
The following article was written in 1998 and revised in 1999 by Exercise Physiologist Dr. K. Shawn Davison.

# Creatine Monohydrate Supplementation and Muscular Performance: Effective, Legal and Safe

## I. Introduction

In the modern sporting arena where competitions are won and lost by increasingly small margins, minuscule increases in muscular performance frequently translate into tremendous gains in an athlete's relative standings. As a consequence of this, many athletes have attempted to attain some form of competitive advantage through supplementation of various hormonal or dietary interventions that have known or claimed ergogenic effects. While hormonal interventions, such as anabolic steroids and human growth hormone, are effective in increasing muscle strength and power, and consequently performance, they are banned from all sporting competition and have numerous negative side-effects associated with their long-term administration. Many dietary interventions or supplements, such as bee pollen, inosine, ferrulic acid, and protein powders, have often been touted as "steroid substitutes", but none has withstood rigorous scientific scrutiny to confirm that they confer any significantly positive ergogenic effects above which a healthy balanced diet would provide.

Until now, If an athlete should make the individual decision to consume an ergogenic agent, it should possess three qualities before it is deemed acceptable for supplementation: it should be effective in increasing performance, legal, and exhibit no harmful side-effects. Supplementation with creatine (Cr) monohydrate exhibits all of these attributes. Interest in Cr supplementation for athletes has increased dramatically in the past year due to both the support of the majority of the scientific community and vast anecdotal evidence. Unfortunately, because Cr has garnered so much recent media attention there is a great deal of misinformation regarding Cr supplementation and it's capabilities as an ergogenic agent.

This review is written with the intent to provide a general background of what Cr is and how it is utilized in the body, to present the general findings from the scientific literature

of Cr supplementation on muscular performance, and to suggest the most contemporary, effective, and safe dosing schedules for Cr supplementation.

## II. Creatine Production and Degradation in the Body

The body's muscles are provided with Cr from both its production within the body itself (endogenous) and from ingestion through the diet (exogenous). Creatine is a naturally occurring essential amino acid that is synthesized within the body in the liver, pancreas, and kidneys from the precursor amino acids glycine, arganine, and methionine. Dietary intake of meats (4-5g/kg meat) and fish (4-10g/kg fish) supply additional creatine to the body through the digestive tract. However, cooking may denature much of the creatine in these sources and thus make it unavailable, so the quantities that are actually biologically available to muscle may be vastly lower than what is suggested. Plants only provide trace amounts of Cr, suggesting that vegetarians may be somewhat Cr deficient since all of their Cr must be produced endogenously. In fact, numerous studies that have investigated the amount of Cr within muscle have concluded that on average vegetarians have lower concentrations of Cr in their muscle when compared to individuals on a regular omnivorous diet.

A 70kg individual naturally loses about 2g of Cr per day from their muscle, which is excreted in the urine as creatinine. No studies have been undertaken to investigate whether active individuals lose more than Cr than sedentary individuals, which would be expected since they utilize a greater proportion of their total Cr stores. Therefore, the estimate of 2g/day loss of Cr may be conservative for an athletic individual. In order for an individual to maintain their present level of Cr they must replace at least what is lost daily to natural degradation processes. The average intake of Cr in a mixed diet has been estimated to be approximately 1g/day. Thus, only part of the daily Cr requirement can be attained from the diet, and must be complemented from endogenous synthesis. It has been suggested that the majority of athletes are in fact Cr deficient, due to the fact that dietary intake is almost always insufficient to maintain optimal Cr levels.

## III. The Role of Creatine in Muscle Contraction

Every cell from as simple as a unicellular algae to any cell within the human body use one particular molecule for all processes that require energy - adenosine triphosphate (ATP). ATP consists of a conglomeration of an adenosine molecule and three phosphate molecules. Muscle cells utilize ATP to provide all the energy needed for muscular contraction, whether it be for fast or slow movements, for short or long durations, or for maximal or submaximal efforts. When the body requires energy for a given process it cleaves off one of the phosphates of ATP, which releases a great deal of energy, leaving the resultant molecules free phosphate and adenosine diphosphate (ADP).

