Effects of L - Carnitine Supplementation on Endurance Athletes: A Review

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ABSTRACT

L-carnitine is very popular supplement among the athletes. The purpose of the review was to summarize the effects of L-carnitine supplementation on endurance athletes' sports performance outcomes. We searched peer reviewed articles in the following databases: PubMed, Google Scholar, Google (up to 2021). Studies were selected if they included samples of adults, had experimental, or observational design. Twenty articles met the eligibility criteria. Finding indicated that the running speed changed according to doses of L-carnitine supplementation. But there was no significantly enhancement in vo2max after L-carnitine supplementation, non-significant effects were observed for carbohydrate metabolite, fat metabolite and hormones (insulin, glucagon). There are few studies on performance outcomes therefore more research is needed to move the field forward.

Key Words: L-carnitine, Sports enhancement, Endurance, Muscle recovery, Skeletal muscle, Supplements.

INTRODUCTION

Nutritional supplements are any dietary supplement that is intended to provide nutrients that may otherwise not be consumed in sufficient quantities; for example, vitamins, minerals, proteins, amino acids or other nutritional substances. Products are usually ingested in capsule, tablet or liquid form.

According to the U.S. Food and Drug Administration (FDA) "A dietary supplement is a product (other than tobacco) that is intended to supplement the diet and bears or contains one or more of the following dietary ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, a dietary substance for use by humans to supplement the diet by increasing its total daily intake, or a concentrate, metabolite, constituent, extract, or combination of these ingredients."

The European Food Safety Authority (EFSA) which uses the term food supplement, states that "A Food Supplement is a concentrated source of nutrients or other substances with a nutritional or physiological effect whose purpose is to supplement the normal diet.

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They are marketed in 'dose' form i.e., as pills, tablets, capsules, liquids in measured doses etc.

Carnitine (β-hydroxytrimethy-lammonium butyrate) is a hydrophilic quaternary amine that plays an essential role in energy metabolism.

Carnitine (L-3-hydroxytrimethy-laminobutanoate) is a naturally occurring compound that can be synthesized in mammals from the essential amino acids lysine and methionine or ingested through diet. Primary sources of dietary carnitine are red meat and dairy products. It is very popular ergogenic aid among athletes. However, L-carnitine is not directly related to performance enhancement. It acts as a transporter of acyl-coA. Carnitine is essential for the transfer of long-chain fatty acids across the inner mitochondrial membrane for subsequent beta - oxidation. Carnitine also binds acyl residues deriving from intermediary metabolism of amino acids & fatty acids. Two separate mechanisms have been suggested for potential benefits of using L-carnitine to enhance performance.

Fritz et al. (1968) proposed that increased levels of L-carnitine may increase fatty acid oxidation since carnitine is required to transport long-chain fatty acids across the mitochondrial membrane. Another possible function of L-carnitine is that it would allow for the maintenance of the acetyl CoA/CoA ratio, which would decrease the inhibition of the pyruvate dehydrogenase complex and enhance the conversion of pyruvate to acetyl CoA (Greig et al.1987). Thus, lactate accumulation could be reduced during incremental exhaustive exercise and result in enhanced performance (Siliprandi et al,1990).

Endurance is defined as the resistance capacity of athletes against fatigue. An endurance sport is any sport in which there is a requirement to sustain an activity level while enduring a level of physical stress. The fundamental requirement for any endurance sport is the ability to sustain a submaximal work rate for a prolonged period. Individual endurance is different due to the oxygen consumption, depending on workload and anaerobic threshold which is known as lactate concentration in blood. Endurance is improved best by means of activities that are carried out at the anaerobic threshold level. Determining which running speed and at which heart rate an athlete reaches their anaerobic threshold is an important criterion for conducting the practice (Orer et al., 2014).
Endurance sports are 4 types there: 1) aerobic endurance, 2) anaerobic endurance, 3) speed endurance.
Aerobic endurance can be sub-divided as follows:

- Short aerobic-2 minutes to 8 minutes (lactic/aerobic)
- Medium aerobic-8 minutes to 30 minutes (mainly aerobic)
- Long aerobic -30 minutes + (aerobic)

Anaerobic endurance can be sub-divided as follows:

