Creatine supplementation
may contribute to enhanced freediving performance

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2008-07-01

Creatine metabolism and mechanisms related to anaerobic performance

Creatine is one of the most common supplements amongst athletes today and several studies have shown positive effects on anaerobic performance.

Adenosintriphosphate (ATP) is the molecule used as energy in the cells. During an anaerobic activity, the muscles first use the available stores of ATP which are hydrolysed during the process with the production of ADP, inorganic phosphate (Pi) and a hydrogen ion (H^+). The stores are limited and have to be regenerated. The molecule available for this purpose is phosphocreatine (PCr), a high energy molecule which donates a phosphate group to ADP and contributes to the regeneration of ATP Figure 1. The enzyme responsible for this reaction is creatine kinase. This rapid utilization effectively buffers the momentary lag in energy production from the glycolysis (1), which contributes to the major proportion of energy during anaerobic activities. There are several mechanisms proposed for the induced anaerobic capacity as a result of creatine supplementation. Apart from the obvious increased capacity to regenerate ATP and stored energy in the muscle cell due to the increased levels of PCr, it has been proposed that an increased rate in the resynthesis of PCr between the exercise bouts is responsible to the increased capacity. Following high intensity exercise approximately half of the pre-exercise muscle PCr content is restored within one minute of recovery, but a complete restoration of the PCr pool takes up to 5-6 minutes (2). This emphasizes the importance of rest between the apneas to allow restoration of PCr to take place.

A third mechanism suggested is that creatine supplementation contributes to a buffering effect on muscle acidity. As mentioned previously, anaerobic activity contributes to the formation of lactate which lowers the pH due to the dissociation of hydrogen ions (H^+). The increased acidity inhibits the enzyme phosphofructokinase which slows down the glycolysis as a result. The low pH also has the ability to displace calcium from troponin, interfering with muscle contraction and stimulate pain receptors. This has a negative effect on high intensity exercise. The resynthesis of ATP by creatine kinase using PCr, consumes H+ which has a buffering effect on the acidity and allow the muscle to accumulate more lactic acid before reaching a fatigue inducing pH. Another positive effect observed during supplementation is an increased muscle glycogen content (3).

Creatine is an osmotically active substance, meaning that a higher level of creatine in the muscle cell leads to a higher amount of water entering the cell (4). Due to this, an increased weight of 1-3 kg can be observed during supplementation of creatine.

Creatine is continually broken down and converted to its metabolic by-product creatinine, this at an almost steady rate of ~2% of the total Creatine content per day (5). The creatinine diffuses out of the muscle cells and is excreted by the kidneys into the urine.

Brain function

Creatine also plays a major role in the brain function. A study showed that in mice in which both mitochondrial creatin kinase and brain-specific kinase were knocked out showed a number of neurological impairments, including severely diminished spatial learning (6).

Vegetarians obtain very little dietary creatine and vegans virtually none. Essentially all of their creatine has to be synthesised in the body. The endogenous synthesis seems to be insufficient in these subjects since ingestion of vegetarian diets is associated with decreased serum and muscle creatine levels (7;8). Interestingly, a study by Rae et al. performed at vegans and vegetarians showed that creatine supplementation significantly improved their performance on a number of cognitive tests (9).

Creatine also seems to have neuroprotective properties which may be of interest for the **freediver**. In a recent study, mice were fed a diet supplemented with creatine for three weeks

and then underwent transient focal cerebral ischemia via occlusion of the cerebral middle artery for 45 min. Dietary creatine supplementation reduced the infarct volume of these mice by about 40% (10).

Antioxidant
Creatine also exerts direct antioxidant effects, particularly towards superoxide and peroxynitrite (11).

Creatine for freedivers?
For the freediver, supplementation with creatine may have positive effects on the performance due to the slightly elevated stores of energy in the muscle cells before performing an apnea. As mentioned above, supplementation may also have neuroprotective properties.

Optimal effect and muscle accumulation
The transport of creatine into the muscle cells is enhanced by insulin. Therefore, creatine should be ingested together with some carbohydrates for optimal uptake (12).