In order for the body to have ATP for energy production, it must burn "fuels" to create these ATP molecules. Typical fuels include glycogen (sugars), glucose (sugars), fatty acids (fats), and amino acids (proteins). The fuel that is used for ATP production at any particular time is dependent upon what intensity and duration the exercise is to be

performed at, and it is not uncommon that the body burns more than one type of fuel at a time.

At rest the muscles “stockpile” ATP for use in immediate muscle contraction. ATP that is found stored within the muscle (intramuscular) results in the most rapid and forceful contractions since the body doesn’t have to wait for any of the previously mentioned fuels to be burned in order to provide ATP. However, the amount of ATP that is available from intramuscular stores is extremely low and can only provide enough energy for 2-3 seconds of high-intensity activity. This process does not require oxygen and is therefore is classified as anaerobic (an - lack of, aerobic - with oxygen). At rest, intramuscular stores of ATP are replenished through aerobic metabolism, which will be discussed shortly.

Glycolysis, which uses glucose or glycogen for a fuel, is the next fastest provider of ATP for muscular contraction. This process is able to produce enough ATP for up to a couple of minutes of fairly high intensity exercise, but also produces the byproducts lactic acid and pyruvic acid, which interfere with normal muscle function.
A third source of ATP to the body is through aerobic metabolism, but while providing the body with a nearly endless supply of ATP, is extremely slow and can only be used primarily for low- to moderate-intensity activity. It uses fatty acids and amino acids as fuel. Aerobic metabolism is responsible for building up the ATP in resting muscle.

So where does Cr enter the picture? Much of the Cr that is found intramuscularly is bound to a phosphate molecule of its own and is then in its phosphorylated form, creatine phosphate (Crp). After all the intramuscular stores of ATP that are available have been used up (2-3 seconds), Crp donates its phosphate molecule to ADP to regenerate ATP, making it immediately available for further maximal energy production (up to approximately 8 seconds total). The pool of Crp within the muscle is approximately 3-4 times that of the ATP pool. Therefore, by the process of Crp giving up its phosphate group to ADP, maximal contractions can be maintained up to approximately 8 seconds, whereas without it power would decline after 2-3 seconds, which allows for up to 200% more high intensity work to be performed. The availability of Crp as an energy substrate is considered to be a possible limiting factor for maintaining muscle force during high intensity exercise. Furthermore, during times of rest, Cr acts as a transport shuttle for already formed ATP from the mitochondria (site of aerobic ATP production) to the muscle contractile tissues (site of utilization).

**IV. Creatine Supplementation: The effects on muscular performance**

Strict scientific research, almost exclusively performed in England and Sweden, has identified three positive effects of Cr supplementation on muscular performance:

1. Cr supplementation allows for quicker recovery after repeated maximal bouts of exercise:

Crp resynthesis after maximal exercise has been shown to be more rapid with a larger intramuscular pool of Cr. What this means is that after an exhaustive maximal or near-

maximal bout of exercise, recovery is faster with Cr supplementation, which allows the athlete to return to high-intensity performance sooner, and often for a longer duration and with greater power output than before supplementation.

2. Cr Supplementation allows the athlete to produce larger power outputs in repeated bouts:

Many studies have shown that Cr supplementation can enhance short duration, dynamic, high intensity, intermittent exercise. This is primarily due to larger Crp stores which allow for more ATP to be resynthesized during maximal or near maximal activity. Supplementation has also been shown to enhance the ability to sustain power output during repeated bouts of high intensity exercise. Thus, any sports that have a large demand for maximal repeated power output will benefit from Cr supplementation.

2a. Anaerobic Activity - Repeated Short Maximal Trials

While there seems to be little effect of Cr supplementation on one-time peak power output, overall exercise capacity in high intensity exercise is improved, especially in repeated tasks. Peak power output over repeated bouts is seen to show a smaller decline after supplementation. Cr supplementation improves muscular performance that allows for more high-intensity work to be done during training which should result in an enhanced training response. One investigation found that a group of resistance trained individuals increased their total lifting volume by 26% after 28 days of supplementation, and another study found that in a group of subjects tested on bicycle ergometers power output in repeated 30-second maximal bouts increased 13-18% after 5 days supplementation.

