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RESEARCH ON THE SUPPLEMENTS TO IMPROVE ATHLETIC PERFORMANCE

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ABSTRACT

Athletes must have a solid foundation in physical conditioning, have experience in their chosen sport, and follow a specialised, periodized diet and training regimen. There may be a place for the use of evidence-based performance supplements once these underlying variables are taken into consideration and the athlete achieves a training and competition maturity where marginal improvements decide success. However, it's critical that any judgments about performance supplements take into account solid evidence suggesting that using a product is safe, acceptable, and beneficial. The review that follows focuses on the available data on a variety of popular (and newly developed) performance-enhancing drugs used in sports. Based on the strength of the evidence supporting their usage for improving sports performance, the supplements mentioned here are divided into three categories: (1) established (caffeine, creatine, nitrate); (2) equivocal (citrate, phosphate, carnitine); and (3) developing. The pertinent performance type, potential mechanisms of action, and the most often utilised procedures for the supplement dose schedule are outlined in each section.

Keywords: Periodized, Citrate, Supplements

1. INTRODUCTION

Peak athletic performance is influenced by many variables. Among these, a solid foundation in physical conditioning and expertise in the particular sport, as well as a customised and periodized nutrition programme, the latter of which is focused mostly on whole food choices, are vital. There may be a place for the use of evidence-based performance supplements once these underlying variables are taken into consideration and the athlete achieves a training and competition maturity where marginal improvements decide success. Despite the fact that a wide variety of supplements are sold to improve athletic performance, many of them lack conclusive proof of their ergogenic effects. Additionally, some may actually hinder performance, frequently because of gastrointestinal (GI) issues, while others may be harmful to an athlete's health. Finally, many substances used in commercial supplements run the danger of unintentionally breaking anti-doping rule, often appearing as contaminants or undeclared compounds. In light of this, athletes and the teams that support them should only take into account performance supplements in situations where a substantial body of research supports their use as safe, acceptable, and beneficial.

The review that follows focuses on the evidence base that is currently available for performance supplements that are frequently used in sports, summarising the kind of event or exercise scenario they are best suited for, any potential mechanisms by which they might have positive effects, and the usual dosing schedule or use protocols. According to the strength of the evidence supporting their usage for improving athletic performance, the relevant supplements have been categorised into three groups. There are three of these categories: established, equivalent, and emerging performance supplements.

2. ESTABLISHED PERFORMANCE SUPPLEMENTS

There is robust evidence that the following supplements can enhance sports performance when used according to established protocols.

Caffeine

The stimulant caffeine, which is included in the diets of the majority of humans, has long been known to improve athletic performance.

Adenosine receptor antagonism, greater endorphin release, improved neuromuscular function, increased attentiveness and alertness, and a decreased impression of exertion during exercise are the processes underlying these advantages. Caffeine supplementation has a long history of research in a variety of performance protocols, such as endurance-based activities, weight training exercises, brief supramaximal efforts, and/or repeat sprint tasks. The effectiveness of lower caffeine doses, differences in when to consume it before and/or during exercise, and the lack of a requirement for a withdrawal period for performance effect optimization are noteworthy recent developments in this field performance over time. Supplementing with caffeine is known to increase endurance capacity during time-to-fatigue exercise tasks, such as repetitions of weight training exercises until failure and treadmill jogging until exhaustion. Additionally, ergogenic advantages are frequently mentioned when participating in competitive activities like real or lab-simulated time trials (TTs). A systematic evaluation of 33 trials (representing 21 studies) conducted by Ganio et al. (2009) indicated that caffeine supplementation improved performance on average of ∼3.2% (±4.3%) when provided before and/or during endurance-based TT activities of varying duration (5–150 min), across numerous exercise modalities (i.e., cycling, running, rowing, cross-country skiing, and swimming). Studies reporting benefits typically used caffeine dosages of 3–6 mg/kg of body mass (BM), in the form of anhydrous caffeine (i.e., pill or powder form), consumed ∼60 min prior to exercise. However, there is also a growing body of work investigating the use of lower caffeine doses (<3 mg/kg BM, ∼200 mg), provided both before and during exercise, which also reports an ergogenic benefit (Spriet, 2014). Of note, larger caffeine doses (≥9 mg/kg BM) do not appear to increase the benefit to performance. In fact, such doses are likely to increase the risk of negative side effects, such as nausea, anxiousness, insomnia, and restlessness—outcomes that would clearly negate any performance- enhancing outcomes. Interestingly, similar performance outcomes are expected in both habituated caffeine users and nonusers, with recent research reporting that high habitual daily caffeine intake (defined as 351 ± 139 mg/day) was associated with equivalent absolute and relative performance benefits as seen in low and moderate daily caffeine consumers.

