2021 meta-analysis of 25 studies found significantly lower levels of creatine kinase, lactate dehydrogenase, and myoglobin at 48 hours post exercise as well as reduced muscle soreness at 24–72 hours post exercise. However, no significant improvement in muscle performance recovery (Doma, Singh et al. 2021). The optimal intake for BCAAs is 2–10g/day with a 2:1:1 ratio of leucine to isoleucine to valine 3 days before to immediately after exercise, with benefits being most apparent in subjects currently experiencing mild-to-moderate muscle damage (Arroyo-Cerezo, Cerrillo et al. 2021, Weber, Dias et al. 2021). no swimmer-specific studies exist, though potential benefits include reduced delayed-onset muscle soreness between training sessions. BCAA supplementation does not directly improve swimming performance, but the evidence supports benefits for muscle damage reduction, soreness attenuation, and immune function. The ACSM categorizes amino acids among supplements that “do not perform as claimed”. BCAA supplementation at typical doses of 10–20 g/day is generally well tolerated in young adults, with the tolerable upper intake level for leucine alone established at approximately

35 g/day (~500 mg/kg/day) in healthy young men based on acute dose-response studies, and adverse effects limited mainly to mild gastrointestinal symptoms at high doses, though elevated circulating BCAA levels have been epidemiologically associated with insulin resistance and cardiometabolic risk (Elango, Chapman et al. 2012, Holeccek 2022).

L-Carnitine

L-carnitine is an endogenous compound that potentially enhances fat utilization and sparing muscle glycogen during exercise; however, most studies show no significant improvement in exercise performance in healthy athletes (Heinonen 1996, Brass 2000). Oral supplementation increased plasma carnitine but did not increase muscle carnitine content (Brass 2000). One exception that has been seen is when L-carnitine was consumed at 2g/day along with 80g of carbohydrates for 24 weeks, carnitine concentration in muscle increased by 21% resulting in glycogen sparing at low intensity, reduced lactate at high intensity and an 11% improvement in work output (Wall, Stephens et al. 2011). A meta-analysis found L-carnitine reduces muscle soreness and damage markers (CK, LDH, myoglobin) at 24 hours post-exercise (Yarizadh, Shab-Bidar et al. 2020). Typical dosing is 1–4g/day, and while generally safe, supplementation over a long period of time can elevate plasma trimethylamine-N-oxide (TMAO), which is a potentially pro-atherogenic compound, warranting concern regarding long-term cardiovascular effects (Sawicka, Renzi et al. 2020). The 2009 ACSM Position Stand classified L-carnitine among supplements that “do not perform as claimed” for performance enhancement (American Dietetic, Dietitians of et al. 2009). L-carnitine supplementation at doses up to 2,000 mg/day is considered safe for chronic use in young adults, with a risk assessment identifying strong evidence of safety at this level and only mild gastrointestinal side effects reported, though long-term supplementation may elevate plasma TMAO, a compound with potential pro-atherogenic implications (Hathcock and Shao 2006).

Antioxidant Supplements

There is limited evidence that antioxidant supplements—including vitamins C and E, β -carotene, and selenium—enhance athletic performance. Moreover, chronic high-dose antioxidant supplementation may impair training adaptations by attenuating reactive oxygen species-dependent signaling pathways involved in mitochondrial biogenesis, endogenous antioxidant defense, and muscle hypertrophy (Merry and Ristow 2016, Higgins, Izadi et al. 2020). A meta-analysis found combined vitamins C and E can attenuate lipid peroxidation, inflammatory cytokine IL-6, cortisol, and creatine kinase post-exercise, but had no effect on muscle soreness or strength (Santos de Lima, Schuch et al. 2023). The ISSN Position Stand (Gonzalez, Dickerson et al. 2026)

recommends supplementation only for nutrient deficiencies or periods of high training stress, emphasizing whole-food sources as preferred for antioxidants. Additionally, doses that exceed the tolerable upper Intake Level may increase oxidative stress. Vitamin E may benefit athletes training at altitude, and acute antioxidant intake may provide short-term recovery benefits (Braakhuis and Hopkins 2015). Overall, a diet rich in fruits, vegetables, and whole grains remains the safest and most effective strategy for meeting antioxidant needs in athletes.

