

# **UBIQUINONE BIOSYNTHESIS: COENZYME Q-10 IMPACTS HEALTH AND AEROBIC METABOLISM**

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## **INTRODUCTION**

Coenzyme Q-10 has been associated with cardiovascular health with some reporting improved exercise performance. The defense relative to these associations for exogenous Coenzyme Q-10 application is rational. Some researchers do not agree that oral Coenzyme Q-10 increase performance in normal healthy subjects, but they do confirm positive affects on cardio pathological patients' health and exercise performance. If cardiovascular health outcome depends upon optimal levels of Coenzyme Q-10, then the question is if suboptimal levels occur, is optimal cardiovascular performance during extreme endurance performance demand possible? Exogenous supplementation of Coenzyme Q-10 is a substrate required for cellular health, energy metabolism associated improved aerobic metabolism in exercise events. This paper discusses what Coenzyme Q-10 is, what it does, how much of it comes from foods, how fast it is depleted, health disorders in patients who suffer from deficiency, and suboptimal exercise performance related to exercise-induced Coenzyme Q-10 deficiency.

## **WHAT COENZYME Q-10 IS AND WHAT IT DOES**

Coenzyme Q is an essential cofactor in the electron transport chain where it accepts electrons from complex I and II<sup>2</sup>. Coenzyme Q also serves as an important antioxidant in both mitochondria and lipid membranes<sup>3</sup>. Coenzyme Q, which also is known as ubiquinone, is a lipid-soluble compound composed of a redox active quinoid moiety and a hydrophobic "tail." The predominant form of coenzyme Q in humans is coenzyme Q<sub>10</sub>, which contains 10 isoprenoid units in the tail, whereas the predominant form in rodents is coenzyme Q<sub>9</sub>, which has nine isoprenoid units in the tail<sup>4</sup>.

Coenzyme Q is highly soluble in lipids (fats) and is found in virtually all cell membranes, as well as lipoproteins<sup>5</sup>. The ability of the benzoquinone head group of coenzyme Q to accept and donate electrons is a critical feature in its physiological functions.

Coenzyme Q can exist in three oxidation states:

1. Fully reduced ubiquinol form (CoQH<sub>2</sub>)
2. Radical semiquinone intermediate (CoQH•)
3. Fully oxidized ubiquinone form (CoQ).

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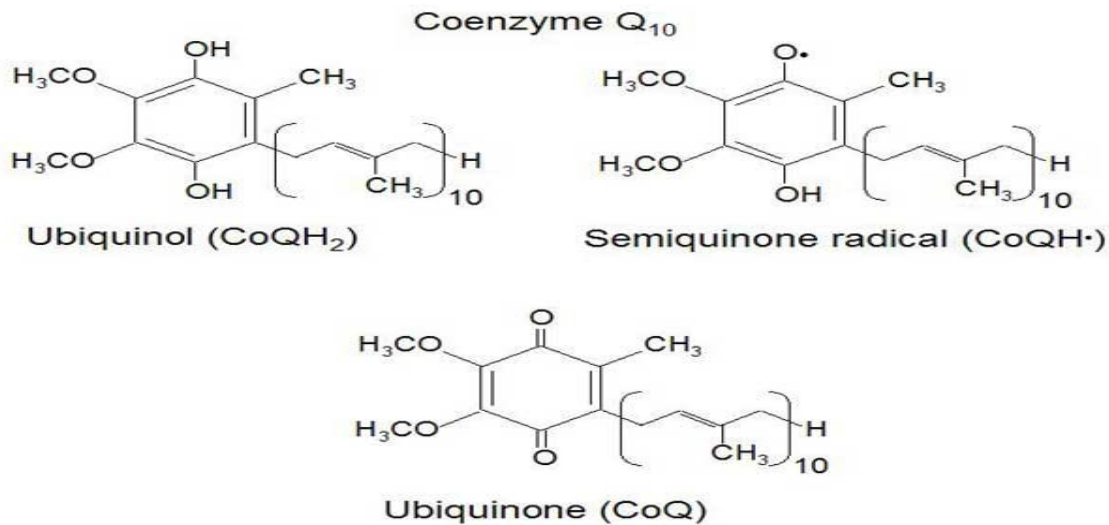
<sup>2</sup> Beyer, R. E. (1992); Ernster, L. & Dallner, G. (1995); Do, T. Q., Schultz, J. R. & Clarke, C. F. (1996).

<sup>3</sup> Noack, H., Kube, U. & Augustin, W. (1994); Forsmark-Andree, P., Lee, C.-P., Dallner, G. & Ernster, L. (1997).

<sup>4</sup> Crane (2001)

<sup>5</sup> Crane (2001).

## STRUCTURE OF COENZYME Q-10<sup>6</sup>:



Coenzyme Q is soluble and mobile in the hydrophobic core of the phospholipid bilayer of the inner membrane of the mitochondria where it transfers electrons one at a time to complex III of the electron transport chain. There has been considerable interest in the use of coenzyme Q<sub>10</sub> for the treatment of [mitochondrial disorders](#). Several reports found both clinical and biochemical improvement in patients with [mitochondrial disorders](#)<sup>7</sup>. If defects in energy metabolism and oxidative damage play a role in the pathogenesis of [neurodegenerative diseases](#)<sup>8</sup> then treatment with coenzyme Q<sub>10</sub> could exert beneficial [therapeutic effects](#)<sup>9</sup>.

