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# The Use of Carnitine and Pyruvate in Weight Management

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# THE USE OF CARNITINE AND PYRUVATE IN WEIGHT MANAGEMENT

by

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## ABSTRACT

Carnitine has been a naturally occurring compound since the beginning of the century, and was considered to be an essential nutrient for quite some time. Carnitine has many essential roles in the body. Carnitine transports fatty acids into the mitochondria for energy, controls ketogenesis, and modulates the acyl-CoA/free CoA ratio. Studies have postulated that exercise decreases carnitine in the body, therefore leading to a deficiency in athletes. Carnitine has also been used as a weight loss product because of its fatty acid oxidation function. Many nutritional supplement companies have marketed on these functions of carnitine, resulting in a big business. Pyruvate is another substance that has be postulated to help individuals lose weight. Pyruvate is needed for conversion of glycerol to acetyl CoA, which produces ATP for energy. Studies from the University of Pittsburgh Medical Center have found that pyruvate does reduce weight regain in individuals after weight loss. There are also numerous companies that market pyruvate for weight loss.

Carnitine is a water-soluble vitamin like compound (1). Carnitine has been a known naturally occurring compound since the beginning of this century, when scientists isolated carnitine from muscle biopsies in animals (2). When carnitine was first discovered in 1905, it was considered to be an essential nutrient for quite some time, since its physiological function remained elusive for years. Carnitine is very important for metabolic reactions in the muscle, but now not considered an essential nutrient since carnitine is formed in the liver from other nutrients (1). The two principal amino acids that forms carnitine are lysine and methionine (2) (Fig. 1).

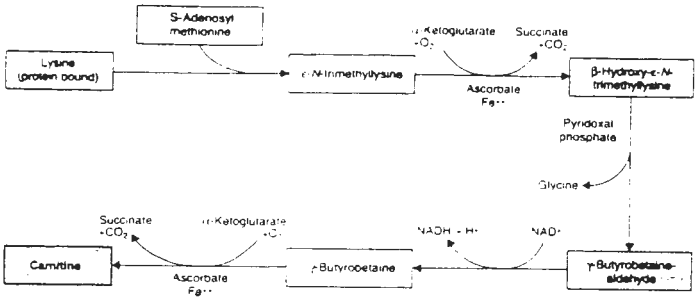



**Fig. 1.** Biosynthesis of carnitine.
**Source:** Heinonen OJ. *Sports Med.* 1996; 2: 109-132.

In addition, carnitine is found in large amounts in animal foods, particularly in meats. Most individuals consume enough carnitine in the diet, and the body has an effective conservation system, so there is no need for a RDA. Deficiencies are rare, however, vegetarians have been noted to have a decreased plasma level of carnitine compared to individuals consuming a mixed diet. Approximately 90% of the body supply of carnitine is located in the muscle tissues. This is important since carnitine supplementation has been theorized to enhance

physical performance (1).

There are primarily two forms of carnitine: L-carnitine and D-carnitine (2). There are other forms available such as l-propionylcarnitine which is used in supplements. L-carnitine is the physiologically active form in the body, and D-carnitine is the unphysiological form and may replace the natural intracellular L-carnitine (1). This is of concern, because large doses of D-carnitine has been shown to cause a deficiency of carnitine in the body or muscle dysfunction (3). Therefore, supplementation of D-carnitine is not recommended.

According to Heinonen, carnitine has many essential roles in the body. Carnitine's major function is for energy metabolism due to its role in transporting fatty acids into the mitochondria for utilization in energy-generating processes (2-4). Long-chain fatty acid oxidation is carnitine dependent in all tissues (2). Due to this, it has been theorized that an increase in carnitine availability to the muscle should increase fatty acid oxidation and in result, spare glycogen (3). Fatty acids must be esterified to acylcarnitines with carnitine so they can be transported into the mitochondria by the use of carnitine-acyl-transferase I. Acylcarnitines can then be easily transported across the mitochondrial membrane by the carnitine translocate to enter the mitochondrial matrix. In the mitochondria, acyl-CoA undergo β-oxidation and form acetyl-CoA by the action of carnitine-acyl-transferase II. This then allows carnitine to be recycled to the cytoplasm. Then in the muscle, acetyl-CoA is oxidized in the Kreb's cycle to produce lots of ATP, or in the liver, acetyl-CoA can be used for the formation of ketone bodies. Therefore, carnitine also contributes to the control of ketogenesis (2) (Fig.2).

