Performance Nutrition Buyer's Guide
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Creatine: State of the Science at the Millennium

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Over the last decade, hundreds of articles have been written about creatine in scientific journals, magazines, newspapers, and on the Internet. The reason for this interest is that creatine has proven to be one of the most effective nutritional supplements available for strength/power athletes and some patient populations. Unfortunately, much of the information that has been written about creatine is inaccurate and/or misleading. The result is that people are often confused about the potential benefits and risks of creatine supplementation. The purpose of this article is to give you an update of the state of the science regarding creatine supplementation as we embark into a new millennium. Additionally, this article will answer some common questions about creatine so that you can make an informed decision about whether to use creatine to enhance your training.

The Science Behind Creatine

Creatine is a naturally occurring amino acid that is primarily stored in the muscle. Most of the creatine is stored as phosphocreatine (66%) while the remaining creatine is stored as free creatine (33%). The total creatine pool (phosphocreatine + free creatine) in the muscle averages about 120 grams for a normal sized person. About 1 to 2% (2 – 3 grams) of the total creatine pool is broken down each day and converted to creatinine in the muscle. The creatinine is then excreted in the urine. The body replenishes lost creatine in two ways. First, about half of the daily creatine need can be obtained in the diet by eating foods that contain creatine. For example, there is about 2 grams of creatine in a pound of uncooked beef and salmon. Under normal metabolic conditions, the remaining amount of creatine needed to replenish creatine stores is synthesized from the amino acids glycine, arginine, and methionine.

The body has the capacity to store up to 160 grams of creatine. Thus, one can think of the normal creatine content in the muscle (about 120 grams) as being a gas tank that is ¾ full. Dietary supplementation of creatine has been consistently reported to increase muscle creatine and phosphocreatine content by 10 – 40%. Consequently, creatine supplementation typically allows an individual to fill up their creatine storage tank to 150 – 160 grams (i.e., 25 – 30%). Some people appear to respond better than others to creatine supplementation. In this regard, creatine supplementation has been reported to increase muscle creatine content as little as 5 – 15% in some people and 15 – 40% in others. Typically, individuals with lower initial creatine concentrations (e.g., vegetarians or patients with creatine synthesis deficiencies) have the largest increase in muscle creatine stores following creatine supplementation. There is some

evidence that the ergogenic benefits of creatine supplementation are related to the magnitude of change in muscle creatine stores. However, research has also indicated that if you follow some of the recommendations below, everyone will experience ergogenic increases in creatine content.

Although cooking can degrade some creatine, nearly 100% of dietary creatine is absorbed by the small intestine into the blood. The muscle then absorbs creatine from the blood as needed. The absorption of creatine in the muscle is influenced by sodium and insulin. In this regard, sodium serves as a co-transporter of creatine into muscle tissue and muscle creatine uptake is enhanced when insulin levels are high. For this reason, it is recommended to ingest creatine with a glucose drink or fruit juice containing about 95 g of carbohydrate or a carbohydrate/ protein drink (e.g., 50-80 grams of carbohydrate with 30 to 50 grams of protein). Extra creatine that the muscle is unable to absorb is excreted as creatine in the urine. This means creatine is not degraded into creatinine in the stomach or the intestinal tract by gastrointestinal acids nor is passed through the intestinal tract without absorption by the intestines. Further, that once your creatine tank is full, taking excessive amounts of creatine is simply eliminated in the urine. Therefore, it only takes about 3 – 5 grams/day of creatine to maintain elevated muscle stores.

Increasing muscle availability of creatine and phosphocreatine can theoretically affect exercise and training adaptations in several ways. First, increasing the availability of phosphocreatine in the muscle may help maintain availability of energy during high intensity exercise like sprinting and intense weightlifting. Second, increasing the availability of phosphocreatine may help speed recovery between sprints and/or bouts of intense exercise. This may allow an athlete to do more work over a series of sprints and/or sets of exercise. Theoretically, this may lead to greater gains in strength, muscle mass, and/or performance over time.