### MITOCHONDRIA ENERGY PRODUCTION - ATP SYNTHESIS

The conversion of energy from carbohydrates and fats to adenosine triphosphate (ATP), the form of energy used by cells, requires the presence of coenzyme Q in the inner mitochondrial membrane. As part of the mitochondrial electron transport chain, coenzyme Q accepts electrons from reducing equivalents generated during fatty acid and glucose metabolism and transfers them to electron acceptors. At the same time, coenzyme Q transfers protons outside the inner mitochondrial membrane, creating a proton gradient across that membrane. [The energy released when the protons flow back into the mitochondrial interior is used to form ATP](#)<sup>10</sup>.

### LYSOSOMAL FUNCTION

Lysosomes are organelles within cells that are specialized for the digestion of cellular debris. The digestive enzymes within lysosomes function optimally at an acid pH, meaning they require a

<sup>6</sup> Higdon (2003).

<sup>7</sup> Abe et al (1991); Bresolin et al (1988); Ihara et al (1989); Nishikawa et al (1989); Shoffner et al (1989).

<sup>8</sup> Beal M. F. (1992, 1995).

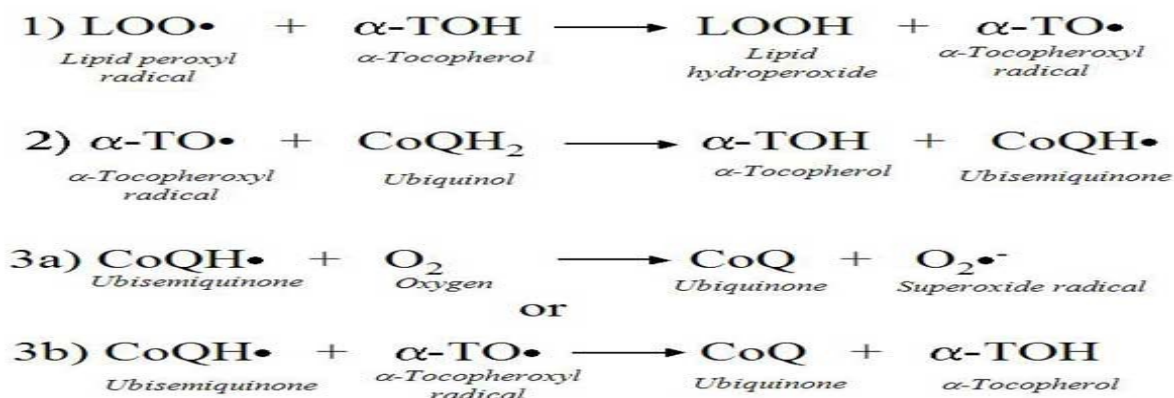
<sup>9</sup> Matthews et al. (1998). Abe et al (1991); Bresolin et al (1988); Ihara et al (1989); Nishikawa et al (1989); Shoffner et al (1989).

<sup>10</sup> Crane (2001).

permanent supply of protons. The lysosomal membranes that separate those digestive enzymes from the rest of the cell contain relatively high concentrations of coenzyme Q. [Recent research suggests that coenzyme Q plays an important role in the transport of protons across lysosomal membranes to maintain the optimal pH for cellular recycling<sup>11</sup>.](#)

## COENZYME Q-10 IS A POWERFUL ANTIOXIDANT

In its reduced form, CoQH<sub>2</sub> is an effective fat-soluble antioxidant. The presence of a significant amount of CoQH<sub>2</sub> in cell membranes, along with enzymes that are capable of reducing oxidized CoQ back to CoQH<sub>2</sub>, supports the idea that CoQH<sub>2</sub> is an important cellular antioxidant<sup>12</sup>. CoQH<sub>2</sub> has been found to inhibit lipid peroxidation when cell membranes and low-density lipoproteins (LDL) are exposed to oxidizing conditions outside the body (ex vivo). When LDL is oxidized ex vivo, CoQH<sub>2</sub> is the first antioxidant consumed. Moreover, the formation of oxidized lipids and the consumption of α-tocopherol (vitamin E) are suppressed while CoQH<sub>2</sub> is present<sup>13</sup>. In isolated mitochondria, Coenzyme Q can protect membrane proteins and DNA from oxidative damage that accompanies lipid peroxidation<sup>14</sup>. In addition to neutralizing free radicals directly, [CoQH<sub>2</sub> is capable of regenerating α-tocopherol](#). COENZYME Q-10 interacts with Vitamin E reducing free radicals. [Vitamin E \(α-tocopherol\) and Coenzyme Q are the principal fat-soluble antioxidants in membranes and lipoproteins](#). When α-tocopherol (α-TOH) neutralizes a free radical, such as a lipid hydroperoxyl radical (LOO•), it becomes oxidized itself, forming the α-tocopheroxyl radical (α-TO•), which can promote the oxidation of lipoproteins under certain conditions in the test tube (**Reaction 1**). When the reduced form of Coenzyme Q (CoQH<sub>2</sub>) reacts with α-TO•, α-TOH is regenerated and the semiquinone radical (CoQH•) is formed (**Reaction 2**). It is possible for CoQH• to react with oxygen (O<sub>2</sub>) to produce superoxide (O<sub>2</sub><sup>•-</sup>), which is a much less oxidizing radical than LOO• (**Reaction 3a**). However, [CoQH• can also reduce α-TO• back to α-TOH, resulting in the formation of fully oxidized Coenzyme Q \(CoQ\), which does not react with O<sub>2</sub> to form O<sub>2</sub><sup>•-</sup>](#) (**Reaction 3b**) [Reaction Scheme below<sup>15 16</sup>](#):



<sup>11</sup> Crane (2001); Nohl & Gille (2001).

