

# RACE FASTER

## High5 Creatine Review

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If history has taught us one thing about sports nutrition, it's that many 'new' and initially promising products that appear on the market fail to live up to their potential when rigorously tested under scientific conditions. But just occasionally, something comes along that actually does what it says on the tin, and there's no better example than creatine! Hundreds of carefully controlled studies have proven beyond doubt that this simple compound (which is present naturally in a number of foods) can bring about real and significant improvements in events or training regimes that rely on short-term, high-energy outputs. Creatine then was the exception to the rule because not only did it deliver real performance gains, the extensive research also was able to explain exactly how and why these gains were produced.

### What is creatine?

Creatine, or methyl guanidine-acetic acid, was first discovered in 1832 by a French scientist called Chevreul and it was subsequently discovered that not only was it a regular constituent of flesh, but also that when supplemental creatine was ingested, not all of it could be subsequently recovered from the urine, strongly suggesting that supplemental creatine could increase the creatine content of muscle cells.

Although creatine is found in both meat and fish, it can also be synthesised in the human body in a two-stage process from the dietary amino acids arginine, glycine, and methionine. The body of a typical 11-stone adult contains around 120-140 grams of creatine, most of which is stored in the muscle tissues and around two thirds of this stored creatine is in the phosphorylated, energy-rich or 'active' form known as phosphocreatine or creatine phosphate, with the remaining third as creatine (see figure 1).

The turnover of creatine in the body is relatively small; typically only around 2 grams a day from the 'creatin pool' are lost in the urine. This lost creatine can be replenished both from eating creatine-rich foods and by synthesis within the body. The key to understanding creatine's importance in boosting sports performance lies in its pivotal role in the energetics of

in muscles. By the end of the late 1980s, it was clear that positive answers were emerging to this questions and before long the athletic community got wind...

### What are the potential benefits of creatine supplementation?

Used in the correct way, taking extra creatine in the form of supplementation

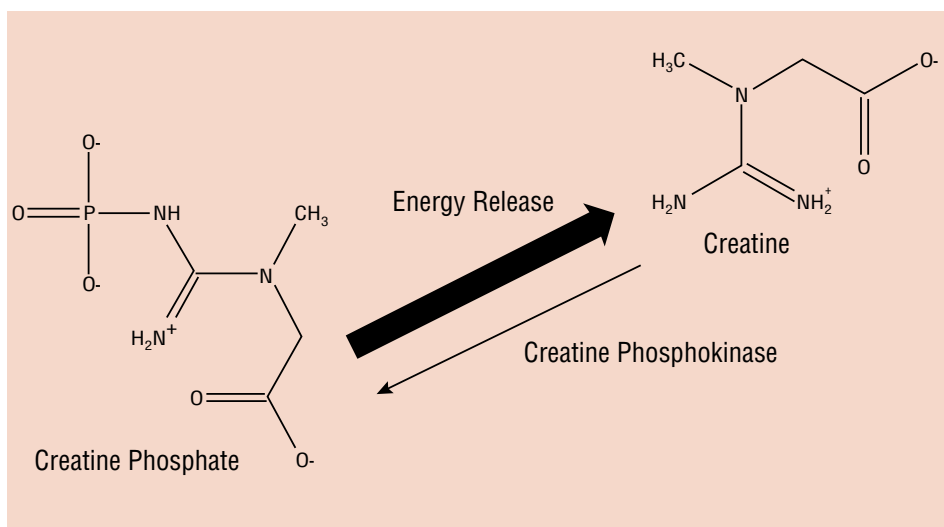


Figure 1: Shows the structure of creatine and the 'energy-rich' active form of creatine called phosphocreatine. When energy demand is very high and can't be met from other sources, phosphocreatine breaks down to creatine plus phosphate and energy is released. When energy demands are low, high-energy creatine phosphate can be resynthesised in the muscles ready for the next high-energy burst!

muscle contraction during high intensity exercise.

