THE EFFECTS OF ACUTE L-CARNITINE SUPPLEMENTATION ON ENDURANCE PERFORMANCE OF ATHLETES

GAMZE E. ORER[1] AND NEVIN A. GUZEL[2]

[1]*School of Physical Education and Sports, Aksaray University, Aksaray, Turkey; and* [2]*Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Ankara, Turkey*

ABSTRACT

Orer, GE and Guzel, NA. The effects of acute L-carnitine supplementation on endurance performance of athletes. *J Strength Cond Res* 28(2): 514–519, 2014—This study examined the effect of acute L-carnitine loading on the endurance performance of footballers. Measurements were performed on 26 candidate professional footballers who volunteered to take part in the study. Athletes were given a glass of fruit juice 1 hour before applying L-carnitine with the 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). Athletes began the exercise test at a running speed of 8 $km \cdot h^{-1}$ and then continued at 10 $km \cdot h^{-1}$. The speed was increased 1 $km \cdot h^{-1}$ every 3 minutes, and the test continued until the subject chose to quit. Heart rate was registered using a portable telemetric heart rate monitor during the test. Blood samples were taken from the earlobes of the footballers both before the test and before the speed increase (during the 1-minute interval), and the lactate (La) concentration was measured electroenzymatically. The test was repeated after 1 week as a group of placebos (P-3 and P-4). The result showed that the running speeds corresponding to specific La concentrations were increased, and La and heart rate responses to the running speeds were decreased in both supplemented groups compared with placebos ($p \leq 0.05$). A significant reduction in heart rate was found in LK-4 and P-4 ($p \leq 0.05$). When the Borg responses to the running speeds were analyzed, a significant difference was found in both supplemented groups ($p \leq 0.05$). The results show that 3 or 4 g of L-carnitine taken before physical exercise prolonged exhaustion.

KEY WORDS sportsmen, load, exhaustion, supplement, carnitine

Address correspondence to Nevin A. Guzel, natalay@gazi.edu.tr.

28(2)/514–519

Journal of Strength and Conditioning Research

INTRODUCTION

Carnitine (L-3-hydroxytrimethylaminobutanoate) is a naturally occurring compound that can be synthesized in mammals from the essential amino acids lysine and methionine (9) or ingested through diet. Primary sources of dietary carnitine are red meat and dairy products; however, commercially produced supplements are also available and have been shown to be safe in humans (21). Carnitine is found in all of the body cells and is particularly abundant in skeletal muscle and myocardium. It is taken into the body through diet or is biosynthesized within the body (liver and kidneys), requiring lysine, methionine, vitamin C, vitamin B6, niacin, and catalysis reaction enzymes (20,25).

It is suggested that L-carnitine does not significantly increase physical strength in sporting performance and does not have a great effect on aerobic strength (25); in contrast, other researchers claim that L-carnitine reduces consumption of oxygen, increases maximal running speed, and causes a decrease in heart rate (25). In addition to this, the common view is that muscle glycogens are used resolutely and fatty acid oxidation is increased through the effect of L-carnitine (6,28).

Endurance is defined as the resistance capacity of athletes against fatigue (16), and at the same time endurance determines the limits of the period when an activity of certain intensity is carried out (4). Individual differences in endurance performance are closely related to work load or consumption of oxygen, corresponding to specific blood lactate concentrations, which are known as anaerobic threshold (AnE) rather than with $\dot{V}O_2max$ (1,14).

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. Training an athlete at anaerobic running speed or heart rate is an easy and convenient method for coaches (4).

This study installed an acute L-carnitine to show the resistance of performance impact. Because it was reported that the scientific studies carried out to date are not adequate for

Table 1. Anthropometric characteristics of athletes.