- Short anaerobic-less than 25 seconds (mainly a-lactic)
- Medium anaerobic-25 seconds to 60 seconds (mainly lactic)
- Long anaerobic-60 seconds to 120 seconds (lactic +aerobic)

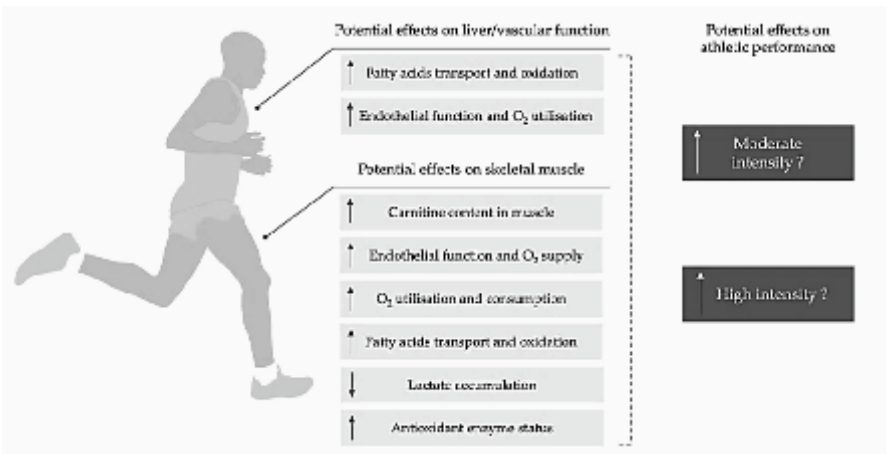
Speed endurance is used to develop the coordination of muscle contraction. Repetition methods are used with a high number of sets, a low number of repetitions per set and intensity greater than 85% with distances covered from 60% to 120% of the racing distance. Competition and time trials can be used in the development of speed endurance.

MATERIAL & METHODS

Identification and selection of studies

The review focused on the following research questions: "is L-carnitine supplementation benefited athletes?", "why sports person chooses L-carnitine as supplement?" PubMed and Medline, Google scholar databases were searched with no publication limit. the search carried out incorporated with various combinations of important keywords related to L-carnitine and sports, they are "L-carnitine "AND "athlete"; "L-carnitine" AND" sports"; L-carnitine" AND "herbal supplementation"; "L-carnitine AND "endurance" AND "muscle"; "L-carnitine" AND "oxidation of fat"; "L-carnitine" AND "performance enhancement"; "L-carnitine" AND "muscle recovery"; "L-carnitine AND skeletal muscle ".

The search was restricted to only English language research papers and only sports related papers. The data was extracted from selected papers where participants and sample size study size, study design, assessed parameter, duration of intervention, exercise test, main findings were related to the effect of L-carnitine supplementation in endurance sports.



Potential effects of L-Carnitine supplementation on different physiological and metabolic pathways that could improve moderate- and high-intensity exercise performance. (Adopted from Mielgo-Ayuso et al., 2021)

Review of Literature:

Running speed : In the 26 professional footballers who volunteered to take part in the study, athletes were given a glass of fruit juice 1 hour before supplementing L-carnitine using double-blind method. Then, 12 participants were given 3 g of L-carnitine (LK-3) and the remaining 14 were given 4 g (LK-4). After exercises, when the running speeds corresponding to specific LK concentrations were examined, significant differences were found in running speeds between the LK-3 and P-3 groups at Lactic acid concentrations of 2, 2.5, 3, 3.5, and 4 mmolL. A significant difference was found in the speeds corresponding to 3.5 and 4 mmolL Lactic acid when the LK-4 and P-4 groups were compared (Orer et al., 2014).

Change in Blood Parameters:

L-carnitine has been shown to increase muscle metabolism without affecting stable carnitine concentrations. At the same time, L-carnitine causes a decrease in plasma lactate. This is connected to the effect on metabolism of active carnitine in blood cells. The protective effect of L-carnitine on blood cells (especially its effect on blood platelets that play a role in wound healing) can prevent muscle damage caused by exercise. (Orer et al., 2014).