For much of the 20th Century, there was only limited interest in creatine, despite some (unconfirmed) reports that athletes from the former Soviet Union had been experimenting with it in training. However, research into the biochemistry and physiology of creatine began to demonstrate its role in recycling ATP (the universal 'energy currency molecule') within working muscles and also that level of the phosphorylated form of creatine was very much related to the development of fatigue during very intense muscle contraction.

Scientists the wondered if whether by raising muscle creatine stores, it would be possible to improve muscle function and energetics, as in a similar way, endurance performance could be boosted by increasing the amount of glycogen stored

can offer a number of advantages to sportsmen and women. The most obvious of these is an increase in the production of short-term, high intensity burst of energy (up to 20 seconds) provided via the phosphocreatine energy system (see below). This increase boosts explosive type or 'sprinting' performance, but can also help athletes whose event is more endurance-orientated, but who may have to include short high-intensity bursts such as a sprint for the line.

As a consequence of the enhancement of the phosphocreatine energy system, creatine supplementation can also help athletes seeking to gain power, lean muscle mass and outright strength. This however is not because creatine has a direct stimulatory effect on muscle growth – it doesn't. Nevertheless, by enhancing the short-term energy system, what creatine does do is enable athletes to perform more intense resistance training sessions (either

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more reps, more weight or both), which in turn stimulates greater gains in muscle tissue accretion and growth. But lounge lizards should take note; supplementing with creatine and then simply sitting around without performing the appropriate training will not make a jot of difference to muscle strength or power!

Another potential benefit of creatine supplementation is also becoming apparent – namely recovery. A number of recent studies have demonstrated that the co-ingestion of creatine with carbohydrate after exercise seems to enhance both the uptake of carbohydrate into muscle cells and the subsequent synthesis of muscle glycogen. This is something we'll come back to shortly.

## How does creatine actually work in the body?

The reason why creatine supplementation can produce real performance gains is down to two fundamental but simple concepts:

- **Creatine saturation** – Part of understanding why creatine supplementation can boost maximal exercise performance is to understand that unlike so many other potentially ergogenic nutrients, ingesting extra creatine orally actually produces a measurable increase in both its concentration and subsequent activity within the body. Although there are wide variations between individuals, the typical creatine content of dry muscle mass is around 110-140 millimoles per kg. However, numerous studies have shown that when you give higher doses of creatine, more can be absorbed and stored. For example, ingesting 5 grams of creatine four times a day for several consecutive days will increase muscle concentrations of creatine by around 25 millimoles per kg<sup>1</sup>. Of this extra, around 30% is present as the active energy donating creatine phosphate. In plain English, most of us have muscles that are not fully saturated with creatine and taking extra creatine can produce saturation. However, it's important to add the caveat here that some people seem to be 'non-responders' to creatine supplementation – ie these individuals do not appear to be able to increase their muscle creatine stores when using creatine and do not therefore experience the

potential benefits. Studies have shown that up to 30% of the population may fall into this category<sup>2</sup>.

- **Enhancement of the phosphocreatine energy system** – The second step is to understand how this extra stored creatine (that occurs when creatine supplements are ingested) can act to enhance short-term (phosphocreatine) energy system in the body. During very intense exercise, ATP, which is the molecule that supplies the energy required for muscular contraction, is rapidly depleted to ADP, because there's not enough oxygen available for the aerobic regeneration of ATP (aerobic regeneration of ATP is the process prevailing during moderate-intensity endurance exercise, which explains why you can continue exercising without becoming exhausted provided you keep the intensity down!). However, the good news is that muscles can store creatine phosphate in much higher concentrations than ATP, so this creatine phosphate is able to form an emergency 'energy reservoir' by donating its high-energy phosphate to ADP, which instantly regenerates ATP, therefore prolonging the duration of the high intensity exercise. It's easy to understand that if there's a higher concentration of creatine and creatine phosphate in the muscles, there'll be more high-energy phosphate available to regenerate ATP from ADP. This explains why athletes supplementing creatine report being able to sustain high intensity bursts of exercise for longer before fatigue sets in. However, research has also demonstrated that higher concentrations of muscle creatine help to hasten the resynthesis of creatine phosphate from creatine and phosphate during the recovery period between bouts of exercise<sup>3</sup>. In other words, not only does creatine enable you to sustain a high-intensity burst for longer, it speeds recovery, enabling you to repeat those bursts sooner.

