

KETONES **FOR PHYSICAL** **PERFORMANCE &** **RECOVERY**



BE GREAT.

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In the realm of physical fitness and athletic performance, we constantly seek the next breakthrough—the key that will unlock our true potential so we can reach optimal physical performance.

This desire doesn't just pertain to highly competitive athletes. Fitness enthusiasts and those who enjoy participating in recreational sporting activities seek optimal physical performance.

For athletes, a slight performance improvement may be the difference between a first and fifth-place finish. For everyone else, a performance boost might be related to the ability to participate at a noteworthy level.

In addition, some individuals may not formally participate in exercise, sport, or fitness activities, but rather, they want to function at a high level while completing their usual activities of daily living (e.g., shopping, cleaning, and yard work).

Choosing nutritional strategies to allow them to feel great and perform well throughout the day is essential, in the same way as it may be to a competitive athlete.

Although multiple variables are at play regarding enhancing physical performance, what receives the most attention, aside from adequate sleep and appropriate physical training, is nutritional intake.

Each year, countless articles are written about the “best” dietary approach to aid physical performance, which specific nutrients should be ingested, and



at what amount. Moreover, millions of dollars are spent annually to fund research projects focused on elucidating the most effective nutritional strategies. And the results are clear—consuming a high-quality, nutrient-dense diet can considerably and favorably impact physical performance and exercise recovery.

This is why nearly all professional and high-level college sports teams now have registered dietitians/nutritionists on staff to guide athletes.

Aside from whole-food nutrition, various nutritional supplements and beverages have been

used successfully to boost physical performance.

One target ingredient that continues to receive attention is ketones. These organic compounds serve as a unique energy source, capable of crossing the blood-brain barrier and aiding focus and cognitive function, as well as attenuating the usual decline in executive function associated with strenuous and repeated tasks, which may indirectly impact physical performance.

The liver naturally produces them from fatty acids (endogenous ketone production). They are also available as a dietary ingredient, often consumed in a beverage (exogenous ketones).

Over the past few years, many anecdotal claims have been made to support using exogenous ketones as a performance aid—particularly for endurance athletes. However, results from controlled laboratory studies are mixed, with some studies noting favorable results, some reporting null findings, and others noting a performance decrement following ketone ingestion. Beyond physical performance, investigators have suggested an improvement in post-exercise recovery following ketone ingestion.

This article provides an overview of exogenous ketone use for enhanced physical performance and recovery. It considers existing science and offers suggestions for practical applications and the need for further research.



AN OVERVIEW OF PHYSICAL PERFORMANCE



When it comes to potential aids to improve physical performance, people often ask one simple question: “Does it work?” The answer will depend on how we define “work.” It may be best to ask a question in return: “Does it work for what purpose?”

Referring to physical performance, this can have many potential meanings and outcomes. Let’s start with exercise. We can break this down into aerobic exercise and anaerobic exercise. The former is often referred to as cardiovascular exercise or

cardiorespiratory exercise.

This includes activities like swimming, running, cycling, stepping, dancing, certain group fitness classes, and certain continuous sports (e.g., cross-country running, soccer, basketball—although the latter certainly have anaerobic components).

Anaerobic activities include activities like weight/resistance training (Olympic weight lifting, powerlifting, bodybuilding), jumping, sprinting (on the ground, on a cycle, in water), and similar

activities that require “all-out” short bursts of activity in which the effort cannot be sustained for long periods.

In terms of actually measuring physical performance, there are many options. It should be noted that variance across research studies in terms of which performance measure was used to evaluate the effectiveness of treatment may be one reason for the discrepancy in findings about ketones’ role in improving physical performance.

That said, a few common outcomes that people tend to focus on include the following:

- Time to exhaustion: a measure of how long a person can endure a physically stressful task before requesting to stop; usually performed on a treadmill or cycle ergometer
- Time trial: the time taken to complete a given duration (i.e., time to complete a 20km ride); a measure of the average or max speed during a given duration of exercise
- VO2max: a measure of aerobic power and the maximum amount of oxygen a person consumes during physical exercise when performing an all-out effort
- Muscular strength: 1 repetition maximum (1RM) or the ability to lift a given weight one time
- Muscular endurance: the ability to lift a given weight repeatedly (i.e., the number of times a person can bench press 100 pounds, in sequence, without racking the weight)
- Muscular power: the ability to move a given weight quickly from point A to point B (a vertical jump is an example of a muscular power test)
- Perceived exertion: a measure of a person’s perception of the difficulty of the physical task (this is a subjective measure, so many scientists do not put much stock in this; although it does have a great deal of real-world application)
- Heart rate: a measure of cardiovascular stress; although not directly a performance measure, a lower heart rate during a given physical task suggests that less effort may have been needed to perform the task, which would be indicative of a performance benefit (although this is not always the case)

As can be seen, many outcomes can be considered in an attempt to determine whether or not a given intervention can improve physical performance. Concerning ketones, the focus has been on those outcomes specific to aerobic exercise and endurance based on the relevant metabolic effects and biochemistry.