As of this writing, there have been over 250 studies on creatine supplementation. Of these, about 180 have evaluated the ergogenic value of creatine supplementation in untrained subjects, athletes, and patient populations. The majority of these studies (about 65%) indicate that creatine supplementation promotes a statistically significant improvement in exercise capacity. This means that 95 times out of 100, if you take creatine as described in the study, you will experience an improvement in the type of exercise evaluated. The average gain in performance from studies reporting ergogenic benefit ranges between 10 to 15%. Short-term creatine supplementation (4 to 7-days) appears to be more effective when performing high intensity exercise lasting less than 30-seconds (e.g., short sprints, repetitive sprinting, weightlifting, etc). However, about half of the studies that have looked at intense exercise bouts ranging from 30-seconds to 10-minutes have also reported statistically significant improvements in exercise capacity. Short-term creatine supplementation does not appear to enhance endurance exercise capacity. However, endurance athletes who incorporate interval sprint conditioning as part of their training may theoretically benefit. Long-term creatine supplementation (e.g., 1 – 12 weeks) appears to enhance the quality of training generally leading to 5 – 15% greater gains in strength and performance.

Nearly all studies indicate that creatine supplementation increases body mass by 1 – 3 pounds in the first week of loading. In training studies, subjects taking creatine typically gain twice as much body mass and/or fat-free mass than subjects taking a placebo. This is equivalent to an extra 2 – 4 pounds of body mass and/or fat-free mass during 4 – 12 weeks of training. In our research and training of athletes, we have frequently seen subjects gain 5 – 15 pounds of muscle mass during 4 – 12 weeks of training without gaining fat. The increased fat-free mass has been suggested to be due to either water retention, a creatine stimulated protein synthesis, and/or an enhance quality of training leading to greater gains in muscle mass over time. Most

creatine researchers feel that the initial gain in body weight during the first several days of creatine supplementation is an increase in intracellular water. The increased cell volume is believed to be one stimulus to increase protein synthesis. Recent research suggests that long-term gains in body mass appear to be due to a training stimulated increase in muscle hypertrophy.

I am not aware of any study that reports that creatine supplementation significantly decreases exercise capacity although two studies reported non-significantly slower performance times in distance running and swimming. If fact, nearly all of the studies reporting non-significant results following creatine supplementation report a 1 to 10% gain in performance. In most instances, the lack of statistical significance appears to be due to small sample size that decreases statistical power, the relatively high variability in conducting performance tests (i.e., 3 – 4%), and/or methodological difficulties. Interestingly, as our understanding about the ergogenic value of creatine supplementation has grown, the percentage of studies reporting statistically significant results has increased to nearly 80% over the last year. Although not all studies report significant results, I am aware of no other nutritional ergogenic aid (including carbohydrate) that has consistently reported such ergogenic benefit. Consequently, in my view, creatine is the most effective nutritional supplement for high intensity/anaerobic athletes.

The only reported side effect from creatine supplementation in studies lasting up to 5-years in duration in healthy and diseased populations has been weight gain. Yet, I have been amazed at all of the supposed side effects attributed to creatine supplementation in the popular media. Simply stated, there is no evidence that creatine supplementation causes dehydration, cramping, muscle strains/pulls, gastrointestinal distress, kidney damage, muscle damage, liver damage, cancer, or death as has been “anecdotally reported” in the popular media. In fact, over the last several years, researchers have conducted a number of studies to determine whether there is any validity to these anecdotal concerns. So far, none of these studies has been able to uncover any of these supposed side effects from creatine supplementation. Moreover, several studies indicate that in creatine supplementation may actually lessen the incidence of some of these problems (e.g., dehydration, cramping, muscle strains/pulls, etc). People who take creatine may experience some of these problems, however, the incidence does not appear to be any greater than subjects who take placebos or who serve as control subjects.