2b. Aerobic Activity - Endurance Exercise

The effects of Cr supplementation in endurance exercise has revealed few positive benefits, which logically would be expected since sports with a large aerobic component do not rely on anaerobic metabolism a great deal for ATP. Typically there is no improvement seen with Cr supplementation, and often a decrease in run times. This decrease in time is most likely due to the weight gain associated with Cr supplementation.

3. Cr serves as an acid buffer within the muscle and spares the production of lactic acid:

Cr within the muscle buffers lactic acid, thereby keeping the pH of the cell near normal for a longer duration. Lactic acid interferes with normal contractile properties of the muscle, and, if too much accumulates, contraction becomes nearly impossible until it is removed. Therefore, the more Cr found intramuscularly, as is observed with supplementation, the more acid it will buffer and the longer high-intensity exercise can be performed. Additionally, since with Cr supplementation there is a greater amount of ATP being resynthesized by Cr, it spares the use of gylcolysis, which produces lactic acid as a byproduct of burning sugars for fuel to produce ATP. In one study with

repeated maximal bouts of high-intensity exercise muscle lactate accumulation was 70% lower following Cr supplementation as compared to before.

Thus muscular performance improvements observed following Cr supplementation are due to higher rate of Cr resynthesis during recovery periods, a greater availability of Crp before each bout as a consequence of a higher pre-exercise concentration, and a smaller decrease in muscle pH.

## V. Creatine Supplementation: suggestions for proper usage

Cr ingestion will not increase the muscle Cr content above the muscle's saturation point, and therefore merely optimizes the fuel store required for intense exercise, analogous to the way carbohydrate loading augments endurance capacity during prolonged endurance exercise. A number of investigations that have studied the effects of Cr supplementation have concluded that the intramuscular stores of Cr can be increased from 3.7-3.9g Cr/kg dry muscle to a saturated level of approximately 5.0g Cr/kg dry muscle. Increases in intramuscular Cr after supplementation will vary greatly between individuals, with some witnessing vast increases in Cr, while others observing little change. Typically, those that have the lowest intramuscular levels before supplementation will display the largest gains. This is particularly evident in vegetarians. It must be stressed that once the muscle saturation point has been attained the muscle will not take up any more Cr than what is naturally turned over daily.

Typically, dosing is split into two distinct phases: the loading phase and the maintenance phase. The most scientifically accepted loading phase consists of 5g. of creatine taken 4 times daily for 5 days. This exogenous Cr (almost exclusively administered in the creatine monohydrate form) is taken up by the body very rapidly and transported to the muscle. In the first day the majority of Cr is taken up by the muscle with the remaining being excreted in the urine as creatinine. As the loading phase continues, progressively less Cr is taken into the muscle and progressively more is excreted. After five days the muscle is generally saturated and loading for even a sixth day will not increase muscular stores. At this point of muscular saturation the Cr supplementation should enter into the maintenance phase. During the maintenance phase only as much Cr need be taken as is eliminated from the muscle per day. Typical dosages have been in the 3g. per day region. It is suggested that the maintenance dose be split into two doses - one just before the workout and one just after to ensure maximal muscular uptake. The maintenance phase should be followed up to six weeks, after which time a period of at least four weeks should be allowed before supplementation is continued. It takes approximately 4 weeks for the muscle Cr to return to pre-supplementation levels.

When consuming Cr it should be taken with food as enhanced Cr uptake is observed when it is administered in the presence of insulin, which is released during the digestion of foods. Vitamin E has been shown to aid in Cr metabolism, so any deficiency in this vitamin could lead to less than optimal anaerobic performance. While supplementing with Cr, the athlete should ensure that they drink in the range of 4-6 litters of water per

day. A few studies have suggested that Cr uptake seems to be higher in exercised muscle than in non-exercised muscle, so activity may also help to “load” the muscles optimally.