Interestingly, exercise is a potent stimulus for creatine uptake by the skeletal muscle. This was showed in a study where a single leg was exercised, resulting in appreciably more creatine uptake than in the unexercised contralateral leg (13).

Caffeine seems to totally negate the ergogenic effects of creatine (14). Therefore athletes who load creatine should refrain from caffeine containing products for several days before competition.

Dosage
Usually 20-25g/day of creatine monohydrate, divided into 4-5 doses, administered for 5-7 days are used during the loading phase, followed by maintenance doses of 2-5g per day.

Safety
Individuals with suspected renal malfunction should refrain from creatine supplementation due to the potential for exacerbating the disorder (15). In healthy subjects, the renal function seems to remain normal with cronic creatine use (16). Creatinine is commonly used as a marker for the renal function where high levels in serum indicate an impaired function. One method used in clinical laboratories to determine the creatinine levels is an enzymatic conversion of creatinine to creatine of which the concentration is subsequently determined. Because of the high serum concentration of creatine in subjects taking creatine supplement, this method is not suitable since the levels appear higher than they actually are (17). This may have contributed to the anecdotal renal dysfunction attributed to creatine supplementation.

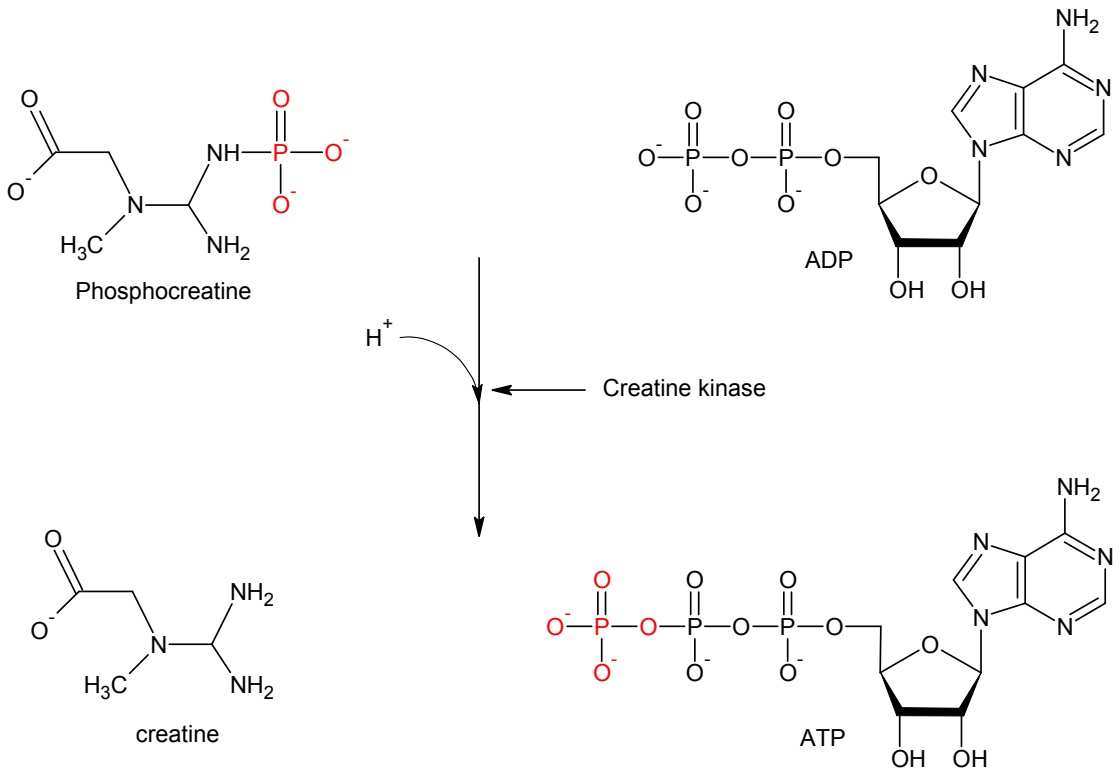

Fig. 1. The regeneration of ATP by creatine kinase

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