	Number of subjects (n)	Length (cm)	Age (y)	Body weight (kg)	BMI ($kg \cdot m^{-2}$)
Mean ± *SD*	26	177 ± 0.06	18.42 ± 0.50	70.37 ± 5.77	22.30 ± 1.42

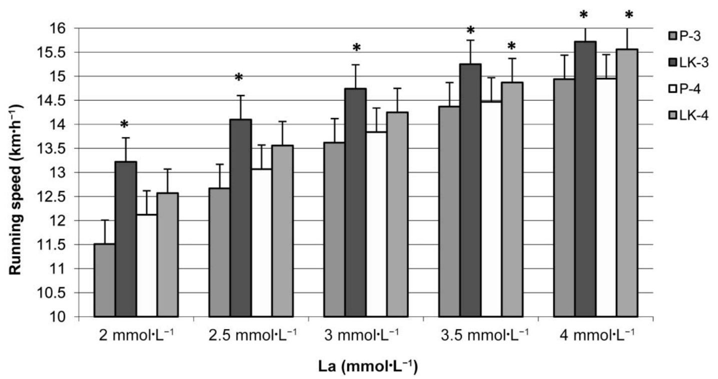

Figure 1. Running speeds ($km \cdot h^{-1}$) corresponding to specific La concentrations. When the running speeds corresponding to specific La concentrations were examined, significant differences were found in running speeds between the LK-3 and P-3 groups at La concentrations of 2, 2.5, 3, 3.5, and 4 $mmol \cdot L^{-1}$. A significant difference was found in the speeds corresponding to 3.5 and 4 $mmol \cdot L^{-1}$ La when the LK-4 and P-4 groups were compared ($p \leq 0.05$).

supporting physical performance and sporting acrogenic effects, it is clear that further research is required (6). This study, therefore, investigated whether there is any effect of acute L-carnitine loading at 2 different doses on the endurance performance of athletes.

Methods

Experimental Approach to the Problem

As far as we know, there are currently no reports associated with the dose-response study on L-carnitine in humans. Administration of L-carnitine at doses of 3 and 4 g to soccer player was examined to determine the changes in lactic acid concentrations. The study was conducted at the School of Physical Education and Sport, Gazi University, and involved a placebo-controlled design.

Subjects

The subjects were 26 healthy males aged 17–19 years. Anthropometric characteristics of athletes are presented at Table 1. All were candidate professional soccer players, who played for Ankaragucu Sports Club. The sportsmen included in this research have been playing together in the same team for 6 years. They have been training 5 days a week, which is composed of 4 days of training and 1 day of match. The sportsmen are included in the test regardless their position in the team except the goalkeeper. All subjects participated voluntarily in the study. The research was conducted in accordance with Helsinki Declaration. The study protocol was approved ethically by Ankara third Clinical Trials Ethics Committee, and at first visit all the participants signed an informed consent form after a detailed introduction of study. The 2 participants under the age of 18 provided written consent from their parents before participating in the study.

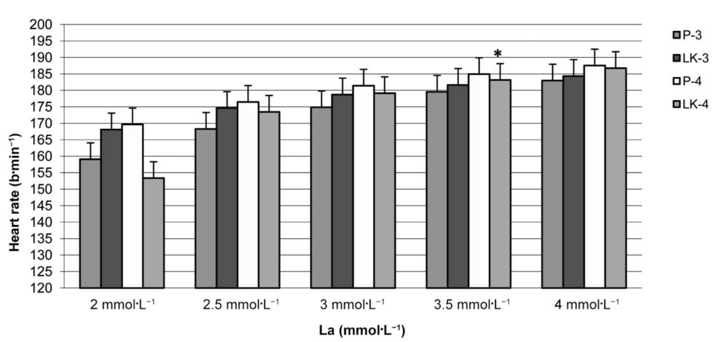

Figure 2. Heart rates corresponding to specific La concentrations. As it can be seen in the figure, a significant difference was found only in the heart rate corresponding to 3.5 $mmol \cdot L^{-1}$ La in the LK-4 and P-4 groups ($p \leq 0.05$).