Before supplementation with Cr is adopted the athlete should first examine their diet, for a sound diet will confer far greater benefits than supplementation with any ergogenic substance. In addition, the athlete should be working out at least 5 times per week before considering supplementation, for any level below this greater gains can generally be realized by increasing the workouts than by supplementation alone. If an athlete should make the choice to supplement with Cr, they should opt for the purer Cr monohydrate as compared to the inferior Cr citrate. Typically, the citrate contains only approximately 65% creatine, where the monohydrate contains 95-99% and seems to be absorbed better.

## VI. Side Effects of Creatine Supplementation

In the 100 years of Cr research the only side effect that has been observed has been that of increased body mass. It is not currently known the long-term effects of a high-dose administration. Therefore, it is suggested that a 6 week on, 4 week off regimen be followed. While endogenous production of Cr is somewhat suppressed during Cr administration, it returns to normal levels after supplementation is completed. It must be stressed that more Cr is NOT better. Once the muscle has hit the saturation point then it is simply excreted. If one was to take high doses continually it may lead to problems with the liver or kidneys (this has not yet been observed, but is hypothesized). In terms of gastrointestinal upset extreme doses of Cr have been associated with acute diarrhea, and some people have experienced mild stomach upset in the loading phase.
Almost unanimously increases in muscle Cr have been accompanied with slight increases in body weight (0.5-2.0 kg). The majority of this gain in weight has been attributed to gains in intramuscular water. However, some studies have suggested that at least part of this weight gain may be due to muscle hypertrophy that was mediated through a stimulatory effect of Cr on protein synthesis.

## VII. Summary

Cr supplementation is an effective, legal, and safe way to increase anaerobic muscular performance, especially in those sports or activities that require maximal or near-maximal repeated sprints. It appears that Cr supplementation increases the amount of Cr available for energy production, speeds recovery, and buffers lactic acid within the muscle cell. There are no known side effects of Cr supplementation aside from slight weight gain which has been attributed to water retention.

# Creatine Monohydrate Dosage Schedule
## The Latest Scientific Evidence

Creatine Background:
Creatine (Cr), in the form of creatine-phosphate, plays an integral role in the resynthesis of ATP within the muscle. Therefore, activities that heavily rely on rapid energy utilization should benefit from Cr supplementation. Research from as early as 1926 has shown the positive muscular effects of Cr supplementation, but recently there has been a surge of research spurred on by a need for a safe alternative to anabolic steroids. The only known side effect of Cr in the literature is that of a slight weight gain, attributed to an increase in intramuscular water stores. Cr is a nitrogenous organic compound found naturally in meat and fish (~5 g. CM per kg.). Cr can increase muscular performance in repeated short sprints and help deal with lactic acid. There is some current research that suggests that CM may increase muscle protein synthesis, through a number of pathways.
Initial Loading Phase:

This phase is characterized by a logarithmic decline in creatine monohydrate uptake. In other words, in the loading phase the body initially takes up all of the Cr and utilizes it intramuscularly, but as the phase continues, the body absorbs less as it becomes saturated - a pattern of diminishing returns.
The most scientifically accepted loading cycle consists of the following (5g. ~ 1 tspn.):
Five days of loading: 4 doses of 5g. per day (breakfast, lunch, dinner, before bed)

Maintenance Phase:
After the initial loading phase, you should move onto the maintenance phase as the body has been saturated with Cr and now you only need replace what is naturally excreted, primarily through the urine.
3g. per day for as long as you wish to continue supplementation (6 weeks maximum!)

Additional Tips for Successful Results:

- Cr uptake is Na+ (sodium) dependent and is aided by insulin, therefore, it is best to take your dose of CM with a meal or at least with some form of fruit juice
- do not take it with hot liquids, such as coffee, for Cr is denatured and rendered ineffective in such an environment
- while supplementing Cr, ensure that you drink enough water, in the range of 4-6 liters per day
- do not supplement for more than six weeks. If you supplement for longer than this the body begins to shut down production of endogenously (naturally) produced creatine - try to remain “off” for as long a period as you were “on”
- do not take more than what is suggested - more is not better!! It is simply excreted in the urine and if this occurs too much could possibly tax the kidneys
- use the more potent creatine monohydrate instead of creatine citrate
- make sure that you have a balanced diet
- if you are not working out at least 5 times a week, then supplementation may not be of as much benefit as increasing your workouts