<sup>12</sup> Crane (2001).

<sup>13</sup> Thomas & Stocker (2001).

<sup>14</sup> Ernster & Dallner (1995).

<sup>15</sup> Thomas & Stocker(2001); Kagan et al (2001).

<sup>16</sup> Higdon (2003).

## COENZYME Q-10 IS INTERNALLY MANUFACTURED FROM MICRONUTRIENTS

**Vitamin B6:** The first step in coenzyme Q10 biosynthesis (the conversion of **tyrosine to 4-hydroxyphenylpyruvic acid**) requires vitamin B6 in the form of pyridoxal 5'-phosphate. Thus, adequate **vitamin B6 is essential for coenzyme Q biosynthesis**. A pilot study in 29 patients and healthy volunteers found significant positive correlations between blood levels of coenzyme Q10 and measures of vitamin B6 nutritional status<sup>17</sup>. Coenzyme Q10 is synthesized in most human tissues.

The biosynthesis of coenzyme Q10 involves three major steps:

1. Synthesis of the benzoquinone structure from the amino acids, tyrosine or phenylalanine
2. Synthesis of the isoprene side chain from acetyl-coenzyme A (CoA) via the mevalonate pathway
3. Joining condensation of these two structures
4. The enzyme hydroxymethylglutaryl (HMG)-CoA reductase plays a critical role in the regulation of coenzyme Q10 synthesis as well as the regulation of cholesterol synthesis<sup>18</sup>.

## COENZYME Q-10 IS SCARCE IN FOODS

While our body produces its own Coenzyme Q-10, it is dependant upon the food chain to supply the required substrates amino acids and fatty acid donors. Based on food frequency studies the average dietary intake of coenzyme Q10 in Denmark was estimated to be **only 3-5 mg/day**<sup>19</sup>. Most people probably have a dietary intake of **less than 10 mg/d of Coenzyme Q-10**. Rich sources of dietary coenzyme Q10 include meat, poultry, and fish. Other relatively rich sources include soybean and canola oils, and nuts. Fruits, vegetables, eggs, and dairy products are moderate sources of coenzyme Q10. Approximately 14-32% of coenzyme Q10 was lost during frying, but the Coenzyme Q10 content of vegetables and eggs did not change when boiled. Some relatively rich dietary sources and their coenzyme Q10 content in milligrams (mg) are listed in the table below<sup>20</sup>:

FOOD	SERVING	COENZYME Q <sub>10</sub> (mg)	AMOUNT REQUIRED TO GENERATE 30 mg
Beef, fried	3 ounces <sup>21</sup>	2.6	2.16 lbs
Herring, marinated	3 ounces	2.3	2.44 lbs
Chicken, fried	3 ounces	1.4	4.01 lbs
Soybean oil	1 tablespoon	1.3	23 tablespoons
Canola oil	1 tablespoon	1.0	30 tablespoons
Rainbow trout, steamed	3 ounces	0.9	6.2 lbs
Peanuts, roasted	1 ounce	0.8	2.30 lbs
Sesame seeds, roasted	1 ounce	0.7	2.67 lbs
Pistachio nuts, roasted	1 ounce	0.6	3.12 lbs

<sup>17</sup> Willis et al (1999).

<sup>18</sup> Ernster & Dallner (1995); Overvad et al (1999).

<sup>19</sup> Weber (2001); Overvad et al (1999).

<sup>20</sup> Weber et al (1997); Kamei et al (1986); Mattila & Kumpulainen (2001).

<sup>21</sup> A 3-ounce serving of meat or fish is about the size of a deck of cards.

Broccoli, boiled	1/2 cup, chopped	0.5	60 cups
Cauliflower, boiled	1/2 cup, chopped	0.4	75 cups
Orange	1 medium	0.3	100 oranges
Strawberries	1/2 cup	0.1	150 cups
Egg, boiled	1 medium	0.1	300 eggs

Langsjoen (1994) also confirmed that to get 30 milligrams CoQ10 from food, you would need to eat one of the following<sup>22</sup>:

1. 1 pound sardines
2. 2 pounds beef
3. 2.5 pounds of peanuts

Folkers argues that suboptimal nutrient intake in man is almost universal and that there is subsequent secondary impairment in CoQ10 biosynthesis<sup>23 24 25</sup>. This would mean that average or "normal" levels of CoQ10 are really suboptimal and the very low levels observed in advanced disease states represent only the tip of a deficiency "ice berg". Coenzyme Q-10 is not therefore widely available in the human food chain. Coenzyme Q-10 is naturally present in small amounts in a wide variety of foods but is particularly high in organ meats such as heart, liver and kidney, as well as beef, soy oil, sardines, mackerel, and peanuts:

#### COENZYME Q-10 DEPLETION RATE & DEFICIENCY PATHOLOGY

Increased body depletion of CoQ10 is the presumed cause of low blood CoQ10 levels seen in excessive exertion, hypermetabolism, and acute shock states. Three mechanisms are operant in varying degrees resulting in Coenzyme Q10 deficiency<sup>26</sup>:

1. Insufficient dietary CoQ10
2. Impaired CoQ10 biosynthesis
3. Excessive utilization of CoQ10

[Karl Folkers takes the position that the dominant source of CoQ10 in man is biosynthesis. This complex, 17-step process, requires at least 9 vitamins and several trace elements:](#)

1. Vitamin B2
2. Riboflavin
3. Vitamin B3
4. Niacinamide
5. Vitamin B6
6. Folic acid

<sup>22</sup> From *Introduction to Coenzyme Q10*; Peter H. Langsjoen, M.D., F.A.C.C.,P.A. 1120 Medical Dr. Tyler, Tx 75701 Copyright 1994.

<sup>23</sup> Littarru et al.

<sup>24</sup> Folkers & Watanabe (1978).

<sup>25</sup> Folkers et al (1993).

<sup>26</sup> Littarru et al (1991).

7. Vitamin B12
8. Vitamin C
9. Pantothenic acid
10. Several trace elements

CoQ10 is also synthesized in all tissues and in healthy individuals normal levels are maintained both by CoQ10 intake and by the body's synthesis of CoQ10. It has no known toxicity or side effects. In other words to consume only 30 mg Coenzyme Q-10, the individual would have to eat enormous amounts of sardines, beef, or peanuts<sup>27</sup>. Clinical studies have concluded that daily doses of at least 30 mg per day are required to significantly raise blood CoQ10 levels. The usual therapeutic dosage for otherwise healthy people is 50-150 mg of Coenzyme Q10 per day, or more precisely, 2 mg of CoQ10 per kg of body weight<sup>28</sup>. The dosage of CoQ10 used in clinical trials has evolved over the past 20 years. Initially, doses as small as 30-45 mg per day were associated with measurable clinical responses in patients with heart failure. More recent studies have used higher doses with improved clinical response, again in patients with heart failure. Most studies with CoQ10 involve the measurement of the level of CoQ10 in blood. CoQ10 shows a moderate variability in its absorption, with some patients attaining good blood levels of CoQ10 on 100 mg per day while others require two or three times this amount to attain the same blood level. All CoQ10 available today in the United States is manufactured in Japan and is distributed by a number of companies who place the CoQ10 either in pressed tablets, powder-filled capsules, or oil-based gelscaps. CoQ10 is fat-soluble and absorption is significantly improved when it is chewed with a fat-containing food<sup>29</sup>. Without at least 30 milligrams Coenzyme Q-10 from food or supplements, deficiency is predicted in an endurance athlete, resulting in suboptimal levels during peak exercise states.

#### COENZYME Q-10 DEPLETION & REPLETION RECOMMENDATION

Decreased plasma levels of coenzyme Q10 have been observed in individuals with diabetes, cancer, and congestive heart failure. Lipid lowering medications (statins) that inhibit the activity of HMG-CoA reductase, a critical enzyme in cholesterol and coenzyme Q10 synthesis, have been found to decrease plasma coenzyme Q10 levels. Nutritional replenishment of coenzyme Q requires a higher level than is available in most food. The normal level in blood is around 1 µg/mL<sup>30</sup>. To increase the concentration significantly requires at least 100 mg/day which can increase the level in blood to around 2 µg/mL or more. An increase to 2 µg/mL in blood can be therapeutic for various conditions<sup>31</sup>; this may indicate that a high blood level is needed to get coenzyme Q into deficient tissues. Even with large amounts of heart or herring in the diet, it would be difficult to supply 100 mg/day.

Since CoQ10 is essential to the optimal function of all cell types, it is not surprising to find a seemingly diverse number of disease states, which respond favorably to CoQ10 supplementation. All metabolically active tissues are highly sensitive to a deficiency of CoQ10. CoQ10's function as a free

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<sup>27</sup> *Ibid.*

<sup>28</sup> Zita et al (2003).

<sup>29</sup> From Introduction to Coenzyme Q10; Peter H. Langsjoen, M.D., F.A.C.C., P.A. 1120 Medical Dr. Tyler, Tx 75701 Copyright 1994.