## How can creatine help endurance athletes?

There's no doubt that boosting the ability of the phosphocreatine system to deliver more energy to hard working muscles during intense and/or repeated bursts exercise is of great benefit to power and strength athletes such as sprinters and throwers. Numerous studies on these performance benefits have been published<sup>4-8</sup>, but what benefits can

creatine supplementation offer endurance athletes?

- **Interval Training** – Almost all endurance athletes carry out interval training, both to increase their basic speed and lactate threshold, and to help them provide the necessary kick at the end of a tight race. High-intensity intervals require an energy input from the phosphocreatine system and supplementation therefore can lead to higher quality interval sessions in training to produce higher speeds in competition and the ability to out-kick rivals.
- **Increased Strength** – Most endurance athletes require a certain degree of strength and strength training to perform



within their event, withstand the rigours of training and to stave off injury. Since high-intensity strength or resistance training is powered almost exclusively by the phosphocreatine system, it's easy to understand how creatine supplementation can facilitate more intense, higher quality workouts, leading to greater strength gains per unit of time invested, in turn freeing more time up for endurance training.

- **Anti-Catabolic Action** – At high aerobic training volumes, so much energy is expended that some muscle tissue breakdown is virtually unavoidable. However, some research indicates that in men at least, creatine supplementation produces an anti-catabolic effect, by reducing the amount of leucine (a crucial and abundant amino acid in muscle protein) oxidised during exercise<sup>4</sup>.
- **Glycogen Resynthesis** – A major challenge for endurance athletes is to maintain stores of muscle glycogen during periods of heavy training and competition. Although the scientific evidence is not yet conclusive, there is encouraging evidence

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that creatine supplementation can enhance muscle glycogen synthesis (more on this later).

## What does the latest research say about creatine?

So far we've seen that by enhancing the ability of the short-term, high-intensity phosphocreatine energy system to produce short bursts of energy, saturating the



muscles with creatine enables athletes to train more intensely and to recover more rapidly between intense efforts. This allows them to perform better in any events that require high-intensity efforts, and importantly, allows all athletes to resistance train more intensely, which can be invaluable in producing greater muscle strength and power. Remember though, the creatine itself doesn't have a direct 'muscle building' effect' it only allows you to train more intensely – ie you still need to train hard and refuel properly!

However, some recent studies have shown that creatine does exert some other direct effects on muscles that could be useful for endurance athletes:

### **Enhanced muscle glycogen synthesis**

Research in the mid-1990s looked at effects of oral creatine loading (i.e. ingesting enough creatine to saturate the muscles over a period of a few days) and discovered that in the urinary volume decreased in the subjects observed and that this decrease exactly paralleled the associated increase in body mass<sup>9</sup>. The clear implication was that the supplemental creatine was stimulating muscle cells to soak up water and become 'volumised' or

hydrated. This finding stimulated a great deal of speculation, because we know that a similar process happens during the process of carbohydrate loading and also that both animal and muscle cell preparation studies have been carried out, which show that an increase in muscle cell volume can stimulate carbohydrate synthesis. The obvious question was if the same process occurs in humans, could creatine supplementation enhance the resynthesis of muscle glycogen in between training sessions?

More recent US research suggests that this may indeed be the case. For example, a study on twelve subjects looked at a muscle glycogen loading protocol under two conditions<sup>10</sup>:

- Under standard conditions – a high carbohydrate diet and rest;
- The same protocol as above but carried out after a creatine-loading phase (20g per day for 5 days).

The results showed that the same amount of carbohydrate administered under the same condition produced greater levels of muscle glycogen after creatine loading compared to no creatine loading (694mmols/kg vs. 597mmols/kg). The researchers concluded that 'a muscle's glycogen loading capacity is influenced by its initial levels of creatine and the accompanying alterations in cell volume'.