Conversely, research has demonstrated a number of potentially helpful clinical uses of creatine for heart failure patients, infants and patients with creatine synthesis deficiencies, patients suffering orthopedic injury, and patients with various neuromuscular diseases (e.g., muscular dystrophies, Parkinson’s Disease, etc). There are even several studies indicating that creatine supplementation may improve blood lipid profiles, which is associated with a reduction in risk to heart disease as well as slow progression of certain cancers. Consequently, all available evidence suggests that short and long-term creatine supplementation appears to be safe when taken within recommended guidelines.

The future of creatine research is very promising. Researchers are attempting to determine ways to maximize creatine storage in the muscle, which types of exercise may obtain the greatest benefit from creatine supplementation, the potential medical uses of creatine, and the long-term safety and efficacy of creatine supplementation. Among these, the most promising area of research is determining the potential medical uses of creatine particularly in patients with creatine synthesis deficiencies and neuromuscular diseases. Nevertheless, in regards to athletes, creatine has continually proved itself to be one of the most effective and safe nutritional supplements to increase strength, muscle mass, and performance. This is despite all

of the inaccurate and misleading information that has been written about creatine over the last several years.

Common Questions about Creatine

Over the years, I have received many questions about creatine supplementation from athletes, parents, coaches and scientists. Many of these questions reflect the types of things that are most confusing for people who take creatine. The following answers some of the most common questions I am asked about creatine supplementation.

What is the best type of creatine?

Nearly all studies on creatine have used pharmacological grade 100% pure creatine monohydrate powder. However, a number of different forms of creatine have recently been marketed (e.g., creatine candy/bars, liquid creatine, creatine gum, creatine citrate, effervescent creatine, etc). Many of these types of creatine claim to be better than creatine monohydrate. However, I am aware of no data that indicates that any of these forms of creatine increases creatine uptake to the muscle better than creatine monohydrate. In fact, the effects of ingesting many of these types of creatine on muscle creatine content have never been determined. A few studies have compared different forms of creatine on performance. These studies generally indicate that they are effective forms of creatine but that they do not work any better than creatine monohydrate. The greatest advantage of some of these types of creatine is that they may be viewed as more convenient, a change of pace, and/or better tasting than creatine monohydrate. However, there is no evidence that they are more effective than creatine monohydrate powder. Additionally, there is no published evidence that you can take less of some of these forms of creatine (e.g., liquid or effervescent creatine) and still get the same benefits as ingesting higher amounts of creatine monohydrate due to less degradation in the stomach, greater intestinal absorption, faster absorption in the blood, and/or greater muscle uptake.

Is all creatine the same quality?

As stated above, creatine monohydrate is the most common form of creatine in nutritional supplements. Creatine monohydrate can be obtained from manufacturers in the United States, Germany, and China. The U.S. and German sources represent the purest and highest quality of creatine monohydrate currently available. They also follow federal guidelines and use pharmacological standards in processing creatine. Most research studies and quality supplement companies use creatine made in the U.S. or Germany. However, over the last several years, a number of supplement companies used creatine from China as their primary source. The reason for this was that China dumped a large amount of inexpensive creatine into the U.S. in an attempt to gain market share. This served to drive significantly decrease the cost of creatine. However, it was later learned that some of this creatine might have contained potentially harmful impurities. Consequently, the Federal Trade Commission successfully prosecuted the Chinese government for illegally dumping poor quality creatine. Because of this, when people ask me about sources of creatine, I suggest they purchase creatine from companies who use the U.S. or German sources of creatine. Additionally, I suggest obtaining quality assurance test results from the lot number of the supplement they purchased that shows purity and content. Many creatine products now include a creatine purity seal on the label (e.g., Creapure™ from SKW in Germany) that guarantees that the creatine is 100% pharmacological grade creatine. This is a convenient way to make sure you are purchasing quality creatine monohydrate.

What is the best dosage?

I recommend taking 0.3 grams/kg/day of creatine monohydrate (about 15 – 30 grams/day depending on body weight) divided into three to four daily equal doses for 5 to 7 days. Then, take 5 grams/day of creatine to maintain elevated creatine stores.

