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Carnitine: Essential Fuel for the Cellular Engine © SIE

By Yousry Naguib, PhD

Carnitine is essential for a variety of important physiological functions in energy metabolism. It shuttles fatty acids to the mitochondria (the part of the cell where energy is produced) to undergo oxidation, and produce energy. (Carnitine is a short-chain nitrogen-containing carboxylic acid and is not an amino acid.)

Carnitine can exist in two optically active forms, designated L and D, which are mirror images of each other and non-superimposable (non-identical). These forms differ in the ability to rotate the plane of polarized light (light composed of waves that vibrate in only one direction). Carnitine exists in nature only in the biologically active L- form.

Sources and Synthesis

L-carnitine is found in meat and dairy foods, and a well-balanced diet provides significant amounts of carnitine as well as the essential nutrients needed for its biosynthesis. L-carnitine is synthesized in the body, predominantly in the liver and kidney, via a biochemical pathway involving the amino acids L-lysine and methionine, vitamin C, and iron.

The essential role of ascorbic acid in the carnitine biosynthesis is demonstrated in an animal study. The study found that pigs fed either 100 mg ascorbic acid or 5 mg ascorbic acid plus 10 mg carnitine daily for two weeks had higher content of plasma carnitine as compared to those fed only a high fat diet, and improved plasma-triglycerides, indicating that high doses of ascorbic acid enhanced carnitine synthesis in the pigs' plasma.

Below are several health benefits of L-carnitine, supported by experimental and clinical research.

Infant Nutrition

Pre-term infants require carnitine for life-sustaining metabolic processes. The adequate dosage of carnitine in baby formula

has been evaluated in a study involving 66 newborn infants. The infants were divided into three groups: the first were breast-fed, the second received a formula with no carnitine added, and the third were fed a formula supplemented with carnitine.

Among the breast fed-group, 97 percent of the infants had a ratio of acyl-carnitine (AC) to free-carnitine (FC) greater than 0.83; and 3 percent had a ratio of FC to total carnitine (TC) less than 0.54. When infants were supplemented with 2.2 mg of L-carnitine per 100 ml in the bovine milk formula, their plasma carnitine and acyl-carnitine levels were similar to those observed in the breast-fed group. These ratios have been considered as markers of "carnitine insufficiency" and "carnitine deficiency," respectively, and were found to be different than those of adults.

In a placebo-controlled, randomized trial, L-carnitine supplementation (25 mg per kg body weight daily) during the gestational weeks (28 to 34) resulted in a significant increase of total, free and acyl-carnitine in both urine and blood as compared to placebo; but no change in growth rate was observed between the carnitine group and the placebo.

Immune System (AIDS)

The effect of long-term L-carnitine supplementation on CD4 and CD8 absolute counts, rate, and apoptosis (programmed cell death) was studied in HIV-infected subjects, who were treated with daily infusions of L-carnitine (6 g) for four months. CD4 and CD8 are specific types of lymphocytes (white blood cells that fight infection and disease); their absolute counts are decreased in patients with AIDS resulting in compromised immune function. At the end of the study L-carnitine was found to substantially increase the rate and absolute counts of CD4 and, to a lesser degree, of CD8 lymphocytes.

In another study, 20 male patients with advanced AIDS and normal serum levels of carnitine and peripheral blood mononuclear cells (PBMC) deficient in carnitine were randomly assigned to receive either a high dose of L-carnitine (6 g per day) or placebo for two weeks. At the end of the trial, L-carnitine was found to significantly reduce serum triglycerides, and to restore intracellular carnitine levels. The study suggested that L-carnitine supplementation could aid individuals with AIDS.

An earlier study also showed that administration of L-carnitine (6 g per day) for two weeks to AIDS patients treated with the drug Zidovudine led to increased PBMC proliferation and reduced levels of triglycerides.

Brain Health

Acetyl-L-carnitine (ALC) is reported in clinical studies to have beneficial effects in major depressive disorders and Alzheimer's diseases. ALC has been considered of potential use in senile dementia of Alzheimer's because of its ability to enhance energy production, and to restore aged cell membranes. Research showed a significant decrease of carnitine acetyl transferase (the catalyst of acylation of L-carnitine to acetyl-L-carnitine) in autopsied Alzheimer's patients.

Pharmacokinetics studies (the action of drugs in the body over a period of time) of ALC in the treatment of patients with senile dementia of Alzheimer's demonstrated the ability of ALC to cross the blood brain barrier (a protective barrier formed by blood vessels to prevent some substances in the blood from entering brain tissue), and hence may benefit patients with Alzheimer's disease.

Eleven patients with Alzheimer's were treated with 1.5 g per day, given in three daily oral doses, for 50 days. At the end of the treatment, the concentrations of L-carnitine and ALC in the plasma and cerebrospinal fluid (CSF) were significantly increased, demonstrating that ALC easily crosses the blood brain barrier.