AN OVERVIEW OF THE DIFFERENT TYPES OF KETONES



During times of acute starvation or very low carbohydrate ingestion, the human body has the remarkable ability to create an alternative energy source known as ketones. Simply put, ketones are produced and used by the body when carbohydrate intake (glucose) is low.

Most people have heard of the “ketogenic diet,” which has gained much popularity in recent years, particularly for those seeking weight/fat loss but also for some athletes who claim improved performance following this approach.

When carbohydrate intake is severely restricted (usually to less than 30 grams/day—an amount that is quite difficult to achieve), blood glucose and insulin levels remain low. Stored fat can then be broken down, and the fatty acids can be released into the bloodstream. These are then transported to the liver and converted into ketones.

The ketones can be released from the liver and travel in the bloodstream to various peripheral tissues, including the brain, heart, and skeletal muscle. In these areas, they can be used as a fuel source. This is particularly helpful within skeletal muscle, which requires a high quantity

of fuel to perform strenuous and repeated exercise tasks.

Considering the relevant metabolic effects, ketones could be most helpful during aerobic exercise. With this form of exercise, for which stored carbohydrate (i.e., glycogen in muscle cells) is of utmost importance for continued fueling, using exogenous ketones is thought to cause a glycogen-sparing effect. In theory, this makes sense.

That is, if ketones are added as a fuel source, these should be used to fuel muscle contractions, and because of ketone availability, glycogen should be spared. This glycogen conservation should then allow for a greater total fuel availability and a longer time to exhaustion due to the extra fuel. (The section below on “ketones and exercise” discusses the scientific findings on this.)

Before addressing the impact of ketones on performance, it is essential to understand that different forms of ketones exist. For example, ketone salts and ketone esters are types of exogenous ketones that can be used to elevate the level of ketones in the blood. They are both considered nutritional ketones but may affect performance measures differently.

Ketone salts are made from β HB bonded to minerals/electrolytes like calcium, magnesium, potassium, or sodium—and the dose of these electrolytes may exceed the recommended daily intake when consuming 10-20 grams daily of ketones (an amount that is often recommended).

Ketone esters, on the other hand, typically bind the β HB to what is known as 1,3 butanediol (1,3-BD), an alcohol molecule—which a recent study indicates may be unhealthy if consumed at high dosages regularly.

Specifically, it was reported that a 20% concentration of 1,3-BD added to the drinking water of adult rats for four weeks produced a systemic concentration of β HB similar to that observed after a 24-hour fast (note: a 5% or 10% solution did not significantly raise β HB) but was also associated with side effects such as body mass loss,

dehydration, and metabolic acidosis.

Tecton ketone esters are bound to glycerol, a “sugar alcohol” or polyol, which is thought to be safe for consumption, even at very high dosages—as shown in a recent study. Ketone esters are far denser than ketone salts since more ketones can bind to alcohol than salt.

Hence, the blood concentration of β HB is higher following ingestion of the ester form, which may impact performance differently, as it appears that β HB levels need to be higher than $\sim 2\text{mM}$ for effects to be realized.



CAN KETONES IMPROVE PHYSICAL PERFORMANCE?

As mentioned above, ketones are thought to aid exercise performance primarily due to their impact on glycogen sparing. During long-duration exercise, when glycogen stores can become depleted (or decreased considerably), having an alternative energy source could be helpful, as this would spare the use of muscle glycogen and help prolong the time to fatigue.

Theoretically, ketones may also help minimize lactate production and accumulation during higher-intensity exercise bouts, as less glucose is oxidized for energy, resulting in less lactate production.

Because elevated lactate has the potential to impair exercise performance (although this is not entirely clear), it is thought that exogenous ketone use (or adherence to a ketogenic diet) may lead to a

performance improvement.

Beyond the acute exercise session, ketones have been touted as agents that can decrease muscle protein breakdown and activate protein synthesis.

Ketones also have antioxidant functionality and possibly serve as an anti-inflammatory agent. Related to the glycogen-sparing effect noted above, ketones have also been reported to help accelerate glycogen resynthesis.

Finally, it has recently been reported that ketone ingestion increases circulating erythropoietin concentrations, suggesting that orally ingested ketones may have the potential to alter hemoglobin mass—which is vital for oxygen-carrying capacity.

In this same study, the authors noted that ketone use stimulates muscular angiogenesis, as well as vascular endothelial growth factor (VEGF) and endothelial nitric oxide synthase (eNOS) expression both at the protein and at the mRNA level, which over time could potentially improve blood flow—having an impact on exercise performance.