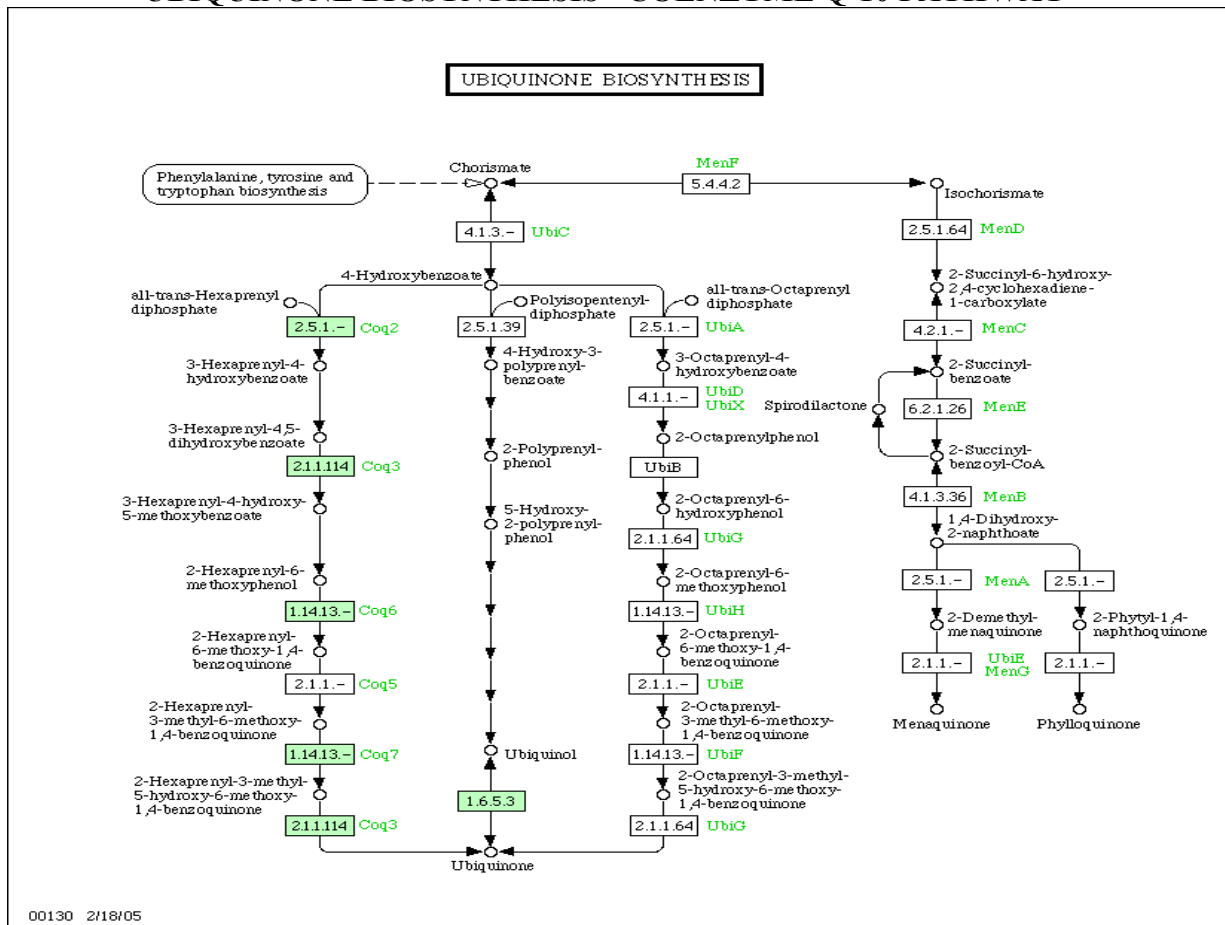
<sup>30</sup> Willis et al (1999); Munkholm et al (1999); Eriksson et al (1999).

<sup>31</sup> Langsjoen & Langsjoen (1999).

radical scavenger only adds to the protean manifestations of CoQ10 deficiency. Preliminary observations in a wide variety of disease states have already been published<sup>32</sup>.

The **UBIQUINONE BIOSYNTHESIS** pathway by which our body manufactures Coenzyme Q-10 is complex and lengthy depending on numerous enzymes, the amino acids Phenylalanine, Tyrosine, Tryptophan, Vitamin B2, Riboflavin, Vitamin B3, Niacinamide, Vitamin B6, Folic acid, Vitamin B12, Vitamin C, Pantothenic acid, and Several trace elements. Unless each of these is sufficient, delay in replacing spent Coenzyme Q-10 may occur. With chronic deficiency reduced energy metabolism and cardio pathological disorders are predicted.

### UBIQUINONE BIOSYNTHESIS - COENZYME Q-10 PATHWAY<sup>33</sup>



What is the internal effects from oral coenzyme Q10?

In an animal study, CoQ10 intake enhanced both CoQ9 and CoQ10 homologues in the plasma, and in homogenates and mitochondria of liver, heart and skeletal muscle. CoQ was elevated in brain mitochondria. The uptake of exogenous CoQ was higher in mitochondria of heart and skeletal

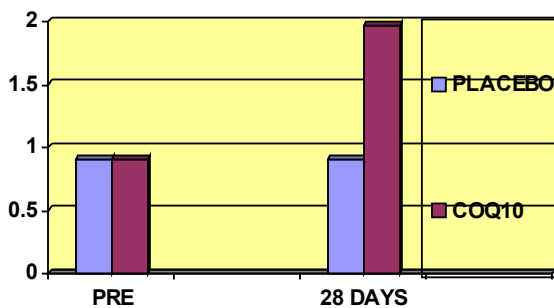
<sup>32</sup> Hansen (1976; Iwamoto et al (1980); Folkers & Langsjoen (1988); Langsjoen & Langsjoen (1991); Cortes et al (1977); Combs et al (1981); Judy et al (1983); Lockwood et al (1994-1995); Folkers et al (1993).