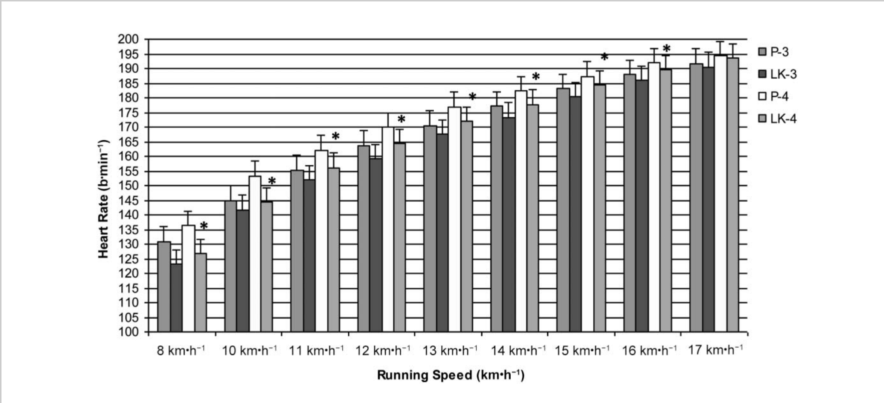

Figure 3. Heart rate responses to running speeds (b $\cdot$ min^{-1}). When heart rate responses to running speeds were examined, significant differences were found in heart rate responses between the LK-4 and P-4 groups at running speeds of 8, 10, 11, 12, 13, 14, 15, and 16 km $\cdot$ h^{-1} ($p \leq 0.05$).

Procedures

The study used a double-blind protocol, and powder L-carnitine (Sigma Chem., St. Louis, MO, USA) was given by mixing it with a glass of fruit juice 1 hour before the measurement (6). Using a random allocation method, 12 of the athletes were given 3 g (LK-3), whereas the remaining 14 were given 4 g (LK-4) L-carnitine. One week later, the test was repeated on the same athletes with placebo fluids (P-3 and P-4). The athletes were told that they should desist from physical activity for 24 hours before the measurement and that they should not use alcohol or caffeine. The study used sports club facilities, and the athletes participated in the study were measured and evaluated in nutrition and sleep patterns. Measurements were conducted in February, 2011, and 1 week after the exact date of previous measurement.

Athletes began exercise at the running speed of 8 km $\cdot$ h^{-1} on a treadmill and continued the test at a speed of 10 km $\cdot$ h^{-1}. Then, the speed was enhanced by 1 km $\cdot$ h^{-1} every 3 minutes, and the test was sustained until the test subject chose to quit. Athletes were given a break for 1 minute before each increase in running speed (13). During the test, heart rate was recorded using a portable telemetrically heart rate monitor (Polar RS 400 multi, Oulu, Finland). Blood samples were taken from the earlobes of the athletes both before the test and the acceleration of speed (during the 1-minute rest interval), and then lactic acid concentrations were measured electroenzymatically using a YSI 1500 lactic acid analyzer without being subjected to any process. Blood lactate concentrations were measured as hemolyzed whole blood using an YSI 1500 Sport (YSI Life Sciences, Yellow Spring, OH, USA) lactate analyzer (accuracy $\pm$ 0.01 mmol $\cdot$ L^{-1}). Before blood samples were analyzed, they were calibrated with 5 mmol $\cdot$ L^{-1} standard concentration in accordance with the manufacturer's instructions.

The Borg scale was used to determine subjects' perception of difficulty before each speed increase (at 1-minute interval) (5).

Statistical Analyses

Mean (X) and *SD* were calculated using SPSS version 15 (IBM Corporation, NY, USA). The differences between measurements were evaluated with the "Wilcoxon Paired Sample Test" for independent groups and with the "Mann-Whitney *U*-test" for independent groups. A significance level of $p \leq 0.05$ was used for all analyses.