Low doses of caffeine consumed during endurance exercise have also been shown to enhance performance. In fact, 100–200 mg (1.5–2.9 mg/kg BM) of caffeine consumed in combination with a carbohydrate electrolyte solution after 80 min of a preload cycling task was shown to result in a ∼4–7% improvement during a sub- sequent TT completed in ∼26–28 min. Furthermore, 200–300 mg of caffeine administered in chewing gum form at the 10-km point of a 30-km cycling TT was shown to improve mean power output (+3.8%) during the final 10 km of the task, in addition to a 4% increase in peak sprint power output at the end of the task. In summary, caffeine supple- mentation provided both before and/or during endurance-based TT activities is likely to achieve positive performance outcomes.

Short-term, supramaximal, and repeated sprint tasks. The effects of caffeine on short-term, supramaximal, and repeated sprint tasks have been less well studied. Nevertheless, a systematic review of caffeine ingestion and high-intensity efforts of ≤5 min duration reported that ∼65% of studies resulted in performance benefits, with a mean task improvement of ∼6.5% (±5.5%; Astorino & Roberson, 2010). Specific protocols involving anaerobic activities include the study of a 1-km cycling TT, where caffeine ingestion (5 mg/kg BM consumed 60 min preexercise) was associated with a 3.1% improvement in task completion time, and a 3.1% and 8.1% improvement in mean and peak power output, respectively. Such performance benefits have also been realized during short-duration maximal dynamic resis- tance training exercise, where measures of muscle torque production were significantly improved after the consumption of 6 mg/kg caffeine in the 60 min prior to exercise. Furthermore, low caffeine doses administered in chewing-gum form (100 mg chewed for 5 min immediately preexercise) were shown to increase the distance thrown (+6%) by well-trained collegiate shot putters (Bellar et al., 2012). With respect to simula- tions of team sport activity, caffeine ingestion (6 mg/kg BM, 50 min before warm-up) improved total work performed during the first (+8.5%)

and second half (+7.6%) of a 2 × 36 min repeat- sprint protocol in moderately-trained team sport athletes. Furthermore, a 1% improvement in mean sprint time was shown, when 300 mg caffeine was provided 60 min prior to a rugby-specific repeated sprint test in semiprofessional rugby-league players.

In summary, low to moderate doses of caffeine (∼3–6 mg/kg BM), consumed 60 min preexercise, appear to have the most consistent positive outcomes on sports performance in research situations, although a variety of other protocols (as mentioned above) also appear beneficial, and are practiced in real-life. Of note, athletes who intend to use caffeine as a performance aid should trial their strategies during training or minor competitions, in order to fine-tune a protocol that achieves benefits with minimal side effects.

Creatine

Creatine is another widely-researched supplement, with creatine monohydrate (CM) being the most common form used to sup- plement dietary intake from meats. When taken according to established loading and/or maintenance protocols, creatine supple- mentation can increase intramuscular creatine stores by ∼30%, with the magnitude of response being inversely related to the starting concentration. Within the muscle, creatine-kinase mediates the phosphorylation of creatine to phosphocreatine (PCr), a key substrate for high- intensity muscle force generation. Whereas PCr levels decrease during high-intensity exercise to rapidly resyn- thesize adenosine triphosphate (ATP) from adenosine diphosphate, elevated creatine stores allow a greater rate of PCr resynthesis, enhancing short-term, high-intensity exercise, particularly by enhancing the capacity to perform repeated bouts of effort.