<sup>33</sup> By permission, courtesy of KEGG: Kyoto Encyclopedia of Genes and Genomes, [KEGG EXPRESSION](http://www.genome.ad.jp/) for mapping gene expression profiles to pathways and genomes, [GenomeNet] <http://www.genome.ad.jp/>

muscle than those in liver. CoQ10 administration also elevated the alpha-tocopherol concentration in tissue homogenates and their mitochondria, thereby providing an in vivo indication of the "sparing" effect of CoQ on alpha-tocopherol. Results of this study demonstrate that, contrary to the historical view, both total and mitochondrial CoQ concentrations in the heart and skeletal muscle and in the mitochondria of brain of young mice can be augmented by dietary supplementation. Furthermore, CoQ intake enhances the antioxidative potential of tissues by elevating the endogenous amounts of alpha-tocopherol<sup>34</sup>.

Taking only 1 milligram per kilogram (example 70 mg for 154 lb athlete) more than doubled plasma CoQ10 concentration.

The effect of orally supplemented coenzyme Q10 (CoQ10) on plasma CoQ10 concentration and aerobic capacity in endurance athletes was evaluated. Eighteen volunteer male road cyclists and triathletes, 8 in a CoQ10 supplementation group (QG) and 10 in a placebo group (PG), successfully completed the experimental protocol. Subjects were evaluated during and following graded cycling exercise tests, which were performed before and after 28 days of supplementation with 1 mg.kg<sup>-1</sup>.day<sup>-1</sup> of CoQ10 or placebo. The presupplementation plasma CoQ10 concentration was significantly increased from 0.91 microgram.ml<sup>-1</sup> to 1.97 microgram.ml<sup>-1</sup> in QG following supplementation (p < .05)<sup>35</sup>:



## WHAT IS THE EFFECT OF COENZYME Q10 ON PERFORMANCE?

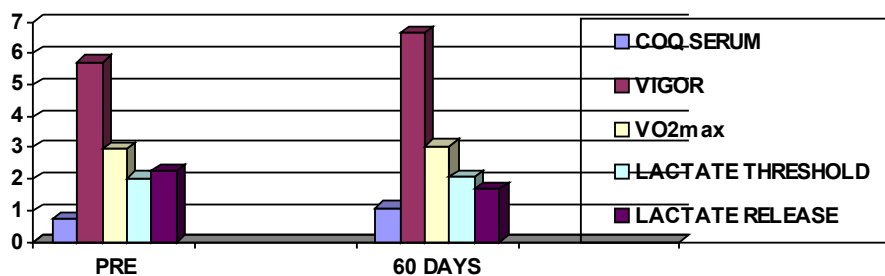
In order to determine the effect of oral Coenzyme Q10 (CoQ10) dosing on exercise capacity, 15 middle-aged men (44.7 +/- 2.0 years) received either CoQ10 (150 mg/day x 2 months-Q10 GRP) or placebo (2 months-CON GRP). Blood CoQ10 levels increased during the treatment in the Q10 GRP (Pre = 0.72 +/- 0.06, 2 months = 1.08 +/- 0.14 micrograms/ml) and were unchanged in the CON GRP (Pre = 0.91 +/- 0.05, 2 month = 0.69 +/- 0.05 microgram/ml). Similarly, the subjective perception of vigor (visual analog scale 1-10 where, 10 = very energetic, and 0 = very, very unenergetic) increased (p < 0.05) in the Q10 GRP (Pre = 5.73 +/- 0.35, 2 month = 6.64 +/- 0.45). However, maximal oxygen consumption (VO<sub>2</sub>max Pre = 2.97, 2 month = 3.05 l/min) and lactate threshold (LT Pre = 2.04, 2 month = 2.08 l/min), as measured on the cycle ergometer, were unchanged as a result of the CoQ10 treatment, Neither forearm oxygen uptake, nor forearm blood flow was found to be affected by the CoQ10. Although lactate release during hand-grip testing tended to decrease in the Q10 GRP (Pre =

<sup>34</sup> Kamzalov (2003).

<sup>35</sup> Weston et al (1997).

227, 2 month = 168.3  $\mu\text{mole}/\text{min}$ ) this was not significant ( $p > 0.05$ ). It can be concluded that short-term (2 months) oral dosing with CoQ10 increases circulating blood levels of CoQ10 and the subjective perceived level of vigor in middle-aged men. However, short-term dosing does not improve aerobic capacity or firearm exercise metabolism as measured in this investigation.

#### NUMERICAL INCREASES ASSOCIATED WITH COENZYME Q-10 DOSE<sup>36 37 38</sup>



Effects of coenzyme Q10 supplementation on exercise performance, VO2max, and lipid peroxidation in trained cyclists (↑).