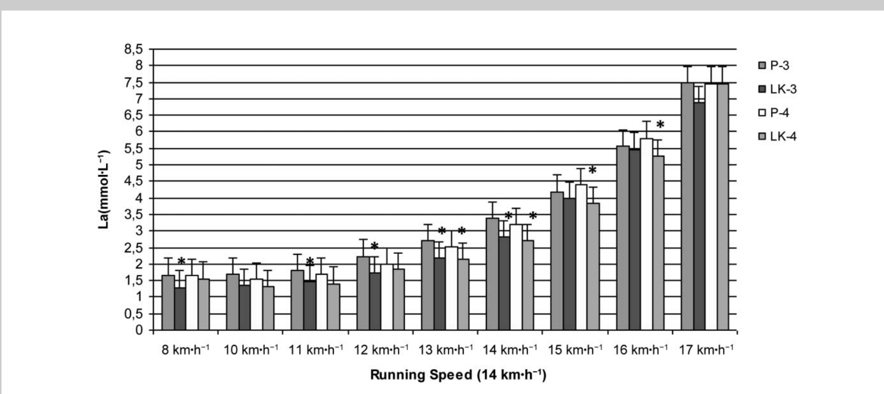

Figure 4. Lactate responses to running speeds (mmol $\cdot$ L^{-1}). When La responses of athletes to running speeds were examined, significant differences were found in La responses between the LK-3 group and P-3 group at running speeds of 8, 11, 12, 13, and 14 km $\cdot$ h^{-1}, whereas significant differences were also found in La responses between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 km $\cdot$ h^{-1} ($p \leq 0.05$).

Results

When the running speeds corresponding to specific La concentrations were examined, significant differences were found in running speeds between the LK-3 and P-3 groups at La concentrations of 2, 2.5, 3, 3.5, and 4 mmol $\cdot$ L^{-1}. A significant difference was found in the speeds corresponding to 3.5 and 4 mmol $\cdot$ L^{-1} La when the LK-4 and P-4 groups were compared ($p \leq 0.05$) (Figure 1).

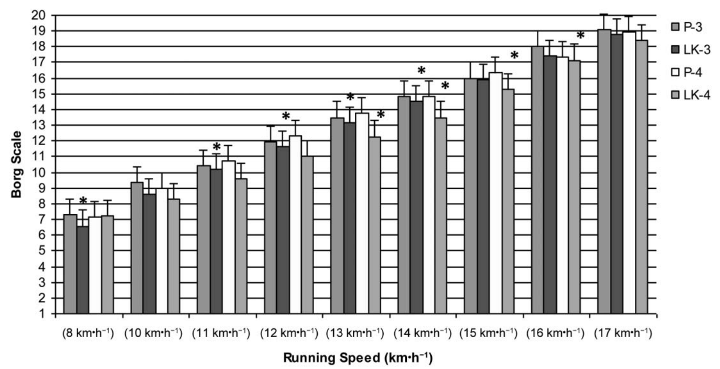

Figure 5. Perceived difficulty according to Borg scale in response to running speeds. When Borg responses to running speeds were examined, significant differences were found between the LK-3 and P-3 groups at running speeds of 8, 11, 12, 13, and 14 $km \cdot h^{-1}$, whereas significant differences were also found in Borg responses between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$).

As it can be seen in Figure 2, a significant difference was found only in the heart rate corresponding to 3.5 $mmol \cdot L^{-1}$ La in the LK-4 and P-4 groups ($p \leq 0.05$).

Significant differences were found in heart rate responses between the LK-4 and P-4 groups at running speeds of 8, 10, 11, 12, 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$) (Figure 3).

When La responses of athletes to running speeds were examined, significant differences were found in La responses between the LK-3 group and P-3 group at running speeds of 8, 11, 12, 13, and 14 $km \cdot h^{-1}$, whereas significant differences were also found in La responses between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$) (Figure 4).

There were significant differences about Borg responses found between the LK-3 and P-3 groups at running speeds of 8, 11, 12, 13, and 14 $km \cdot h^{-1}$, whereas significant differences were also found in Borg responses between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$) (Figure 5).

When running speeds and heart rates corresponding to specific La concentrations were examined, no statistically significant difference was found between the LK-3 and LK-4 groups and no significant difference was found between the LK-3 and LK-4 groups about heart rate, Borg scale, and lactate responses to running speeds.

Discussion

The results show that when the groups that were given L-carnitine were compared with their own placebo values, the differences in all parameters were significant. However, no significant difference was found between any of the parameters for the data collected after L-carnitine loading.

L-carnitine is produced in the human body and its use as an ergogenic supplement is approved by the International Olympic Committee because it causes no side effects (3,10,15,27).

It was indicated that there was no significant decrease in the amount of L-carnitine in the body during low-intensity exercises; however, it was reported that there was a significant decrease in both plasma and muscle L-carnitine levels during high-intensity exercises (12). Therefore, some previous studies suggested that L-carnitine should be taken as a supplement to greatly reduce potential effects of this decrease and to retain high muscle and plasma carnitine levels (12,22).