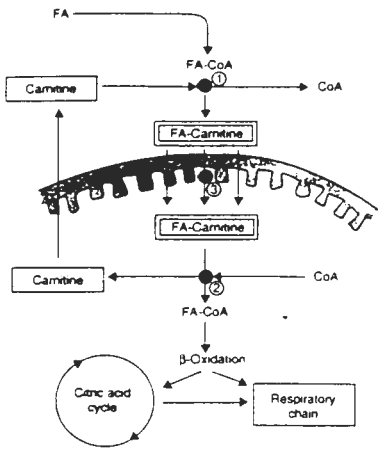



**Fig. 2.** Carnitine as a carrier of long-chain fatty acids (FA) into the mitochondria. *Abbreviations:* CoA=coenzyme A; FA-carnitine=acylcarnitine; 1=carnitine-acyl-transferase I; 2=carnitine-acyl-transferase II; 3=carnitine translocase.
**Source:** Heinonen OJ. *Sports Med.* 1996; 2: 109-132.

Another function of carnitine is to modulate the acyl-CoA/free CoA ratio (4). The way carnitine modulates this ratio is by the formation of acylcarnitines. If acyl-CoAs are produced faster than they are used, intra mitochondrial free CoA is regenerated as carnitine binds acyl-groups and the high intramitochondiral acyl-CoA/free CoA ratio is corrected (5,6). Human skeletal muscle contains 0.06 mmol/g dry mass of total CoA, and the muscle content of free plus acetylcarnitine is more than 20 mmol/g dry mass (7).

The way these different acyl-CoA compounds accumulate inside the mitochondria can result from normal and abnormal metabolism such as in exercise, fasting, ischaemia, and diabetes. These CoA intermediates may inhibit several enzymes of intermediary metabolism and have a direct toxic effect on the mitochondria membrane. Excess CoA is transported out of the mitochondria as acylcarnitines bound to carnitine to be catabolized in the liver or excreted by the kidneys. This is why carnitine is considered a detoxifying agent (2).

A study by Lennon and associates in 1983 (8), suggested a potential loss of acyl-carnitine

from the muscle to plasma occurs during exercise. These researchers noted that during submaximal cycle ergometer exercise the muscle total carnitine level fell by 20%, additionally, the percentage of plasma acylcarnitine increased from 17% at least to 22% by 40 of exercise. This rise of plasma acylcarnitine is suggested to be due to the release of carnitine from muscle during exercise. This finding led to the speculation that intense exercise could induce carnitine deficiency in muscle. Carlin and associates in 1986 (9), noted that low intensity exercise of 39% $VO_{2max}$ for 90 minutes and noted no change in the muscle carnitine, but there was a large elevation in the acylcarnitine and fall in the free carnitine. These plasma acylcarnitines progressively increased during exercise which was mostly due to a decrease in free carnitine and not due to a net loss of muscle carnitine as Lennon postulated (9). Several studies have noted that there is a slight decrease in free carnitine and possibly an increase in total carnitine during exercise which is due to many regulatory factors that occur during exercise. Such regulator factors include changes in blood volume, carnitine uptake and release in the muscle and acylation of carnitine outside contracting muscles (2). Further research is needed on these mechanisms.

Clarkson stated that physical training allows the body to increase the capacity of skeletal muscle to oxidize fatty acids (FA). To do this, there must be an increased transport of fatty acids into mitochondria and use in the trained muscle. Changes in carnitine levels and/or activities of its associated enzymes may also occur (3). The whole carnitine system may be involved in the biochemical adaptation to training. Fatty acids are also an important source of energy in the resting muscles, and during prolonged low-intensity exercise FA oxidation eventually becomes the major energy source for muscles. Due to the essential role of carnitine in FA oxidation and because muscle fat oxidation in muscle correlates with the carnitine level, supplementation with