Three years later, a Dutch study reached similar conclusions<sup>11</sup>. The researchers set out to assess how creatine loading followed by 6 weeks of creatine supplementation affected muscle glycogen storage and also to see whether creatine acted by increasing the concentration of GLUT-4 transporter proteins in the walls of muscle cells. GLUT-4 transporters play a vital role in helping to shuttle glucose molecules (from the digested carbohydrate we eat) into muscle cells, where the glucose can be synthesised into glycogen.

Twenty subjects were split into two groups; the creatine group followed a creatine-loading phase as above and continued to supplement creatine at 2g per day for six weeks. The placebo group followed an identical protocol, but used a placebo instead. Muscle biopsies were taken after loading and again at six weeks to determine muscle glycogen and GLUT-4 levels. The results showed that the creatine-loading phase increased muscle glycogen storage

by around 18% compared to placebo (similar to the study above), but that the levels of GLUT-4 transporters didn't change with creatine supplementation, indicating that this probably wasn't the mechanism behind increased glycogen synthesis. As an aside, the results also showed that 2g per day of creatine wasn't enough to keep the muscles fully saturated with creatine, or to maintain peak levels of glycogen storage observed after the loading phase. It's also worth adding that in a recent study carried out in rats, muscle glycogen levels increased by a whopping 40% and importantly, creatine supplementation did increase GLUT-4 expression, indicating more research may be needed in this area<sup>12</sup>.

By contrast, an Australian study carried out last year found that creatine supplementation had no beneficial effects on muscle glycogen synthesis<sup>13</sup>. This study investigated the effect of creatine supplementation in 13 healthy, physically active subjects on muscle glycogen content, sub-maximal exercise performance, fuel utilisation and endurance performance following 4 weeks of endurance training. The group was split into creatine and placebo users and muscle biopsies were then taken before and following the training period for assessment of muscle creatine and glycogen content. The results showed that while training increased quadriceps glycogen content to the same degree



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(approximately 20%) in both groups, there was no significant treatment effect of creatine supplementation. However, it's worth pointing out that unlike the studies above, no 'loading phase' to saturate the muscles took place, which means that the muscles may not have been sufficiently creatine-loaded to achieve a significant glycogen enhancing effect.

## Effects on fuel utilisation

If creatine does help to enhance glycogen synthesis in recovering muscles, the jury's still out about precisely how this occurs. However, a study on creatine supplementation in rats carried out by Canadian researchers came up with some surprising findings suggesting that creatine may actually help decrease the rate of basal lactate production in



muscle<sup>14</sup>. The rats were supplemented with creatine, insulin or both for 48 hours and although creatine neither altered the glycogen and GLUT4 contents of the cells nor the insulin-stimulated rates of glycogen synthesis and glucose oxidation, what it did seem to do was reduce the amount of lactate produced by around 40%, probably by helping to activate enzymes that assist in fully converting glucose to energy, (rather than partial conversion to lactate). A supplement that can lower levels of lactate production in muscles would be a real bonus for athletes; however, a study on rats does not necessarily translate into exercising humans and to date, there's no further evidence in the scientific literature to confirm these findings. It's an old cliché, but more research really is needed!

## Creatine and cognitive function

Although most people associate creatine with improved physical performance, particularly for high-intensity short duration exercise, a fascinating new study carried out by British researchers earlier this year has indicated that creatine can enhance 'central executive' mental tasks (the brain processes that include planning, organising, applying mental rules and, maintaining attention and concentration) in sleep-deprived exercising adults<sup>15</sup>. In

the study the subjects were divided into a creatine supplementation group and a placebo group. They each took 5 grams of creatine monohydrate or a placebo, four times a day for 7 days immediately prior to the experiment and then underwent tests examining their central executive functioning as well as short-term memory, choice reaction time, balance, mood state and perceived effort. These tests were taken at baseline and then again after 18, 24 and 36 hours of sleep deprivation, with moderate intermittent exercise performed in between. Although there were no differences in the scores for the other tasks, the creatine group demonstrated a significant linear improvement in performance of the central executive tasks throughout the experiment, while the placebo group showed no significant effects. Although further work will be needed to confirm these effects, the initial results appear promising, especially for sportsmen and women sports where a high degree of concentration and/or attention is required.

