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THE BIOCHEMISTRY OF CREATINE AND ITS EFFECTS ON PREFORMANCE TRAINING

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1.0 Abstract

Among the thousands of commercially available supplements on the market today that claim to enhance physical performance and enhance muscle growth in the gym, none of them are as controversial and talked about than creatine. It is claimed to improve strength and promote the growth of lean muscle mass, including the benefits of aiding in muscle recovery during exercise allowing for athletes to achieve better results in the gym. The most common form of creatine consumed and used for training is creatine monohydrate, $C_4H_9N_3O_2$, and will be the form of creatine in refence used throughout this paper. Creatine monohydrate is sold commercially in its most stable solid form, in aqueous solution creatine is unstable and is degraded into creatinine due to intramolecular cyclization, at a lower pH and higher temperature this conversion occurs even faster (Kreider et al, 2017).

2.0 Creatine Monohydrate Synthesis

Endogenous creatine that exists inside the body is composed of the three amino acids: L-methionine, L-arginine, and glycine and is produced in the kidneys, liver, and pancreas and is stored primarily in the skeletal muscle tissue and in small amounts in the brain (Balsom et al, 1994). Steps involved in the synthesis of endogenous creatine after consumption of either the dietary supplement or red meats and fish begin in the kidney (Balsom et al, 1994).The first process involves the enzyme arginine:glycine amidinotransferase which helps to mediate the transfer of the amino group from the glycine and arginine in order to form the Guanidinoacetate compound (Balsom et al, 1994). This product then undergoes a methylation reaction by the Guanidinoacetate N-methyltrasnferase complex in order to form creatine.

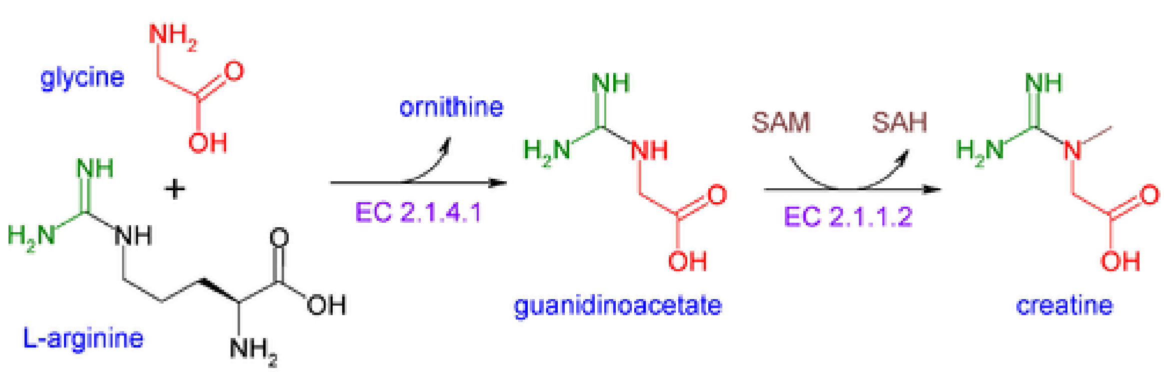

Figure 1: Biosynthesis of Creatine from L-arganine and glycine amino acids using the enzyme catalyst arginine:glycine amidinotransferase and Guanidinoacetate N-methyltrasnferase within the kidneys. (NCBI, 2021).

2.1 Creatine and ATP regeneration

The muscles in the body work by using ATP to contract the muscle fibres to move a load or produce a force, in performance training and anaerobic exercise, ATP is consumed rapidly, and so the need to replenish the energy stores is vital for continued exertions. When we use ATP, it is consumed in a hydrolysis reaction to the more stable form, Adenosine Diphosphate, also known as ADP, a phosphate group is produced along with the free energy (Cooper et al, 2012). Thus, as athletes intake supplementary creatine, it gets converted to Phosphocreatine through the addition of a Phosphate group and is stored in the skeletal muscles ready for use. Additionally, the reaction is readily reversible, which allows for the buffering of ATP concentrations providing greater success of the compound used in short burst exercises, which is why most athletes who use dietary creatine engage in sports like basketball and sprinting opposed to marathon running (Cooper et al, 2012).

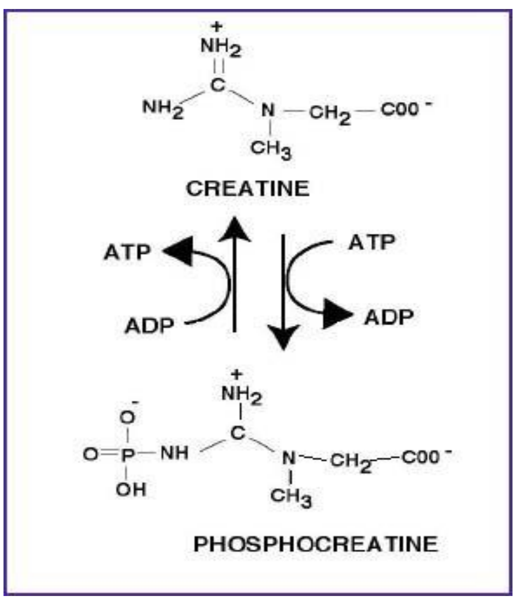

Figure 2: The chemical structure of creatine and its conversion to the catalytic energy conversion state of phosphocreatine. (image from: https://www1.udel.edu/chem/C465/senior/fall00/Performance1/phosphocreatine.htm.html)

3.0 Creatine supplementation

An average diet contains roughly 1-2g of creatine daily from meats and fish, skeletal muscle contains a capacity of 60-80% saturation of creatine on such levels. Thus, supplementation of dietary creatine looks to increase the phosphocreatine and creatine stores by 20-40% (Bemben et al, 2005). This requires athletes using dietary creatine to typically undergo a week long loading phase of consuming 5g of creatine monohydrate four times a day for a total of 20g a day for 1 week, which ensures that creatines stores are maximally saturated. Then, a maintenance dose of 3-5g of creatine a day (or ~0.3 g/kg body weight) is maintained to regulate the loss of the molecule during ATP hydrolysis in performance training (Bemben et al, 2005). Loading and maintenance phases can vary in the amount and duration of the phase depending on the individual, however the maximal increase of creatine and phosphocreatine saturation in the muscles are reported in the first two days of loading (Bemben et al, 2005).