# Creatine Monohydrate Supplementation: A Second Look

**by K. Shawn Davison**

## 1.0 Introduction

About a year-and-a-half ago, a review article in this newsletter addressed the efficacy and safety of creatine monohydrate (CM) supplementation (Creatine Monohydrate Supplementation and Muscular Performance: Effective, Legal and Safe). At that time use of CM was widespread, but since then the use of CM has only further increased in almost every facet of the sporting population. In fact, as a testament to the popularity of CM, a recent market analyses indicated that last year the total sales of CM supplements was in the hundreds of millions of dollars.

Creatine monohydrate's tremendous popularity as an ergogenic agent has spurred on copious amounts of research, sometimes done with little regard for proper scientific procedure and often completed with the financial backing of supplement companies, making the research results and conclusions questionable. Additionally, with CM's increased popularity there has been a growing groundswell of debate regarding the proper usage of CM and whether it is safe if taken chronically. This article was written with the intent to provide the most current information on the efficacy and safety of CM supplementation.

## 2.0 Efficacy of Creatine Monohydrate Supplementation

### 2.1 Creatine Monohydrate and Maximal or Near-maximal Activity

A review of the most current well-controlled investigations of CM supplementation shows that in the majority of studies it does appear to be effective when used to increase power output in a series of repeated high-intensity bouts (5-90 second bouts, usually). It is important to note that not all investigations show this positive effect – there are almost as many investigations that show no effect. However, many of the studies that do show no effect are often flawed in their methodological design, specifically in their dosing schedule of CM or in their poor control of dietary factors. These results make sense when the bioenergetics of the creatine phosphate system (responsible for all maximal or near-maximal intensity activity of 1-10 seconds) are taken into consideration – if there is more creatine available there will be more rapid and complete recovery of this system when multiple bouts with short recovery periods are performed. This improved recovery will allow for the higher outputs witnessed in these trials of successive high-intensity bouts. Additionally, creatine acts as a buffer in the muscle, combining with lactic acid to allow for longer high-intensity activity to occur.
In terms of a single high-intensity bout, there doesn't really appear to be that much benefit of CM supplementation. Theoretically, single sprints should also benefit to some extent, since higher levels of creatine phosphate should allow for longer maximal power output, but this has not been well supported by the literature. However, if training for a single explosive bout involves multiple bouts, then CM supplementation may be

effective in allowing for a greater workload to be performed and therefore a greater training response the result.

Therefore, CM supplementation seems to bring higher levels of power output for athletes involved in multiple high-intensity trials (especially those that do not allow enough time between bouts for a full recovery – 2-3 minutes).

**2.2 Creatine Monohydrate and Aerobic Activity**

Aerobic athletes have been documented as attempting to use CM supplementation to improve their performance. Not surprisingly, these athletes have had little success with this regimen of supplementation. Endurance athletes have very little demands placed on the anaerobic alactic system (the systems which almost exclusively benefits from CM supplementation), with the exception of the finishing kick of a race.

The marginal benefit afforded by a slightly greater kick at the end of the race is theorized to be completely eliminated by the effects that CM has on water retention in the body, an almost inevitable side-effect of CM supplementation. This increased water retention negatively effects the endurance athlete in two ways. First, in any sport that is weight bearing an increase in non-productive weight will increase the relative amount of work that must be performed by the musculature at any given workload. Thus, the water gain associated with CM supplementation will cause the athlete to increase their body weight and certainly slow the athlete. Secondly, since each muscle fiber is expanding from taking in additional water, the distance that an oxygen molecule has to travel from the blood stream into the active aerobic mechanism within the muscle cell (mitochondria) is increased. This increased distance that the oxygen molecule must travel in order to get to its site of active metabolism within the muscle cell slows the aerobic system and diminishes its power.

For these two reasons scientific investigations have quite consistently shown that there is in fact a negative effect of CM supplementation in aerobic athletes. The message is loud and clear for endurance athletes – don't supplement with CM.

For a more in-depth review of the bioenergetics of the creatine phosphate system, please see the article mentioned above.