During the exercise the glycolytic flux become high, reducing muscle free carnitine availability, limits the CPT-1 reaction and ultimately mitochondrial fatty acid import and oxidation. When the glycolytic flux is reduced, as in the case of prolonged exercise or at lower exercise intensity, the reduced supply of glycolysis-derived acetyl-CoA allows saving a greater amount of free carnitine, which can then be used for the transport and oxidation of fatty acids into mitochondria. Thus, it appears evident that muscle total free carnitine availability influences fuel selection during exercise.

VO2 Max:

Shannon et al (2018) measured variables in 20 untrained male participants twice-daily after consumption of 80 g carbohydrate (CON) or 3 g l-carnitine + carbohydrate (CARN). After 24 weeks of supplementation and HIIT training, such as VO2 max, maximum power, and total work in a high-intensity interval test on a cycle ergometer, no significant differences in any parameters was found.

Vecchiet et al (1990) demonstrated an increase in maximal oxygen

consumption and power output during an incremental exercise test to exhaustion. In addition, they reported decreased VO2, VCO2, ventilation, and lactate concentration at the same relative submaximal exercise intensity.

Trappe, et al (1994) suggested that administration of 4 grams of L-carnitine for seven days did not elicit an ergogenic benefit during repeated high-intensity anaerobic exercise. The velocity (m. s) swam for each repeat indicated nearly identical replication for the five repeated bouts from the control trial compared with the treatment trial. In addition, total time for the entire set did not differ between conditions for either group.

Total acid soluble serum carnitine increased approximately 71 %, while free and short-chain values increased 63 % and 79%, respectively. These values were obtained after seven days of administration of 4g day, and demonstrated a significant increase in L-carnitine concentration. (Trappe et al., 1994).

More recent studies suggest that L-carnitine has an important role in prevention of cell damage. The fact that L-carnitine is used by blood cells increases haematopoiesis, prevents collagen induced blood platelet aggregation, and can prevent apoptosis in immunity cells (Orer & Nevin 2014).

In a study performed by Novakova et al (2015), sixteen vegetarians and eight omnivores participated with the oral supplementation of 2 g l-carnitine for 12 weeks. Sub-maximal exercise (75 % VO2max for 1 h) revealed no significant differences between vegetarians and omnivores (respiratory exchange ratio, blood lactate and muscle metabolites).

On the other hand, Wall et al (2011) supplemented L-Carnitine along with the intake of CHO and found no improvements in a scale of perceived exertion during moderate-intensity exercise, due to the supplementation the saving of muscle glycogen and the increase in fat oxidation revealed by muscle biopsies during this test allowed an improvement in the work capacity of later tests at greater intensity.

Metabolite & hormones:

Seven male subjects were given supplements of 2 g L-carnitine 2 h before the start of a marathon runand again after 20 km of the run. The plasma concentration of metabolites and hormones was analysed 1 h before, immediately after and 1 h after the run, Plasma concentrations of the different metabolites and hormones, and activities of enzymes are revealed no significant differences between the two groups for concentrations of carbohydrate metabolites (glucose, lactate, pyruvate), fat metabolites (free fatty acid (FFA), hydroxybutyrate (BHB), glycerol), hormones (insulin, glucagon, cortisol) (Colombani et al.,1996).

Supplementation with l-carnitine

significantly increased the total plasma carnitine concentration(24 % in omnivores, 31 % in vegetarians) and the muscle carnitine content in vegetarians (13 %). Despite this increase, Pmax and VO2max as well as muscle phosphocreatine, lactate and glycogen were not significantly affected by carnitine administration (Novakova et al.,2015).

Heart rate and perceived exertion:

(Orer et al (2014) stated that Heart rate was not different between trials for either males or females. Although heart rate was lowest throughout exercise on the chronic ingestion trial in both males and females. There was also no difference between trials in rating of perceived exertion throughout exercise in males or females.

Training:

It has been assumed that a combination of LC supplementation with increased energy expenditure may positively affect body composition. However, either with aerobic or resistance (Koozehchian et al., 2018) training, LC supplementation has not achieved successful endpoint. Six weeks of endurance training (five times per week, 40 min on a bicycle ergometer at 60% maximal oxygen uptake) together with LC supplementation (4 g/day) did not induce a positive effect on fat metabolism in healthy male subjects (% body fat 17.9 ± 2.3 at the beginning of the study) (Lee et al., 2007).