Numerous reviews of CM supplementation identify perfor- mance benefits in single (+1–5%) and repeated bouts (+5–15%) of high-intensity exercise of <150 s in duration, with the most pronounced effects being seen during tasks of <30s. As a result, creatine loading can acutely enhance the performance of sports involving repeated high- intensity exercise (e.g., team sports), as well as the chronic out- comes of training programs based on these characteristics (e.g., resistance or interval training), leading to greater gains in lean mass and muscular strength and power.

Additional, albeit conflicting, evidence points to modifications in cellular signalling, metabolism, and water storage brought on by creatine supplementation. These modifications may have a cascade effect that affects protein synthesis, glycogen storage, and thermoregulation. As a result, supplementing with creatine may have less widely known advantages for athletes who compete in endurance sports. In fact, recent research suggests that combining carbohydrate (CHO, 6-12 g/kg/day) and creatine (20 g/day for 5 days + 3 g/day for 9 days) loading may increase power output during repeated high-intensity sprint efforts performed during the late stages of prolonged (>3 hr) simulated TT cycling, possibly reflecting the physiological demands of a late-stage breakaway during endurance events. When choosing to use this supplement, users should keep in mind that CM supplementation is frequently reported to cause a 1-2 kg increase in body mass after the "loading-phase," which is likely the result of water retention. This effect may actually be detrimental to the performance of endurance and/or other weight-sensitive sports. A recent meta-analysis of the most common and effective strategies for CM supplementation determined that a “loading- phase” of 20.9 ± 4.5 g/day (divided into four equal 5-g doses per day), for 5–7 days was reported across >80% of CM studies. Subsequently, a “maintenance-phase”, typically involving a single 3–5-g CM dose per day, should follow the “loading phase” for the duration of the supplementation period. Such protocols have been established primarily from early work investigating muscle creatine loading in males. Interestingly, concurrent consumption of CM with a mixed protein/carbohydrate source (~50 g of protein and carbohydrate) effect, suggesting that creatine doses are best taken with a meal (or separate food supplement). No negative health effects have been reported with the long-term use of CM (up to 4 years) when appropriate loading protocols are followed. In fact, some reports propose CM supple- mentation to be anti-inflammatory, and to reduce exercise-induced oxidative stress. In summary, when accepted CM supplementation protocols are followed, the expected increase in intramuscular creatine stores are likely to enhance lean mass, maximal power/strength, and the performance of single and repeated bouts of short-term, high-intensity exercise.

Nitrate

Dietary nitrate (NO –) is a popular supplement initially found to improve oxygen uptake (VO2) kinetics during prolonged submaximal exercise. The ingestion of dietary NO – leads to an enhanced nitric oxide (NO) bioavailability via the NO –-nitrite-NO pathway, a reduction catalyzed initially by bacteria in the mouth and the digestive system.

NO plays an important role in the modulation of skeletal muscle function, with proposed mechanisms for improved exercise performance including a reduced ATP cost of muscle force production, an increased efficiency of mitochondrial respiration, increased blood flow to the muscle, and a decrease in blood flow to VO2 heterogeneities.

Of note, a ~5% reduction in O2 cost of submaximal exercise following nitrate supplementation, coupled with augmented mus- cle function, has been associated with large (4–25%) improvements in time to exhaustion, with smaller enhancements observed (1–3%) in sport-specific, TT performances. To date, there is limited support for beneficial effects during exercise >40 min in duration, however, this is possibly due to the lower relative exercise intensity, and the diminished role of nitrite-driven pathways for NO production (Jones, 2014). Recently, nitrate supplementation has been proposed to enhance the function of type II muscle fibers, with improved performance (~3–5%) shown during bouts of high-intensity, intermittent, team-sport exercise of 12–40 min in duration. However, the evidence remains equivocal for any benefit to exercise tasks of shorter duration (<12 min), with some studies showing no effect of acute supple- mentation on repeated sprint performance, and others showing significant benefits in single- (1.2%) and repeated-sprint (3.9%) tasks following chronic supplementation for 5 days. Differences in these findings may possibly relate to the lower dose of nitrate provided in the acute instance; indeed, a dose-response effect of NO – supplement use has been shown previously, with higher NO – doses having a greater impact on 2,000-m rowing performance. The athlete's training status may also affect the supplement efficacy, with greater amounts of nitrate likely needed to produce an effect in higher-level athletes. However, the benefit of nitrate supplementation for very highly-trained (elite) athletes requires more research, with some, but not all, studies showing benefits in such cohorts. Finally, chronic NO – supple- mentation may facilitate training adaptations when taken prior to key sessions, with greater improvements (8.7% vs. 4.7% in placebo control) seen in maximum work rate following 3 weeks of sprint interval training after ingesting 8 mmol (or 500 mg) of NO – 2.5 hr before each training sessions.