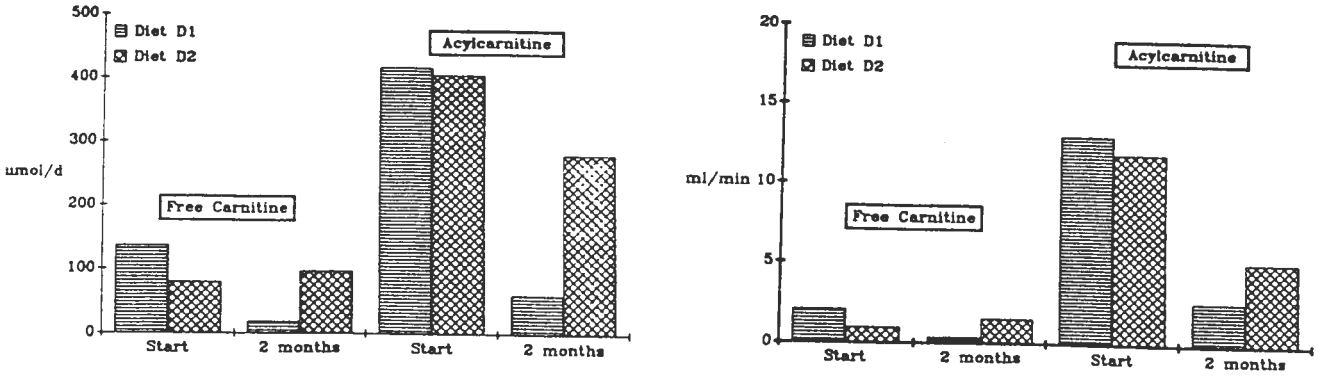
carnitine has been thought of as a means to stimulate FA oxidation during exercise. This is a sound theoretical idea since enhanced FA oxidation would also spare glycogen and postpone fatigue during exercise (2).

Carnitine has been widely used by athletes and dieters to improve performance or to lose weight (3). Unfortunately, there is no unequivocal support to this practice. Carnitine is used since it is a natural component of muscle, and is not harmful even after excessive intake. Carnitine has had the potential of enhancing metabolism in certain situations. Several rationales have been forwarded by Wagenmaker in support of the potential ergogenic effects of oral carnitine supplementation (10). Since FA oxidation is carnitine dependent, an increased carnitine level might, by stimulating FA oxidation, spare glycogen and postpone fatigue. Carnitine is a "fat burner" (oxidizer) therefore, it helps to reduce body fat and to lose weight. Carnitine supplementation increases the $VO_{2max}$. Intense exercise training causes a loss of carnitine from the muscles and creates a risk of carnitine deficiency for athletes (10).

Unfortunately these seem like appropriate rationales. However, the truth is, carnitine supplementation neither enhances FA oxidation in vivo nor spares glycogen or postpones fatigue during exercise. Carnitine supplementation does not unequivocally improve performance of athletes. Carnitine does not reduce body fat or help to lose weight. There is no theoretical basis for these assumptions and much less clinical support. Most studies have concluded that, carnitine does not affect the $VO_{2max}$. During exercise there is a redistribution of free carnitine and acylcarnitines in the muscle but there is no loss of total carnitine. Athletes are not at risk of carnitine deficiency and do not have an increased need for carnitine (10).

A study conducted by Davis and associates in 1990 (4), evaluated the different effects of

feeding two very low calorie diets upon the fractions of plasma and urinary carnitine in obese females. Subjects received either Diet 1 which consisted of Optifast and provided 4.4 umol of carnitine per day, 420 calories, and 70 grams of protein or Diet 2 which consisted of 500-600 calories /day from lean meat, fish, or poultry. They found that total plasma carnitine in D2 subjects was significantly higher than in D1 groups. After 2 months, D1 subjects had a significantly reduced excretion of carnitine and acylcarnitine. They concluded that a long term use of a very-low calorie diet will cause alterations in plasma carnitine metabolism (Fig. 3,4).




**Source:** Davis AT, et al. *J Am Col Nutr.* 1990;9: 261-264.

There is so much conflicting data available, but one must realize that carnitine supplementation has been proven effective in animal studies as well as *in vitro* (1). The public wants a quick method for weight loss or increased athletic ability, so these studies seem "true". We need to look at the whole picture and not focus on one area.

With so many supplement companies out there, it is no wonder why this is a big business. These companies generally focus on un-scientific research to base their claims. On the Internet, there are loads of information on weight loss gimmicks. One article from *Better Nutrition* quoted several doctors and urged readers to take carnitine supplements. The title of this article

was *L-carnitine and chromium are top nutrients for any weight loss plan.* The article states that carnitine is found in every cell in our bodies and shuttles fat into the cell's mitochondria, where fat is burned for energy (11). We all know this is true. The article goes on and states that carnitine not only promotes the loss of fat, but also increases lean body mass. Carnitine is crucial for proper fat burning. By taking supplemental carnitine, the body is able to create energy by metabolizing stored fat, allowing the person to shed a few extra pounds in the process. In addition, this article states that carnitine helps control low blood sugar, meaning it can function as an appetite suppressant. In addition, carnitine deficiencies can lead to liver, heart and muscle problems (11). A carnitine deficiency can lead to these problems, but the article failed to mention that a deficiency is very rare (2).