**3.0 Safety of Creatine Monohydrate Supplementation**

With so many people ingesting CM in blind faith that it is a harmless supplement, there have been many questions regarding the safety of its supplementation. Let me first state that to my knowledge there is no evidence in the scientific literature showing that there is any negative effect of CM supplementation over the short term. Indeed, a number of short-term studies have concluded that there are no side effects, aside from water retention, of CM supplementation. Now, let me add that there has not been proper investigations performed yet that have looked at its safety for chronic usage. One only has to remember when the medical community deemed thalidomide "safe". The message here is that we have to be extremely cautious whenever we put any foreign agent into our body, for ultimately it is our responsibility to err on the side of

caution. This goes doubly for any doping or supplement agent. With respect to this, I have pieced together all of the information I am aware of in an attempt to attain some form of mosaic that will elucidate some of the possible health hazards of CM supplementation.

There are many factors to consider when addressing the safety of a ergogenic supplement. Since supplemented CM is not isolated in the muscle, it has effects throughout the whole body, and each must be investigated in order and weighed against the performance benefits it provides.

**3.1 Hydration Status, Flexibility and Muscle Strains and Tears**

Approximately 95% of the CM found within the body is stored in the muscle. With a vast increase in CM storage within the muscle, as is seen with supplementation, there is a resulting vast increase in the water stored inside the muscle as well (remember from high school biology that a solute will pull a solvent through a membrane in order to establish a concentration equilibrium). This increase in muscular water stores is evidenced by the increase in body mass of the athlete following CM supplementation. In a perfect world, we would all be fully hydrated at all times, however we don't live in a perfect world and very few of us diligent enough to be fully hydrated at any given time. A fully hydrated state allows the body to perform physiologically optimally relative to its state of present training. CM supplementation puts a further responsibility on the athlete to stay super-hydrated. During the initial loading phase of CM supplementation it has been shown that urine output drops dramatically for a number of days – this is the body's way of trying to become hydrated (water conservation), since it "senses" that it is very dehydrated as a result of increased intramuscular CM stores. The very presence of a decreased urine output signals a state of dehydration. It is essential that during supplementation that the athlete drink copious amounts of water and avoid diuretics such as coffee to allow for full hydration.

Dehydrated muscle cannot perform biochemically optimally, which is a performance factor, but in terms of safety flexibility becomes a big issue. In states of dehydration flexibility decreases, which again may effect performance, but in high – or maximal intensity activity inflexibility in muscles usually leads to one thing – muscle strains and tears. While no investigation has documented an increase in strains and muscle tears, discussions with elite teams have elucidated indeed an increase in the incidence of these traumas and a decrease in flexibility. Therefore, it is imperative for the athlete to have sound nutritional practices, and for them to be extremely diligent about proper hydration at all times.

**3.2 Stronger Muscles but Relatively Weaker Tendons**

As mentioned earlier, there is little debate that CM supplementation will increase power output over short durations. So do anaerobic steroids. One of the big problems (aside from organ failure) that is attributed to steroids is that they are too specific to muscle when the musculotendinous union is taken into consideration. In essence, steroid strengthens the muscles faster than the corresponding strength in the tendons and ligaments can be established, which leads to the situation of extremely strong muscles

being supported by relatively weak tendons and ligaments. In any chain of systems the weak link breaks, and that is what happens with steroids – tears of tendons and ligaments are exceedingly high.

Athletes that have been supplementing with CM seem to be having higher rates of these tendinous and ligamentous tears as well (again, this is all anecdotal and from personal observation). What is happening? The muscles are indeed getting stronger but at a faster rate than the tendons and ligaments, leading to an unbalanced system. Muscles have tremendous blood supply and therefore can recovery and strengthen quickly whereas tendons and ligaments have extremely poor blood supply and heal slowly and strengthen slowly. This is a growing problem with CM administration that has not yet been officially reported.