#### COENZYME Q-10 & VITAMIN E REDUCES FREE RADICALS IN MARATHON RUNNERS

Effect of combined coenzyme Q10 and d-alpha-tocopheryl acetate supplementation on exercise-induced lipid peroxidation and muscular damage: a placebo-controlled double-blind study in marathon runners. To test the effects of combined coenzyme Q10 (Q10) and d-alpha-tocopheryl acetate supplementation on exercise-induced oxidative stress and muscular damage Kaikkonen et al (1998) conducted a double-blind study in 37 moderately trained male marathon runners. These were randomly allocated to receive either an antioxidant cocktail: 90 mg of Q10 and 13.5 mg of d-alpha-tocopheryl acetate daily (18 men) or placebo (19 men) for three weeks before a marathon (42km) run. Just before the run, plasma Q10 was 282% ( $p < 0.0001$ ) and plasma vitamin E 16% ( $p < 0.007$ ) higher in the supplemented group, than in the placebo group. Also the proportion of plasma ubiquinol of total Q10, an indication of plasma redox status in vivo, was significantly higher in the supplemented group. Furthermore, the susceptibility of the VLDL + LDL fraction, to copper-induced oxidation, was significantly reduced in the supplemented group, compared to the placebo group. The exercise increased lipid peroxidation significantly in both study groups, as assessed by the elevated proportion LDL of LDL and the increased susceptibility of lipoproteins to copper induced oxidation. However, the supplementation had no effect on lipid peroxidation or on the muscular damage (increase in serum creatine kinase activity or in plasma lactate levels) induced by exhaustive exercise. Plasma ascorbate, Q10, whole blood glutathione and serum uric acid concentrations increased during the exercise, elevating significantly the TRAP value of plasma by 10.3% and the proportion of plasma ubiquinol of total Q10 by 4.9%. These results suggest that even though exercise increases plasma lipid peroxidation, it also elevates the antioxidative capacity of plasma, as assessed by the increased plasma TRAP and the proportion of Q10H2 of total Q10.

<sup>36</sup> (Porter et al 1995).

<sup>37</sup> Tomono et al (1986).

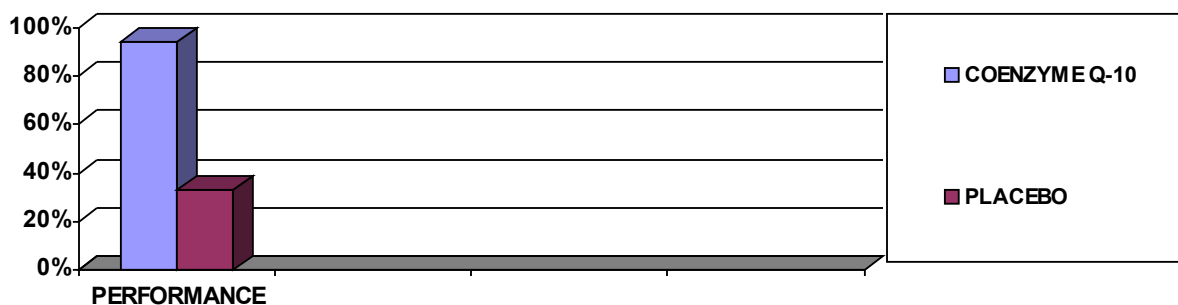
<sup>38</sup> Weber et al (1994).

However, prior supplementation with small doses of Q10 and d-alpha-tocopheryl acetate neither attenuates the oxidation of lipoproteins nor muscular damage induced by exhaustive exercise such as encountered in a marathon run<sup>39</sup>.

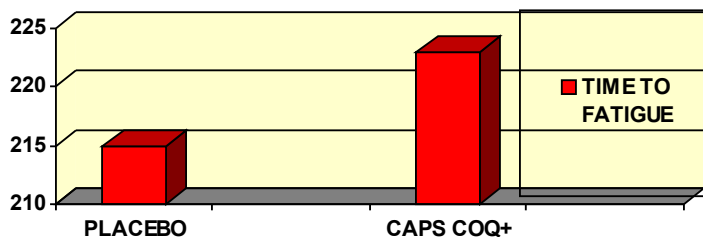
### COENZYME Q10 IMPROVES EXERCISE PERFORMANCE

Ylikoski et al (1997) studied Coenzyme Q10 supplementation (Bio-Qinon Pharma Nord, 90 mg/day) in a double-blind cross-over study of 25 Finnish top-level cross-country skiers. With CoQ10 supplementation, all measured indexes of physical performance (AET, ANT and VO2Max) improved significantly. **During COQ-10 supplementation, 94% of the athletes felt that the preparation had been beneficial in improving their performance and recovery time vs. only 33% in the placebo periods<sup>40 41</sup>.**

ALL MEASURED INDEXES PHYSICAL PERFORMANCE AET, ANT, VO2 MAX



COENZYME Q-10 AFFECT ON TIME TO FATIGUE - SNIDER et al (1992)



Snider et al (1992) examined the effects of the Coenzyme Athletic Performance System (CAPS) on endurance performance to exhaustion. CAPS contains 100 mg coenzyme Q10, 500 mg cytochrome C, 100 mg inosine, and 200 IU vitamin E. Eleven highly trained male triathletes were given three daily doses of either CAPS or placebo (dicalcium phosphate) for two 4-week periods using a double-blind crossover design. A 4-week washout period separated the two treatment periods. An exhaustive performance test, consisting of 90 minutes of running on a treadmill (70% VO2max)

<sup>39</sup> Kaikkonen et al (1998).

<sup>40</sup> Ylikoski et al (1997).

<sup>41</sup> AET = Aerobic Threshold. ANT = Anaerobic Threshold. VO<sub>2</sub> Max = Maximum O<sub>2</sub> Use.

followed by cycling (70% VO<sub>2</sub>max) until exhaustion, was conducted after each treatment period. The mean (+/- SEM) time to exhaustion for the subjects using [CAPS \(223 min\)](#) was different (p = 0.57) from the [placebo trial \(215 min\)](#). Blood glucose, lactate, and free fatty acid concentrations at exhaustion did not differ between treatments. CAPS had SOME benefit<sup>42</sup> on exercise to exhaustion.