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 (19).

It is indicated that L-carnitine reduces the hazardous effects of hypoxic exercises and plays an important role in recovery from damage caused by exercise. 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 hematopoiesis, prevents collagen-induced blood platelet aggregation, and can prevent apoptosis in immunity cells (19).

Many studies reported that between 1 and 6 g of L-carnitine can be taken as a daily supplement and approximately 1 hour before exercise (6). As a result of this, athletes in the present double-blind study were categorized into 2 groups: The first group was given 3 g of L-carnitine and the second group was given 4 g of L-carnitine. The same measurement was repeated on the same athletes 1 week later, using a placebo.

Various studies reported that taking additional carnitine particularly reduced blood lactate level and heart rate, yet increased maximal oxygen consumption and fatty acid oxidation (23,26). It has been suggested that L-carnitine does not significantly increase physical strength in sporting performance and does not have a great effect on aerobic strength (24). In contrast, other investigators claim that L-carnitine reduces consumption of oxygen, increases maximal running speed, and causes a decrease in heart rate (6). In addition, the common view is that muscle glycogen is used resolutely while fatty acid oxidation is increased through the effect of L-carnitine (7).

A study by Silipnaldi et al. (23) in 1990 of 10 athletes reported that 1 g of L-carnitine taken 1 hour before exercise reduced plasma lactate concentration. Another study indicated that 2 g of L-carnitine given 1 hour before the exercise increased maximal oxygen consumption and also reduced plasma lactate concentration (26). A study that investigated whether 1 g of intravenous L-carnitine given to elite athletes had an acute effect on exercise performance determined that L-carnitine improved athletic performance and reduced lactic acid level (18). These results were supported by similar findings in the present study.

When the LK-3 carnitine and P-3 groups were compared, significant differences were found in running speeds at mmol La concentrations of 2, 2.5, 3, 3.5, and 4 mmol, whereas significant differences were found in running speeds corresponding to 3.5 and 4 mmol La when the LK-4 and P-4 groups were compared ($p \leq 0.05$). These results indicate that the athletes receiving 3 g of L-carnitine reached all lactate threshold values at later or higher running speeds, whereas the athletes receiving 4 g of L-carnitine reached 3, 5, and 4 $mmol \cdot L^{-1}$ lactate threshold values at later or higher running speeds. Thus, it can be expressed that fatigue occurred later.

The exercise intensity corresponding to blood lactate concentration under 2 $mmol \cdot L^{-1}$ in endurance exercise is used as a criterion for recovery and renewal; around 2 $mmol \cdot L^{-1}$ for common endurance exercises, 3–4 $mmol \cdot L^{-1}$ for intensive endurance exercises, 4–6 $mmol \cdot L^{-1}$ for common repetition exercises, and 6–12 $mmol \cdot L^{-1}$ for intensive repetition exercises (17). Taking these data into consideration, when La responses to running speeds of the athletes in our study were examined, significant differences were found between the LK-3 and P-3 groups at running speeds of 8, 11, 12, 13, and 14 $km \cdot h^{-1}$ and between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$). This indicates that when 3 g of L-carnitine was taken, the running speeds at which anaerobic threshold was reached were lower compared with the placebo; however, when 4 g of L-carnitine was taken, anaerobic threshold was reached at higher running speeds. In other words, intake of 4 g of L-carnitine delayed reaching anaerobic threshold by using the athletes' aerobic energy system more effectively. Likewise, these findings were supported by the Borg responses to the perceived difficulty level of the exercise. When the Borg responses to running speeds were examined, significant differences were found between the LK-3 and P-3 groups at running speeds of 8, 11, 12, 13, and 14 $km \cdot h^{-1}$ and between the LK-4 and P-4 groups at running speeds of 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$). However, some studies indicate that supplementation of L-carnitine has no effect. In one of these studies, carried out by Brass et al. (8) on 14 healthy male subjects, it was indicated that intravenous L-carnitine (92.5 or 18.8 $mol \cdot kg^{-1}$) given 1 hour before the start of exercise (92.5 or 18.8 $mol \cdot kg^{-1}$) had no effect on respiratory exchange ratio, oxygen consumption, and lactate values in exercise with stable supplementation.