**3.3 Effects of Chronic Supplementation on the Liver and Kidneys**

Lastly, there have been concerns regarding the safety of CM on the organ systems, most specifically the liver and kidneys. The body naturally produces some creatine from three precursor amino acids. This endogenous creatine is largely produced in the kidneys and liver. Once supplementation has begun, often the endogenous supply will shut down since it senses that there is not additional creatine needed as the system has become saturated. It is assumed that once supplementation has ceased that the endogenous production will continue, but there has been some debate recently as to whether it is able to regain its old level of production. This is one small concern.
Since creatine is filtered through the kidneys and liver, chronic supplementation may in the long run lead to kidney and/or liver stress, which could lead to organ damage over the long-term. Again, this has not been documented, but is possible since no long-term studies have been completed. Since other medications such as antibiotics and anitfungals are also hard on the kidneys, it is suggested that CM supplementation cease if an individual is taking one of these agents.

A big problem in athletics is the thinking that if some is good than more is better. With CM this could certainly tax the liver and kidneys beyond their capacity. Again, the long-term effects of this agent are not known, so beware of chronic use.
Another worry is that to date no investigation has looked at the effects of CM supplementation on adolescents – possibly one of the largest single groups of CM users. This research is direly needed as we know that there are many differences between mature and immature individuals physiologically.

**4.0 Proper Dosing Schedule for Creatine Monohydrate Supplementation**

It is imperative that during the maintenance phase of loading that there only be as much creatine taken as there has been lost naturally – approximately 2g per day – any more and the kidneys and/or the liver will suffer. In fact even during the loading phase, 40% of the ingested CM is lost in urine the first day, 60% the second day, 70% the third day and so on. The optimal dosing schedule has changed little in that there should be 4-5 days of loading at 4x5g per day, which is followed by up to 5 weeks of maintenance of 2x1g per day.

The CM should be taken with food as it has been shown to be insulin dependent. Occasionally, mild stomach upset is witnessed in the loading phase and occasionally diarrhea is observed. After the CM supplementation phase there should be a wash-out phase of 4-6 weeks.

Interestingly, many investigations have shown that there is tremendous variability in the natural levels of creatine within the muscles of different individuals. Vegetarians have been consistently shown to have the lowest endogenous levels before CM supplementation. Even within an omnivorous group of individuals there is a sizable difference in the amount of intramuscular creatine there is present. Typically, in dosing studies those individuals that have the lowest levels of creatine at the start of the investigation are those which make the largest gains from CM supplementation. Those individuals with the highest levels typically didn't see that much improvement of performance or really an appreciable difference in the concentration of creatine within the muscle. Thus, it seems evident from the literature that there are certain individuals that may respond better to CM supplementation than others. Since almost all of the creatine ingested from foods come from meat and fish sources, it isn't surprising to witness that vegetarians have the lowest levels of intramuscular creatine. Even for those individuals who ingest a lot of meat or fish, often the creatine is denatured from the cooking and is virtually useless to the body after this.

**5.0 Sharpening the Blade**

While the positive effects of CM supplementation on some forms of athletic performance are becoming more apparent every day, the athlete must first weight the benefits of supplementing with the positive effects that could be obtained from other sources before supplementation is begun.

Before an athlete ingests a given supplement, he or she should ensure that it possesses three fundamental qualities: efficacy, legality and safety. There is now little question on the efficacy and so far there have been no movements towards banning the supplement (which would be nearly impossible to measure anyway). The only question lies in the safety. While the short-term usage has so far shown no long-lasting side effects no one is sure of the effects of chronic use over the long term. For that reason CM should only be considered for those elite athletes who have exhausted all of the traditional methods of increasing performance – proper training and nutrition.
The gains that are witness with CM supplementation are far less than those that can be realized by proper dietary habits. As well, unless the athlete is working out at least five sessions per week, better performance gains would be realized by simply placing them on an intelligent training program of a higher frequency. Only after the athlete has proper nutritional habits and have exhausted their training options should they reach for a supplement such as CM.

While CM is legal we still don't know if it is entirely safe. Until proper long-term investigations have been completed we should be cautious in our administration of CM and only use it as the last factor in a successful training program for an individual that is mature enough to realize the possible health risks associated with its use. As there has

been no experimentation done with adolescents, CM should not be used in this population until it is proven to be safe.