Collectively, these effects should allow for a favorable impact on exercise recovery, as it has been reported that ketone ingestion postexercise may prevent the development of overreaching.

It is also possible that ketones may help athletes' physical performance by improving their mental clarity and focus. Researchers have found that ketones may help combat oxidative stress, which can lead to enhanced concentration. Athletes may thus experience improved performance after ingesting ketones due to their increased mental awareness and concentration.



WHAT HAPPENS WHEN YOU EXERCISE WITH KETONES?

Ketones may improve athletic performance. Over the past several years, scientists have expanded their investigation on ketones' role in aiding performance. To this end, multiple reviews and meta-analyses have been published about using ketones to serve as an ergogenic aid.

Collectively, the data are conflicting, with studies noting both a benefit and no effect on performance

following ketone ingestion, and some studies finding that ketones might even impair performance (McCarthy et al., 2023; O'Malley et al., 2017; Poffé et al., 2021; Whitfield et al., 2021).

Possible explanations for the discrepancy in findings include the type and dosing of ketone, the subjects being sampled, and the sample size used. In addition, attention must be paid to the specific exercise tests chosen as evaluation tools, with strong consideration for including exercise protocols that are reflective of real-world competition.

One item to consider when interpreting the research findings is that many studies include only a small number of subjects (<20). While some may have experienced a performance improvement (the so-called "responders"), because others may not have and the variability between subjects was relatively high, no statistical significance may have been noted—yielding a general study conclusion of "no effect."

This is not at all uncommon in the food science/nutritional supplement literature, as subject variability in many outcome measures is often high.

A rather large sample of subjects is often needed to achieve statistical significance. Without this, there may be several "responders" to treatment, but the overall take-home message may still be "the treatment was ineffective."

This is where practical application and experimentation may need to come into play, considering the available science but also understanding the limitations of a small laboratory-based study.



KETONES AND AEROBIC EXERCISE

While data are certainly mixed on the topic, with some studies indicating that exogenous ketones will not aid physical performance, some studies support using ketones as an ergogenic aid during aerobic exercise.

For example, a ketone ester-based form of nutritional ketosis was studied in 39 high-performance endurance athletes. It was noted to decrease muscle glycolysis and, as a result, blood lactate concentrations. It was also recently reported that a ketone drink consumed four times daily and a carbohydrate-rich diet improved exercise performance in a sample of trained endurance athletes.

Interestingly, when subjects adhered to a ketogenic diet, performance decreased by 48-57% on all race days—likely due to the carbohydrate restriction, despite the elevated blood levels of β HB. When considering the collective literature, it appears that blood concentrations of β HB need to be elevated significantly ($\sim 2\text{mM}$) before a performance effect is realized.

However, this is not always the case, and no performance improvement has also been noted when β HB values exceeded 3mM or when very high doses (75 grams) of ketone ester were ingested. In some situations, adding bicarbonate to ketone ester may help, as has been shown in a recent study of well-trained cyclists who were noted to have greater mean power output during a 15-minute time trial.

When considering the impact of ketone use on endurance performance, one explanation for the lack of effect may be related to the inability of ketones to spare muscle glycogen, as noted in a recent paper where authors concluded, “Exogenous



ketosis produced by oral ketone ester ingestion during the early phase of prolonged endurance exercise and against the background of adequate carbohydrate intake neither causes muscle glycogen sparing nor improves performance in the final stage of the event.”

Since the sparing of glycogen appears to be one of the mechanisms of action resulting in an ergogenic effect of ketone use, it follows that if such an effect is not realized, performance may not be favorably altered.

KETONES AND ANAEROBIC EXERCISE

Very little has been done to investigate the impact of ketone ingestion on anaerobic exercise performance. In human subjects, male athletes were put through a series of tests to exhaustion, with and without ketone ingestion before and during the exercise bouts.

Compared with carbohydrates alone, one study found that co-ingestion of ketones by team sport athletes attenuated the rise in blood lactate concentrations but did not improve shuttle run time to exhaustion or 15-meter sprint times during intermittent running.

Another study recently reported a performance

improvement in healthy rats following ketone ingestion, with a particular benefit noted for maximum carrying capacity and high-intensity intermittent exercise (20-second weighted swim session with a 10-second rest between sessions).

Taken together, ketones may minimize the lactate response to higher-intensity exercise, possibly impacting resistance exercise performance.

However, this is speculation, as there simply are not enough controlled trials to draw firm conclusions about the impact of exogenous ketone ingestion on anaerobic exercise performance.

KETONES AND EXERCISE RECOVERY

With the data for physical performance being mixed, an additional area of investigation that deserves attention is that pertaining to the role of ketones in aiding exercise recovery. Very few clinical trials have been conducted in this area, with one recent study noting no impact of ketone ingestion on muscle force recovery following eccentric exercise.