Another web site found was for *Genuine Nutrition.* This company offers a wide range of supplements. They claim we must supplement because the processing and preparation of our foods and the depletion of the soil have left it impossible to receive all the necessary nutrients we need for good health. In addition, we must supplement every day so that we will have optimum nutrition and health. This group further states that in order to lose weight, build muscle, increase strength/endurance, and improve nutrition, we must use supplements (12).

Pyruvate is the "salt" for pyruvic acid (13). Pyruvic acid is a naturally occurring substance found in various foods, and is the end product of glycolysis. In an aerobic condition, pyruvate is converted to acetyl CoA and can then enter the Kreb's cycle. If the cell is in an anaerobic condition, pyruvate is converted to lactic acid. Pyruvate is necessary for conversion of glycerol to acetyl CoA or lactic acid, which can then enter the Kreb's cycle for production of ATP (1).

Studies from the University of Pittsburgh Medical Center (14) have investigated the possibility of inhibiting gain in body fat without effecting body protein by addition of 3-carbon compounds such as pyruvate into the diet. These studies used a mixture of pyruvate and dihydroxyacetone (PD) to accomplish this goal in animals. This group found that in rats, the PD not only inhibited lipid accumulation in the liver, but also inhibited lipid accumulation in adipose tissue and associated weight gain. The mechanism of action of PD in these experimental animals was an inhibition of lipid synthesis and enhancement of energy expenditure. When this group tried this experiment on humans, they found that 3-carbon compounds also will enhance body fat and weight loss with feeding of mildly restricted and severely restricted hypoenergetic diets. Since there are numerous studies showing that obese patients lose weight when on hypoenergetic diets, this study wanted to focus on the minimization of body weight regain, which occurs in many of these patients once they resume eating. They found that substitution of 3-carbon compounds for carbohydrate will inhibit weight gain by 36% and body fat deposition by 55% during hypoenergetic feeding in obese individuals. These compounds also inhibit fat deposition, as evidenced by a lack of inhibitory effect of these compounds on nitrogen balance, plasma proteins, and fat free mass.

Another study from the University of Pittsburgh Medical Center (15) found that in patients with hyperlipidemia consuming high fat/high cholesterol diets who supplemented with pyruvate, had lowered total cholesterol and LDL. In patients consuming a low-fat/low cholesterol diet, no changes were noted after pyruvate supplementation. More studies need to be done in this area.

Numerous supplement companies have marketed these findings from the University of

Pittsburgh. Adbiotk (16) discusses the results from the two studies on pyruvate that were conducted at the University of Pittsburgh Medical Center. They listed the studies results on their web site: increased levels in muscle endurance, increased muscle mass, increased fat loss by 48%, increased levels of glucose extraction. The product they market is creatine pyruvate which can be up to 5 times more effective, and claim this form is better absorbed in the body. After being ingested, creatine pyruvate is split by hydrochloric acid in the stomach where each substance can be absorbed directly into the bloodstream without having to be converted in the liver. What this product does, is helps to regenerate creatine stores that are used during short, intense contractions. This product may also delay muscle fatigue and discomfort. According to this web site, this product provides "complimentary nutritional support for maximizing muscular performance and endurance in high intensity exercise programs".

Another supplement company, Whole Health Discount Center (17) also indicated those studies from the University of Pittsburgh Medical Center. The product they market is calcium pyruvate, which is used for increasing the amount of energy to the mitochondria, and to also reduce fat. This company did note that pyruvate is not a magic diet pill that will allow someone to lose weight while watching TV and eating potato chips. Calcium pyruvate may take 1 to 2 months before results are noticed. They also recommended that individuals exercise 3-4 times per week for 20 to 30 minutes. They state individuals will notice a loss in inches not weight, due to the loss of fat mass, not muscle mass.

In conclusion, there is currently no scientific basis for carnitine supplementation (2). Pyruvate has little effect on plasma lipids in normal weight individuals, but has been shown to reduce cholesterol and fat in individuals who consume high amounts of each (15). Pyruvate may

however, help reduce the amount of weight regain in obese individuals. According to the studies at the University of Pittsburgh Medical Center, pyruvate may increase muscle endurance (14). Definitely more research is needed in these areas to determine their exact function in humans.

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