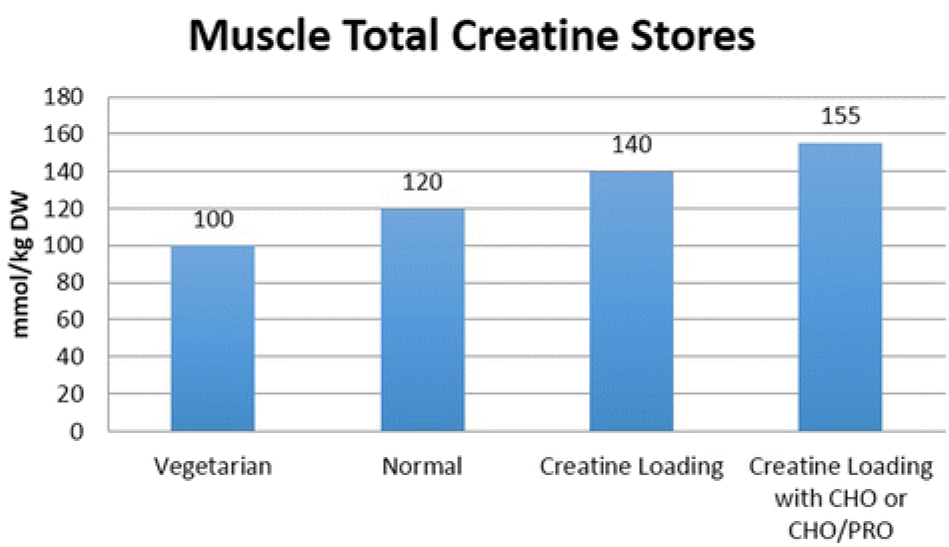

Figure 3: Muscle total creatine stores of varying dieting groups in mmol/kg dry weight (Bemben et al, 2005).

3.1 Short Burst Performance

Izquierdo and colleagues observed the effects of creatine supplementation using twenty trained male handball platers which were randomly assigned groups taking 20g of creatine a day for 5 days or a placebo group. The power output of the men were tested using a bench press at 60% for one repetition at maximal strength and a half squat at 70% of their one rep maximal strength, and completing a single set of 10 repetitions, followed by a 2-minute rest break, then a second set until failure (Bemben et al, 2005). The cadence of the lifts the athletes preformed were controlled by a metronome at 19Hz and their power and velocity output data was collected using a rotary encoder. The study found a significant improvement in the number of repetitions preformed until failure as well as an increase in the total average power output during both the half squat and the bench press in both phases of the exercise (Bemben et al, 2005). Additionally, there was a notable decrease in the amount of power and velocity drop off throughout the lifts of the athletes, allowing for a greater sustained power output during resistance training and performance (Bemben et al, 2005).

3.2 Endurance Performance

Many of the literature on the effects of creatine performance focus on its improvements in exercises and activities that are rapid and involve small windows of large power outputs as well in anaerobic exercise. In endurance exercise, there are few reported benefits to creatine supplementation. Jones and colleagues studied the effects of creatine on the kinetics of oxygen uptake during submaximal exercises. They took 12 regional triathletes and tested their blood oxygen levels at rest, then preformed a 30-minute cycle exercise at 70% maximum heart rate. Afterwards, the subjects started a 5g three times daily loading phase for 6 days of creatine monohydrate, after recording the athlete's blood oxygen concentrations before and after completing a 30-minute cycling routine at 70% maximal heart rate, they found no change in oxygen uptake kinetics (Kreider et al, 2017).

4.0 Effects of supplementation

With thousands of new studies and companies marketing creatine for dietary purposes, the most consistently reported side effect from supplementation is an increased water retention resulting in weight gain and often bloating (Kreider et al, 2017). This has led to other reports of individuals claiming to be dehydrated, experience muscle cramping, as well as gastrointestinal upset, as a result of this increased water retention (Maughan et al, 2018). Ferreira and associates looked at the effect on feeding Wistar rats creatine (2g/kg/d for 10 weeks) and observed no effects on the renal plasma flow and glomerular filtration (Ferreira et al, 2005). And yet, another study by Baracho and colleagues observed that rats with renal cystic disease being fed dietary creatine at 0,0.5,1, and 2g/kg/d exacerbated the progression of the diseased rats (Baracho et al, 2005). Critics of the supplement highlight the warning labels listed on the creatine products sold commercially that individuals 18 years old or younger are not recommended to be taking it as it may be potentially unsafe. However, there is no scientific evidence to suggest that supplementation of creatine at a young age could cause harm and is merely a legal marketing precaution.

Conclusion

Creatine monohydrate is very widely used by many different types of athletes in varying competitive fields, it is shown to provide greater performance efficiency in heavy compound movements like the squat and bench press, and other short burst exercises. This is due to the supplement converted to the readily stored version, creatine phosphate using ATP, which allows for a greater store of molecules that will convert ADP to ATP during muscle contraction (Cooper et al, 2012). One should only take creatine after considering all possible side effects and is recommended to consult a physical before taking in order to achieve the safest and reliable method of consumption.

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