In a randomized, double-blind, placebo-controlled trial, patients with Alzheimer's who received 1 g of ALC twice daily for 24 weeks showed an improvement in relation to the Names Learning Test and a Digit Recall Test, both related to aspects of short-term memory.

The beneficial effect of ALC was also demonstrated in a one-year double blind, placebo study involving seven patients with Alzheimer's disease. Patients received ALC showed significantly less deterioration in their Mini-Mental Status and Alzheimer's Disease Assessment test than placebo-treated patients.

The health benefit of L-carnitine in old age depression was shown in a study of 60 patients aged 60 to 80 years suffering from depression who were randomly assigned to receive either 3 g per day ALC or placebo. After 60 days, the ALC group showed a significant reduction in the depression symptoms as compared to the placebo.

Cardiovascular Health

Patients with heart disease tend to have reduced myocardial free carnitine levels as compared with people without heart

diseases. L-carnitine supplementation of patients with congestive heart failure for 12 weeks significantly improved the exercise tolerance of patients with effort angina. Angina is a chest pain caused by inadequate delivery of oxygen to the heart muscle. The study suggested that L-carnitine is a useful therapeutic agent for the treatment of congestive heart failure in combination with traditional drugs.

A randomized, double-blind, placebo-controlled study involving 44 men with stable effort-induced angina also showed that treatment with L-carnitine (1 g twice daily) for four weeks increased exercise tolerance and reduced ECG (electrocardiogram to monitor heart contraction) indices of ischemia.

A Japanese study also demonstrated that administration of 0.9 g daily of L-carnitine to 12 patients with stable effort angina improved their exercise tolerance, using a multistage treadmill exercise test.

Increasing myocardial carnitine content could improve heart function in patients with carnitine deficiency. The isolated hearts from rats treated with sodium pivalate to induce carnitine deficiency, showed a 60 percent reduction in total heart carnitine content and depressions in cardio function, which were reversed upon treatment with L-carnitine.

Studies involving about 2,500 patients with coronary artery disease (CAD) treated with carnitine for a year also showed a reduced incidence of angina, a decreased need of cardiac drugs, and a greater effort tolerance.

In a randomized, double-blind placebo-controlled trial, patients with suspected acute myocardial infarction (irreversible injury to heart muscle) received either 2 g per day L-carnitine or placebo for 28 days. The L-carnitine group showed a significant reduction in the mean infarct size (dead tissue due to lack of oxygen), and angina, compared to placebo. The study suggested that L-carnitine supplementation to patients with suspected acute myocardial infarction might provide protection against cardiac complications.

Physical Performance

The use of L-carnitine by athletes has become popular in recent years. L-carnitine is hypothesized to increase lipid turnover in working muscles leading to glycogen saving and, as a consequence, allow longer performances for a given heavy workload.

A study on the effects of L-carnitine supplementation, 4 g per

day for two weeks, on the aerobic and anaerobic performance of endurance athletes showed that VO₂ max (maximal aerobic power) was significantly increased.

Eccentric muscle effort is known to induce delayed muscle soreness and muscle damage. Eccentric activity involves the contraction of muscles while they are simultaneously being stretched as when running downhill. (The force of gravity stretches your muscles at the same time as they are contracting to stop you from falling forward.)

L-carnitine supplementation, 3 g per day for six weeks, was shown in a single-blind study to significantly reduce pain, and tenderness induced by a 20 minute eccentric effort of the muscle. The effect was attributed to the vasodilatation property of L-carnitine, which improves energetic metabolism of the damaged muscle.

Research also showed that L-carnitine supplementation significantly increased both maximal oxygen uptake and power output in moderately trained young men who took 2 g of L-carnitine one hour before an exercise on a cycle ergo meter. The study concluded that pre-treatment with L-carnitine favored aerobic processes resulting in a more efficient performance.

Other Health Benefits

Renal patients treated with chronic hemodialysis appear to lose carnitine during treatment, and require a dietary intake of carnitine.

In a placebo, crossover study, ten healthy men received 3 g of L-carnitine-L-tartrate (LCLT) daily for three weeks. No difference was found between LCLT-group and placebo in the markers of liver and renal function, blood counts and metabolic enzymes. The data indicate that LCLT has no adverse effects on metabolic and hematology in healthy men.

In a crossover design study, patients with chronic fatigue syndrome (CFS) received either L-carnitine or amantadine (a drug for treating CFS) for two months, with a two-week washout period between treatments. Amantadine was poorly tolerated and did not significantly improve symptoms, while L-carnitine treatment significantly improved symptoms in CFS patients without side effects. The study concluded that L-carnitine is safe and very well tolerated in improving and alleviating symptoms in CFS patients.

Summary

L-carnitine helps produce energy in muscles, including the

heart, and plays a crucial role in cardiovascular health,
exercise performance, infant nutrition, and brain wellness. SIE

Supplement Industry Executive

A-2 Brier Hill Court, East Brunswick, NJ 08816

Tel: (732) 432-9600 **Fax:** (732) 432-9288 info@vitaminretailer.com