When running speeds corresponding to certain La concentrations were examined, there was no statistically significant difference between LK-3 and LK-4 groups. Colombani et al. found that 2 g of L-carnitine given before starting a 20-km marathon race had no effect on performance. In another study, it was also demonstrated that 1 g of L-carnitine given in treadmill exercise did not affect lactate concentration (11,19). Also in the present study, no statistically significance was found between lactate responses to running speeds between the LK-3 and LK-4 groups. The same condition is valid for perceived exercise difficulty in these groups.

In a study of the effects of chronic L-carnitine supplementation, the effects of 4 g of L-carnitine in 14 male athletes, it was indicated that L-carnitine had no effect on blood lactate levels measured during the exercise and muscle carnitine levels. In another study of 9 healthy males, it was also indicated that 3 g of L-carnitine taken orally for 7 days had no effect on lactate, heart rate, fatty acids, and oxygen consumption of the subjects (2,12).

In a study of 6 male athletes, 3 g of L-carnitine supplementation 3 hours before acute exercise and for 13-day-long period and responses were compared with a placebo group. No significant difference was found in oxygen consumption, blood lactate levels, and heart rates in 3 groups (27). Similarly, in the present study, when heart rates of LK-3 and P-3 and LK-4 and P-4 groups corresponding to certain La concentrations were examined, no significant difference was found at 2, 2.5, 3, and 4 $mmol \cdot L^{-1}$ threshold values; a significant difference was found only in the heart rate in LK-4 and P-4 groups corresponding to 3.5 $mmol \cdot L^{-1}$ La ($p \leq 0.05$). When heart rate responses to running speeds were examined, it was found that although heart rate showed a reduction in both L-carnitine and the placebo groups, which were given 3 and 4 g, the difference was found statistically significant between LK-4 and P-4 groups in heart rate responses at running speeds of 8, 10, 11, 12, 13, 14, 15, and 16 $km \cdot h^{-1}$ ($p \leq 0.05$).

These results show that L-carnitine supplementation affected performance positively in terms of running speed corresponding to specific lactate concentrations and lactic acid and Borg scale responses corresponding to running speeds. This suggests that L-carnitine intake of 3 or 4 g before exercise delayed blood lactate formation and, as a result, fatigue occurred later. However, it was observed that there was no statistically significant difference between the groups given 3 and 4 g of L-carnitine. Further studies are required.

Practical Applications

All those aforementioned results of the study are consistent with the finding that the installation of L-carnitine increases the effectiveness of endurance performance.

References

1. Allen, WK, Seals, DR, Hurley, BF, Ehsani, AA, and Hagberg, JM. Lactate threshold and distance–running performance in young and older endurance athletes. *J Appl Physiol* 58: 1281–1284, 1985.