Leafy green and root vegetables (i.e., spinach, rocket, celery, beetroot, etc.) are the primary source of dietary NO; however, a recent meta-analysis of 76 nitrate trials showed that beetroot juice was the supplemental NO – source used in the majority (76%) of exercise interventions (McMahon et al., 2016). Performance benefits may manifest acutely (i.e., within 2–3 hr) following a NO – bolus of 5–9 mmol (310–560 mg), with recent work highlighting that a cumulative influence of repeated NO3– intake (>3 days) may also be beneficial especially in well-trained athletes (Jones, 2014). Finally, performance benefits may be maintained for at least 15 days, if con- sumption of the supplement is continued for this duration.

3. SUMMARY POINT FOR ESTABLISHED PERFORMANCE SUPPLEMENTS

Each of the aforementioned supplements should be taken into account as it's possible to find them in foods that are considered to be a part of the "daily diet." Potentially, the aforementioned supplement doses and performance effects can be obtained by consuming commonly consumed foods and beverages at slightly elevated dietary levels (e.g., caffeine through coffee consumption and nitrate through leafy green and root vegetable consumption); however, in other cases, it may be challenging to obtain the necessary volume without a dedicated supplement source. Whatever the case, it is unquestionably comforting to know that each of these well-established performance supplements may be bought in a variety of forms on the shelves and in the refrigerators of the neighborhood grocery store.

Equivocal Performance Supplements

The following supplements are also used by athletes; however, the evidence-base for their potential to enhance athletic performance is less clear.

Sodium Citrate

Similar to NaHCO3, sodium citrate acts as a blood buffer by increasing pH in the extracellular environment, and increasing the gradient between the blood and the active muscle. This is achieved by the dissociation of sodium citrate into its constituent ions, leading to a decrease in [H+] and an increase in [HCO –] as electrical equilibrium is restored (Requena et al., 2005). Early studies trialed sodium citrate doses ranging from 0.1 to 0.5 g/kg BM, consumed 90 min prior to a 60-s maximal sprint test. Here, a dose response was seen, with ergogenic benefits requiring a minimum ingestion of 0.3 g/kg BM, which increased proportion- ally with the amount of supplement consumed (McNaughton, 1990). Subsequently, a 0.5 g/kg BM dose was reported to achieve a ~12% increase in total work completed over exercise tasks last- ing 2–4 min, but higher doses (0.7–0.9 g/kg BM) were found to increase the symptoms of GI distress without increasing the degree of alkalosis produced. The more recent discovery that the time to peak blood pH occurs 180–240 min after sodium citrate ingestion suggests that the dosing protocol should occur at a minimum of 3 hr preexercise. Despite these few positive investigations, it should be noted that the ergogenic effect of sodium citrate ingestion remains equivocal, with a previous meta-analysis highlighting a negligible benefit (0.0 ± 1.3% improvement) associated with the use of this supplement. Considering the detrimental side effects from both NaHCO3 and citrate, and the potential for limited benefits with the latter, athletes and support staff are encouraged to carefully trial the use of these blood buffers in training before implementing an individualized and bespoke protocol in a competition setting.

Phosphates

Numerous hypotheses have been proposed to support the potential benefits of phosphate supplementation on athletic performance. The proposed mechanisms underpinning these benefits include an enhanced rate of ATP and PCr resynthesis; improved buffering capacity to support high rates of anaerobic glycolysis; improvement of myocar- dial contractility leading to increased cardiac efficiency; and an increased erythrocyte 2,3 diphosphoglycerate (2,3 DPG) concentration, leading to a reduced affinity of oxygen with hemoglobin and a greater unloading of oxygen to the peripheral tissues.