Ginseng

Ginseng is marketed as a supplement that enhances energy and reduces fatigue. No swimmer-specific studies on ginseng supplementation were identified in the literature. Based on general research regarding endurance and aerobic exercise, ginseng's potential benefits for swimmers may include reduced lactate accumulation, improved VO₂max, increased exercise time before exhaustion, and accelerated muscle recovery (Szymanska, Nowak et al. 2024, Zhang, Shang et al. 2026). A meta-analysis found ginseng significantly increased exercise time before exhaustion and VO₂ max in human studies which are direct factors of swim performance (Szymanska, Nowak et al. 2024). Ginseng appears generally safe in young adults at doses of 200 mg to 2 g/day for up to 4–16 weeks, with adverse events similar to placebo and limited to mild symptoms such as headache, insomnia, and gastrointestinal discomfort (Coon and Ernst 2002). However, important cautions include potential drug interactions (particularly with warfarin and hypoglycemic agents), estrogen-like hormonal effects, and the lack of dedicated safety studies specifically in adolescents (Liperoti, Vetrano et al. 2017).

HMB (β-Hydroxy-β-Methylbutyrate)

HMB is a leucine metabolite that works through enhancing muscle protein synthesis and reducing muscle protein breakdown, making it effective for reducing muscle damage and promoting recovery (Rathmacher, Pitchford et al. 2025)(Wilkinson, Hossain et al. 2013). The 2025 ISSN Position Stand recommends supplementation at 3g/day, noting improvements in body composition, strength, and power particularly in untrained individuals during high intensity training periods, with benefits increasing >6 weeks (Rathmacher, Pitchford et al. 2025). A meta-analysis found HMB significantly improves endurance performance and VO₂max (Durkalec-Michalski and Jeszka 2015, Fernandez-Landa, Todorovic et al. 2024). Currently, no swimmer specific studies exist but the demonstrated aerobic and recovery benefits could theoretically benefit young swimmers during high volume training. HMB at the standard dose of 3 g/day is considered safe for chronic consumption in young adults, with the ISSN position stand confirming safety for both calcium HMB and free acid HMB forms for up to at least one year, no adverse effects on glucose tolerance or insulin sensitivity

(Rathmacher, Pitchford et al. 2025).

Omega-3 Fatty Acids

Omega-3 fatty acids (EPA/DHA) work by inhibiting NF-κB activation and promoting synthesis of specialized pro-resolving mediators, enhancing inflammation resolution and tissue repair while increasing cellular antioxidant capacity (Li and Zhang 2026). The 2025 ISSN Position Stand supports omega-3 supplementation for enhancing endurance capacity, cardiovascular function, reducing muscle soreness, and supporting immune function in athletes (Jager, Heileson et al. 2025). A 2026 meta-analysis found ≥2 g/day EPA+DHA for ≥6 weeks significantly reduced inflammatory markers (IL-6, TNF-α), creatine kinase, and delayed-onset muscle soreness (Li and Zhang 2026). In runners, 12 weeks of supplementation improved VO₂ peak by ~4.5% (Tomczyk, Jost et al. 2023). No swimmer-specific studies exist, but the endurance and recovery benefits are relevant to swimming's aerobic demands. Omega-3 fatty acid supplementation is generally safe and well tolerated in young adults, with a systematic review and meta-analysis of 90 RCTs confirming no serious adverse events and only mildly increased odds of diarrhea, dysgeusia (fishy taste), and bleeding tendency compared to placebo (Chang, Tseng et al. 2018, Chang, Tseng et al. 2023).

Vitamin D

Vitamin D acts through the vitamin D receptor (VDR) in skeletal muscle, regulating myocyte proliferation, type II muscle fiber size, calcium homeostasis, and reducing inflammation (Abrams, Feldman et al. 2018). Meta-analyses show supplementation improves lower-limb muscle strength, particularly in indoor-training athletes (Zhang, Quan et al. 2019), and 2000 IU/day for 12 weeks improved VO₂max and anaerobic power in active males (Ramezani Ahmadi, Mohammadshahi et al. 2020). For swimmers, a study in NCAA Division 1 swimmers found 4,000 IU/day maintained sufficient vitamin D status over 6 months while placebo athletes experienced a 50 nmol/L decline, highlighting that indoor pool training increases deficiency risk—though no direct performance outcomes were measured. Supplementation ≥2000 IU/day also attenuates muscle damage and inflammation post-exercise (Rojano-Ortega and Berral-de la Rosa 2023). Benefits are most evident in deficient individuals; the ACSM states that current data does not support vitamin D as a performance enhancing supplement for non-deficient athletes (Byers, Connolly et al. 2020). Vitamin D supplementation at doses up to 4,000 IU/day is generally considered safe in young adults, with the tolerable upper intake level set at 4,000 IU/day by the National Academy of Medicine, toxicity being rare and typically occurring only at doses exceeding 10,000 IU/day with serum 25(OH)D levels well above 150 ng/mL, and studies in healthy young adults showing no clinically relevant disturbances in calcium, magnesium, or