Do I need to load with creatine?

The most rapid way to increase muscle creatine stores is to follow the loading method described above. Most of the creatine is taken up by muscle during the first 2 – 3 days of the loading period. While there is one study that suggests that taking lower doses of creatine over time (3 grams/day for 28 days) increased muscle creatine content, it is less clear whether this low dose protocol enhances exercise capacity. Consequently, I recommend that people follow the creatine loading technique and then use lower doses to maintain creatine stores.

Do other nutrients enhance creatine uptake into the muscle?

Ingesting creatine with carbohydrate or carbohydrate/protein has been reported to enhance muscle creatine uptake. Therefore, I recommend that individuals ingest creatine using the guidelines described above. Many commercial creatine supplements claim to have advanced creatine transport formulations that enhance creatine uptake. Yet, many of these supplements only have 20 to 40 grams of carbohydrate. I am not aware of any data that indicates that muscle creatine uptake can be enhanced with this amount of carbohydrate or other nutrients contained in some of these supplements (e.g., taurine, sodium, potassium, etc). I am also not aware of any published data that shows that liquid or effervescent creatine increases muscle creatine content to a greater degree than creatine monohydrate.

Should I cycle on and off creatine?

At present, we don't know whether cycling on and off creatine is more or less effective than loading and maintaining creatine intake. It takes about 4 – 6 weeks after cessation of creatine supplementation for muscle creatine stores to return to normal. Additionally, the greatest benefits of creatine supplementation appear to be to enhance training adaptations. Therefore, if an athlete wants to cycle creatine, I suggest that they take creatine during training and/or take loading doses of creatine for several days at least once every 2 – 3 weeks.

When is the best time to take creatine?

Once an athlete has loaded with creatine, I suggest that they take creatine with a carbohydrate and protein following their workout in order to promote glycogen resynthesis, protein synthesis, and creatine uptake.

Does caffeine affect creatine?

Two studies indicate that co-ingesting creatine with large amounts of caffeine may negate some of the performance enhancing effects of creatine supplementation. For this reason, some have suggested that creatine should not be taken with caffeine. However, many initial studies on creatine that reported ergogenic benefit mixed creatine in hot coffee or tea to help dissolve the creatine. Additionally, muscle creatine content was increased in these studies despite the presence of caffeine. Consequently, it is my view that this concern is somewhat overstated.

Do acidic drinks degrade creatine?

Some have warned that mixing creatine in acidic solutions (e.g., juices) may degrade creatine to creatinine. However, the acid level (pH) of coffee (about 4.5), grape juice (about 3), and orange juice (about 2.8) is less than that found in the gastrointestinal tract (1 – 1.5). It is well established that creatine is not degraded into creatinine through the digestive processes despite very low pH levels. One recent study indicates that creatine is not degraded into creatinine throughout the first six hours of digestion. Therefore, it is unlikely that mixing creatine in fruit juice would degrade creatine unless you mix it in juice and let it sit for several days.

Do men and women respond differently to creatine supplementation?

Several short-term studies on females have revealed limited ergogenic value. This has led some researchers to question whether women respond to creatine differently than men. However, several recent well-controlled studies in women have reported that creatine supplementation significantly improved exercise capacity and fat-free mass in a similar manner as men. Therefore, it appears that women respond well to creatine supplementation.

Should children or teenagers take creatine?

Most creatine studies have been conducted in male and female athletes ranging between 18 and 24 years of age. Although, no study has indicated that creatine supplementation may be harmful, less is known about the effects of creatine supplementation in younger individuals. Consequently, it is my view that children and adolescent athletes should not take creatine unless creatine is medically prescribed or the child is past puberty; eating a well-balance diet; involved in serious training that may potentially benefit from creatine supplementation; well informed about creatine; and, that the supplementation program is supervised by the child's parents, coach, athletic trainer, and/or physician to make sure they take quality supplements in the proper manner. Under these conditions, I feel that creatine can serve as an effective and safe nutritional supplement for serious adolescent athletes.

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