2. Barnett, C, Costill, DL, and Vukovich, MD. Effect of L-carnitine supplementation on muscle and blood carnitine content and lactate accumulation during high-intensity sprint cycling. *Int J Sport Nutr* 4: 280–288, 1994.
3. Beltz, SD and Doering, PL. Efficiency of nutritional supplements used by athletes. *Clin Pharm* 12: 900–908, 1993.
4. Bompa, TO. *Periodization Training, Theory and Methodology of Training.* Ontario, Canada: Human Kinetics, 1999.
5. Borg, G. *Borg's Perceived Exertion and Pain Scales.* Champaign, IL: Human Kinetics, 1998.
6. Brass, EP. Supplemental carnitine and exercise. *Am J Clin Nutr* 72: 618S–623S, 2000.
7. Brass, EP. Carnitine and sports medicine: Use or abuse? *Ann N Y Acad Sci* 1033: 67–78, 2004.
8. Brass, EP, Hopple, CL, and Hiat, WR. Effect of intravenous L-carnitine on carnitine homeostasis and fuel metabolism during exercise in humans. *Clin Pharmacol Ther* 55: 681–692, 1994.
9. Bremer, J. Carnitine: Metabolism and functions. *Physiol Rev* 63: 1420–1480, 1983.
10. Cerretelli, P and Marconi, C. L-carnitine supplementation in humans. The effects of physical performance. *Int J Sports Med* 11: 1–14, 1990.
11. Colombani, P, Wenk, C, Kunz, I, Krähenbühl, S, Kuhnt, M, Arnold, M, Frey-Rindova, P, Frey, W, and Langhans, W. Effects of L-carnitine supplementation on physical performance and energy metabolism of endurance-trained athletes: A double-blind crossover field study. *Eur J Appl Physiol Occup Physiol* 73: 434–439, 1996.
12. Decombaz, J, Deriez, O, Acheson, K, Gmuender, B, and Jequıer, E. Effect of L-carnitine on submaximal exercise metabolism after depletion of muscle glycogen. *Med Sci Sports Exerc* 25: 733–740, 1993.
13. Demarle, AP, Heugas, AM, Slawinski, JJ, Tricot, VM, Koralsztein, JP, and Billat, VL. Whichever the initial training status, any increase in velocity at lactate threshold appears as a major factor in improved time to exhaustion at the same severe velocity after training. *Arch Physiol Biochem* 111: 167–176, 2003.
14. Farrel, PA, Wilmone, JH, Coyle, EE, Billing, JE, and Costill, DL. Plasma lactate accumulation and distance running performance. *Med Sci Sports* 11: 338–344, 1979.
15. Gleim, GG and Glace, B. Carnitine as an ergogenic aid in health and disease. *J Am Coll Nutr* 17: 203–204, 1998.
16. Harre, D. *Principle of Sports Training: Introduction to the Theory and Methods of Training.* Berlin: Sportverlag, 1982.
17. Jassen, P. *Training Lactate Pulse Rate.* Oulu, Finland: Polar Electro Oy, 1994.
18. Karlic, H and Lohninger, A. Supplementation of L-carnitine in athletes: Does it make sense? *Nutrition* 20: 709–715, 2004.
19. Nuesch, R, Rossetto, M, and Martina, B. Plasma and urine carnitine concentrations in well-trained athletes at rest and after exercise. Influence of L-carnitine intake. *Drugs Exp Clin Res* 25: 167–171, 1999.
20. Rebouche, CJ. Carnitine function and requirements during the life cycle. *FASEB J* 6: 3379–3386, 1992.
21. Rubin, MR, Volek, JS, Gomez, AL, Ratamess, NA, French, DN, Sharman, MJ, and Kraemer, WJ. Safety measures of L-carnitine L-tartrate supplementation in healthy men. *J Strength Cond Res* 15: 486–490, 2001.
22. Sahlin, K. Muscle carnitine metabolism during incremental dynamic exercise in humans. *Acta Physiol Scand* 138: 259–262, 1990.
23. Silipnaldi, N, Di Lisa, F, Pieralisi, G, Ripari, P, Maccari, F, Menabo, R, Giamberardino, MA, and Vecchiet, L. Metabolic changes induced by maximal exercise in human subjects following L-carnitine administration. *Biochim Biophys Acta* 1034: 17–21, 1990.
24. Soop, M, Björkman, O, Cederblad, G, Hagenfeldt, L, and Wahren, J. Influence of carnitine supplementation on muscle substrate and carnitine metabolism during exercise. *J Appl Physiol* 64: 2394–2399, 1988.
25. Tanphaichitr, V, Lerdvuthisopon, N, Dhanamitta, S, and Broquist, HP. Carnitine status in Thai adults. *Am J Clin Nutr* 33: 876–880, 1980.
26. Vecchiet, L, Di Lisa, F, Pieralisi, G, Ripari, P, Menabò, R, Giamberardino, MA, and Siliprandi, N. Influence of L-carnitine administration on maximal physical exercise. *Eur J Appl Physiol Occup Physiol* 61: 486–490, 1990.
27. Williams, M. Nutritional ergogenics in athletics. *Int J Sport Nutr* 13: 65–67, 1995.
28. Williams, MH. *The Ergogenics Edge Pushing the Limits of Sports Performance.* Human Kinetics, 1997.