Current investigations of phosphate supplementation (sodium, calcium, or potassium phosphate) have focused on the physiological and performance-related outcomes of laboratory protocols including graded exercise tests to exhaustion, the 30-s Wingate test, 6 × 20 m (~3–4 s) repeat sprint efforts, and TT situations ranging in duration from 3–60 min. Overall, there is equivocal evidence of performance enhancement from phosphate supplementation. In some instances, phosphate has been shown to enhance VO2max, anaerobic threshold, and cycling TT performance. However, in the case of repeated sprints, the magnitude of benefit has been shown to be varied and unclear. Finally, there is also a large amount of contrary evidence from the same physiological and performance measures that suggests phosphate supplementation (in isolation, or in com- bination with other buffer agents) has no impact on exercise capacity or performance outcomes. No doubt, the lack of clear consensus defined by this collective work is explained by variations in the supplement protocol used (i.e., differences in dose, type, exercise protocol, etc.) as well as individual responses to the supplement itself.

4. DEVELOPING PERFORMANCE SUPPLEMENTS

This section discusses supplements that are becoming more and more popular and whose support for their use in enhancing athletic performance is growing. However, additional research is required before firm recommendations on their application can be made, and there might be some variations in the underlying ideas or mechanisms that make them useful. The performance enhancements described in the preceding sections are offered in light of a solid body of research that shows they have a direct impact on athletic performance by enhancing various rate-limiting processes. Other supplements, on the other hand, might indirectly affect performance by supporting the training process, by influencing variables like inflammation modulation, oxidative stress, and signalling pathways for adaptation, or by supporting repetitive performance by reestablishing homeostasis in between exercise bouts. For instance, the amino acid N-acetylcysteine functions as an antioxidant and may help athletes recuperate by interacting with the reactive oxygen species brought on by exercise. Such a result might have an effect on an athlete's performance, for example, if the supplement programme aims to increase fatigue resistance during demanding competition schedules. Food polyphenols may function similarly and have potent anti-inflammatory and antioxidant characteristics that may aid in the recuperation process after exercise. As an illustration, it has been demonstrated that tart Montmorency cherries' high anthocyanin content lowers the inflammatory and oxidative stress reactions to marathon running and to multiple days of stochastic, high-intensity cycling. It should be noted that only blood biomarkers were provided to suggest such a benefit in the studies stated above; as a result, these findings need be further confirmed by muscle analysis in future investigations.

Notably, there are a number of problems that make it more challenging to prove that these supplements improve performance. One reason is that it could take some time before better exercise recovery or training support results in observable improvements in competition performance. Second, it's possible that greater homeostasis preservation or restoration or a reduction in the oxidative and inflammatory stress experienced during training sessions could lessen the body's ability to adapt to the exercise stimulus. For instance, prior studies on anti-oxidant vitamin supplementation (i.e., vitamins C and E) have demonstrated a reduction in the cellular signalling pathways that support the adaptive response to exercise, lessening the total training response and diminishing any possible performance benefits. As a result, the ultimate benefit of using these supplements may vary depending on how and when they are used. For instance, they may be used in situations involving repeated competition events to minimise exercise disruptions and improve recovery and subsequent performance, but they should be avoided during training sessions where optimal adaptation is fueled by complete exposure to oxidative or inflammatory stress.

5. CONCLUSION

This study covers the research regarding several supplements that are frequently utilised and taken with the intention of improving athletic performance. Here, the emphasis was on items with a distinct mechanism or function that would be pertinent to a certain kind of sporting activity, as well as on a body of study that looked into how to translate this mechanism into a perceptible performance enhancement. The coach, athlete, and/or support group can make decisions on performance supplements that may be appropriate for their circumstances with the use of this kind of information. This should also be considered in light of the little but frequently significant benefits that can be attained through wise usage of these products, as well as pragmatic factors like variable tolerance and response to a particular supplement. As a result, before using performance supplements in a competition setting, they should be thoroughly tested in training. In certain cases, results such as a lack of efficacy or negative reactions may exceed any projected performance improvement.

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