parathyroid hormone levels even at doses up to 8,000 IU/day when monitored (Kralova, Jirasko et al. 2025).

Discussion and Conclusion

Based on current evidence, the supplements with the strongest support for swimming specific performance enhancement are creatine monohydrate, caffeine, beta alanine, and sodium bicarbonate. Creatine monohydrate is most effective for repeated sprint ability and high intensity training and can be consumed using a loading protocol of 20 g/day for 5–7 days followed by 3–5 g/day, or as 3 g/day without loading (Table 1). Caffeine is recommended at 3–6 mg/kg body mass approximately 60 minutes before competition, with attention to individual sensitivity, genetic variability, and avoidance of late day use to protect sleep. Beta alanine should be taken at 4–6 g/day in divided doses for 4–8 weeks and is most beneficial for events lasting ~1–4 minutes (100–200 m). Sodium bicarbonate (0.2–0.3 g/kg body mass 60–90 minutes pre-event) may enhance performance during high intensity efforts, but gastrointestinal tolerance should be assessed individually. Supplement use should be periodized alongside training cycles, with creatine and beta alanine loading initiated well before key competitions, caffeine used strategically to preserve sensitivity, and sodium bicarbonate trailed during training rather than introduced for the first time in competition.

Dietary supplementation for sport performance enhancement should ideally be personalized based on an individual athlete's baseline nutrient and metabolic status. The IOC Consensus Statement on dietary supplements emphasizes that a complete nutritional assessment should be undertaken before decisions regarding supplement use are made, and that individual responses to performance enhance supplements vary widely due to genetics, microbiome, and dietary habit (Maughan, Burke et al. 2018). Although evidence supports that creatine monohydrate has great potential enhancing exercise performance. The magnitude of benefit from these supplements can depend on individual factors; for example, genetic variants in CYP1A2 influence caffeine metabolism, and baseline muscle creatine stores affect the response to creatine loading (Kerksick, Gonzalez et al. 2026). In addition, micronutrient supplementation in well-nourished athletes does not enhance physical performance, and excessive intake could impair the body's physiological adaptations to training stress (Beck, von Hurst et al. 2021). Conversely, correcting a diagnosed deficiency—such as iron deficiency impairing oxygen transport or vitamin D insufficiency compromising muscle function—can restore performance capacity that was otherwise limited (Rawson, Miles et al. 2018). Therefore, practitioners should use a robust framework that integrates physiological testing (e.g., VO_2max , lactate threshold, metabolic substrate utilization) and blood biomarker profiling (e.g., serum ferritin, 25-hydroxyvitamin D,

B vitamins) to develop individualized supplementation strategies tailored to training demands and competitive goals, rather than adopting a blanket supplementation approach (Rowland, Edwards et al. 2026).

All supplementation protocols should prioritize safety and anti-doping compliance, with products sourced exclusively from manufacturers that provide third party certification (e.g., NSF Certified for Sport or Informed Sport). Athletes are advised to maintain detailed records of supplement use and to consult qualified sports dietitians and team physicians before initiation. Overall, the strongest evidence for enhancing swimmer performance supports the use of creatine monohydrate, caffeine, beta alanine, and sodium bicarbonate, while emerging data suggest potential benefits from collagen peptides and combinations such as royal jelly plus coenzyme Q10, although further research is needed. In contrast, many commonly marketed supplements—including glutamine, BCAAs, L carnitine, antioxidants, ginseng, chromium picolinate, and HMB—lack robust evidence of benefit in trained athletes. Given the significant risk of supplement contamination, particularly in competitive swimming, careful product selection and professional oversight remain essential, and future research should prioritize swimmer specific trials and stronger industry quality assurance standards.

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