Muscle damage and muscle soreness:

During heavy exercise muscle get damage which leads muscle soreness. LC has been thought to provide cell membranes protection against oxidative stress (Barnett et al. 1994) It has been hypothesized that LC supplementation would mitigate exercise-induced muscle damage and improve post-exercise recovery. Since plasma LC elevates following 2 weeks of supplementation (Vukovich et al., 1994) short protocols of supplementation may be considered as effective in attenuating post-exercise muscle soreness. The findings indicated that 3 weeks of LC supplementation, in the amount 2-3 g/day, effectively alleviated pain (Rafraf et al., 2015).

(Koozehchian et al (2018) carried out different high-intensity tests in endurance-trained athletes. Significant improvements were found in peak power and absolute peak power (30 s Wingate test) after 9 weeks of 2 g/day L-Supplementation. Additionally, they showed improvements on the number of repetitions and volume lifted in the third set of leg press.

DISCUSSION

The aim of comprehensive review was to summarize the effects of L-carnitine on the endurance athletes. It has been assumed that LC supplementation, by increasing muscle carnitine content,

optimizes fat oxidation and consequently reduces its availability for storage. Direct measurements of carnitine in skeletal muscles failed to show any elevation in the muscle carnitine concentration following 14 days of 4 g/day (Siliprandi et al, (1990), or 6 g/day LC ingestion. These findings implied that LC supplementation was not able to increase fat oxidation and improve exercise performance by the proposed mechanism. Indeed, many original investigations, summarized in later review, indicated that LC supplementation lasting up to 4 weeks, neither increase fat oxidation nor improve performance during prolonged exercises. (Orer et al., (2014). the carnitine supplementation had an additive effect on phenotypic changes in muscle fibre type and fibre size when combined with training, but that did not induce any additional positive effect on fat metabolism. After 24 weeks of supplementation, the muscle PCr/ATP ratio in the Carnitine group was significantly greater than Control ($P < 0.05$) and baseline ($P < 0.05$) following exercise at 80% VO2max (Wall. et al., 2011). The LC supplementation has no significant result in perceived exertion male and female under exercise state, some studies have reported that carnitine can have a protective effect against muscle disruption after strenuous exercise, with a significant reduction in the release of cytosolic proteins such as myoglobin and creatine kinase. Moreover, carnitine supplementation, by increasing the muscle androgen receptor, may improve protein signalling, needed for recovery after exercise. In addition, mitigating oxidative stress during exercise, carnitine can facilitate muscle recovery, reduce the muscle pain after heavy workout (Rafraf et al., 2015). Studies show that LC supplementation have no significant improvement in VO2max, Vco2max, respiratory exchange ratio in endurance athletes (Trappe et al., 1994; Shannon et al., 2018; Vecchiet et al.,1990). One study shows 9 weeks with 2g/day supplementation improve the peak power and absolute peak power in 30s Wingate test (Koozehchian et al., 2018)

CONCLUSION

It is concluded that the several studies shows that the LC supplementation does not change metabolism-especially exercise metabolism is based mostly on short-term supplementation protocols. L-carnitine supplementation may have an effect on the phenotypic expression and size of muscle fibre types, which have more glycolytic characteristics. When combined with endurance exercise, L-carnitine supplementation does not appear to induce a positive effect on fat metabolism. But still the L-carnitine is used by many elite and sub elite athletes. Recent studies suggest that LC supplementation may elevate muscle TC

content; therefore, modify muscle fuel metabolism and performance during the exercise. Due to insulin-mediated LC transport to the muscle, oral administration regimen should be combined with Carbohydrate. Because of LC poor bioavailability, it is likely that the supplementation protocol would take at least 3 months. Shorter period of supplementation may be effective in prevention of exercise-induced muscle damage, but not metabolic changes. LC provide cell membrane protection against oxidative stress. But in the case of Heart rate has no positive effect. Plasma concentration of hormones, metabolites and enzymes activity are unchanged. while L-C supplementation with CHO and 2.72 g of L-C for a prolonged period of 24 weeks could increase muscle carnitine content, fat oxidation, and glycogen sparing during low-intensity testing, it seemingly had no effect on moderate-intensity exercise performance.

More research is necessary to explain the results and provide greater clarity and scientific evidence about the acute and chronic supplementation protocol of L-C in moderate-intensity, endurance exercise performance and related outcomes.

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