However, the ketones were provided following a massive dose of exercise (300 eccentric quadriceps contractions) in a small sample of predominantly women. With such a high volume of exercise, it is doubtful that any nutritional intervention would be capable of offsetting the degree of damage.

Similar findings were noted in a separate study of moderately active young adults using ketones during the days following a strenuous session of 100 drop



jumps.

A recent review on the topic explained the multiple applications of ketones pertaining to post-exercise recovery. Additional researchers have suggested that ketones may increase postexercise glycogen replenishment, decrease proteolysis, and act as metabolic modulators and signaling metabolites.

Another set of researchers concluded that “ketone ester intake is a potent nutritional strategy to prevent the development of non-functional overreaching and to stimulate endurance exercise performance,” highlighting ketones’ impact as a recovery agent.

And a 2023 study noted an increase in dopamine and improved mental alertness surrounding a long-distance run; however, it should be noted that subjects ingested a very high dosage of ketone ester [before (25 g), during (25 g·h⁻¹), and after (5

× 25 g in 24 h)]. This ketone-induced increase in dopamine signaling is associated with improved sleep efficiency and quality following high-intensity exercise. So, athletes who add ketones to their regimen may experience improved performance because they experience improved sleep compared with relying on caffeine and other stimulants.

Finally, it has also been noted that a high dosage of ketones inhibits postexercise skeletal muscle macrophage infiltration, which may aid recovery.

Considering the above, although well-controlled human studies are needed, it is reasonable to hypothesize that using a ketone aid may favorably impact recovery from strenuous exercise. If so, exogenous ketone use may be recommended for athletes engaged in high-intensity and high-volume training, as recovery from such physical stress can be challenging, and any nutritional support that may be helpful is welcome.



CAN KETONES IMPROVE ATHLETIC PERFORMANCE?

When considering the entire body of science, it is difficult to arrive at a firm conclusion regarding the use of ketones to support exercise performance and recovery. There are clearly studies documenting a performance benefit, which support the multiple anecdotal reports of athletes who seem to praise the benefits of exogenous ketones.

In such cases, the β HB levels in circulation may have been high, necessitating relatively high dosing of ketone ester, which can be done safely with Tecton ketone beverage.

That said, other studies fail to note an improvement in select performance metrics, despite high levels of β HB. As with dietary supplements, there appear to be “responders” to ketone treatment and non-responders. The noted responders typically feel an improvement in perceived energy and vigor during their exercise session, possibly with heightened focus and enhanced post-exercise recovery. If observing such outcomes, ketones may be contributing to these effects.

The good news is that scientists continue to study ketones for physical performance improvement and recovery. A review of the clinicaltrials.gov, which includes a database of ongoing studies, notes that several studies utilizing ketones are currently underway. Hence, additional information should be available in the coming months and years on the impact of ketone use on human performance and related health measures.

In the meantime, individuals will need to experiment with ketone beverages and various dosing schedules to determine if ketone use is right for them. The same is true regarding ketone use to support exercise recovery. Scientists need



to continue studying the use of ketones for these purposes, focusing on using adequately powered designs (i.e., enough subjects to detect a statistically significant effect, assuming one exists) and real-world exercise protocols and outcome measures.

Doing so will provide additional information regarding the benefits of ketone use to support physical performance and recovery.

TECTON'S KETONES ARE SAFE FOR ATHLETES TO DRINK BEFORE, DURING AND AFTER WORKOUTS

Ketones are considered to be the 4th macronutrient that provide significant health benefits. Previously, the only way to get these benefits was through a highly restrictive, carbohydrate-restrictive keto diet. Now, Tecton's nature-identical ketone beverage provides many of these benefits without strictly adhering to the diet.

Tecton is the world's first and only ready-to-drink beverage that contains 10g of nature-identical ketones that doesn't contain 1,3 butanediol (a secondary alcohol or ethanol dimer). Tecton has been noted to be safe, even at very high dosages, as reported in a recent publication in the scientific journal, Nutrients.

Scientists also tested the absorption rate to determine how quickly

Tecton ketones get into the bloodstream after drinking a can of the product.



So, with analyses by Mayo Clinic scientists, a pharmacokinetics (PK) study showed that Tecton's ketone ester has a rapid absorption rate, reaching a maximum concentration in just 30 minutes, putting the user into mild ketosis in minutes. A similar blood level of ketones usually requires two days of fasting or several days of strict adherence to a keto diet!

Because Tecton has zero sugar and zero caffeine, it is a simple and safe alternative, or accompaniment, to fasting or a restrictive ketogenic diet. Regarding intermittent fasting, Tecton ketones may allow for an extension of the fasting period, which may aid overall weight loss/fat loss over time.

*The Food and Drug Administration has not evaluated these statements. This product is not intended to diagnose, treat, cure, or prevent any disease.



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