## Using creatine

There's general agreement that creatine is best used in a loading/maintenance pattern of supplementation. Loading is usually achieved by consuming 5g four times a day for around a week or so (it can also be achieved with lower daily dosages, but this takes longer to achieve saturation), while the maintenance phase involves topping up the saturated muscles with 2-3g per day of creatine to replace the losses that occur naturally on a day-to-day basis. However what's generally less appreciated is how to maximise the absorption of creatine or how it might be used to enhance the recovery process (eg by maximising glycogen storage).

**Maximising creatine uptake** –there's solid evidence that the co-ingestion of carbohydrate helps to maximise creatine uptake into muscles. In a landmark study carried out by British scientists, the creatine uptake into muscles was measured in 24 males under two conditions<sup>16</sup>:

- Five grams of creatine in solution four times a day for 5 days;
- As above but on each occasion followed thirty minutes later by 93 grams of simple carbohydrate (sugar) in solution.

Although muscle creatine levels rose in both groups, the creatine plus simple carbohydrate supplemented group increased their muscle levels by a massive 60% over the no-carbohydrate group! Measurements on blood insulin levels in both groups showed that this effect was almost certainly because the carbohydrate stimulate a large rise in insulin, which then acted to help 'drive' the co-ingested creatine into muscle cells. The current consensus of scientific opinion is that ingesting 75-100g of carbohydrate along with each creatine dose appears to maximise creatine uptake into muscles<sup>17</sup>. Another substance that appears to enhance creatine uptake is alpha lipoic acid. In a study by Canadian scientists, 16 male subjects were split into 3 groups<sup>18</sup>:

- One group ingested 20 grams per day creatine monohydrate for 5 days;
- The second followed the same protocol as above but with 100 grams of sucrose per day accompanying the creatine;
- Group 3 was as group 2 except they also ingested 1000mgs of alpha lipoic acid per day.

Although all groups showed a significant increase in total muscle creatine concentrations following creatine supplementation, the group ingesting alpha-lipoic acid showed a significantly greater increase in muscle levels of phosphocreatine and total creatine.

**Maximising recovery and glycogen synthesis using creatine** – the relationship between creatine and carbohydrate is



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synergistic in nature; co-ingestion of carbohydrate helps uptake of creatine into muscles, while on balance, the evidence suggests that high levels of muscle creatine (preferably saturation levels) help muscles to increase the uptake of glucose and glycogen synthesis when carbohydrate is consumed. Given the above, it's hard to escape the conclusion that the best policy for maximising both glycogen synthesis and creatine uptake is to co-ingest a combination of the two.

As the US study above indicates<sup>10</sup>, the higher the muscle creatine level, the higher the increase in glycogen synthesis, so a strategy of co-ingestion for maximum recovery would seem to be best employed once creatine saturation has already been achieved. However, the creatine-loading phase may itself be helped by carbohydrate/creatine co-ingestion!

## Conclusion

Although there are no definitive studies into the long-term use of creatine and carbohydrate ingestion, it seems reasonable to assume that there could be benefits if a maintenance dose of creatine (2-3g) was incorporated into a carbohydrate drink that supplied around 75-100g of carbohydrate. If athletes consume more than this amount of carbohydrate drink in a day, this would not be problem due to the extremely low toxicity of creatine. However, the safety of very high loads of creatine over prolonged periods of time has not yet been fully assessed, so this would have to be borne in

mind for those athletes routinely ingesting very large amounts of carbohydrate drinks in training. There also seems no reason why alpha lipoic acid could not also be incorporated into such a drink; not only does it function as a powerful antioxidant (a good thing!), the evidence suggests that the higher the volume and intensity of aerobic exercise, the more antioxidant protection may be needed.

As for the timing of a creatine/carbohydrate drink, the evidence is that the synergistic effects occur when consumed together, so co-ingestion is what counts. And given the substantial body of evidence regarding carbohydrate supplementation and replenishment, it seems very reasonable to conclude that the recommendations for optimum timing of ingestion of any creatine/carbohydrate drink would be pretty much the same as for carbohydrate-only drinks!

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