### [COQ10 SUPPLEMENTATION INCREASES ENERGY METABOLISM IN POST-POLIO INDIVIDUALS TO A GREATER EXTENT THAN IN CONTROL SUBJECTS](#)<sup>43</sup>

Effects of oral supplementation of coenzyme Q10 on skeletal muscle energy metabolism in middle-aged post-polio subjects and normal volunteers.

Mizuno et al (1997) the effects of oral supplementation of 100 mg coenzyme Q10 (CoQ10) for 6 months on muscle energy metabolism during exercise and recovery in middle-aged post-polio (n = 3) and healthy subjects (n = 4) by the use of phosphorus-31 nuclear magnetic resonance spectroscopy. The metabolic response to isometric plantar flexion at 60% of maximal voluntary contraction force (MVC) for 1.5 min was determined in gastrocnemius muscles before, after 3- (3MO) and 6-month (6MO) of CoQ10 supplementation. The MVC of plantar flexion was unchanged following CoQ10 supplementation. The resting Pi/PCr ratio in gastrocnemius muscles of all subjects decreased after 3MO- and 6MO-CoQ10 (P < 0.05). The post-polio individuals showed a progressive decrease in this ratio, while less pronounced changes were observed in the control subjects. Similarly, the post-polio individuals showed a lower Pi/PCr ratio at the end of 60% MVC in both 3MO- and 6MO-CoQ10, whereas no change in the ratio was observed in the control subjects. A less pronounced decrease in muscle pH was observed at the end of 60% MVC in both 3MO- and 6MO-CoQ10 in the post-polio individuals, but not in the control subjects. No systematic difference in end-exercise ATP was observed between the three phases in both groups. The half-time of recovery for PCr decreased in all subjects after 6MO-CoQ10 supplementation. [The results suggest that CoQ10 supplementation affects muscle energy metabolism in post-polio individuals to a greater extent than in control subjects. The mechanism for this effect is not clear, but may involve an effect of CoQ10 on peripheral circulation in the calf muscles, its action in mitochondrial oxidative phosphorylation and/or its antioxidant potential.](#)

### HEART PATIENTS INCREASE HEART EJECTION FRACTION<sup>44</sup> AND SURVIVAL RATE

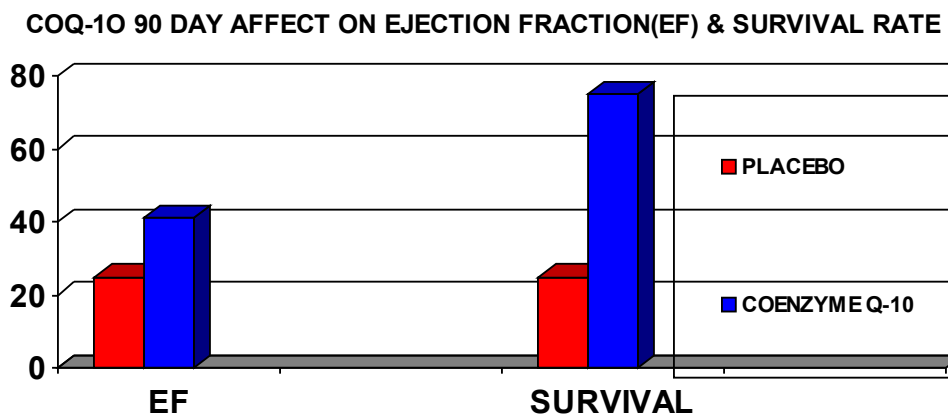
The total amount of blood pumped out of the ventricle per heartbeat is called the "ejection fraction". Some blood lingers behind in the heart chamber on each contraction. Normal ejection fraction is between 55-75%. A measurement under 40% may be evidence of heart failure or cardiomyopathy. During 1982-86, 43/137 patients with cardiomyopathy, Classes II, III and IV, had ejection fractions (EF) below 40%, and a mean EF of 25.1%. During treatment of these 43 patients with coenzyme Q10 (CoQ10), EF increased to 41.6 (p less than 0.001) over a mean period of 3 months (range, 2-4 months). At four subsequent periods up to 36 months: EF ranged from 43.1 to 49.7 each period. The mean CoQ10 control blood level was 0.85 micrograms/ml, which increased on treatment to 1.7 to 2.3 micrograms/ml for five periods up to 36 months (each period, p less than 0.001). The survival rates for all 137 patients treated with CoQ10 and for the 43 patients with EF

<sup>42</sup> A 3.7% performance advantage to exhaustion is the difference between 1<sup>st</sup> and last place, though the authors Snider et al 1992 did not regard the difference as significant.

<sup>43</sup> Mizuno et al (1997)

<sup>44</sup> Langsjoen et al (1985, 1990, 1997).

below 40% were both about 75%/46 months. These two survival rates were comparable between 24 and 46 months, which is of extraordinary significance and importance when compared to survival of about 25%/36 months for 182 patients with EF below 46% on conventional therapy without CoQ10. The improved cardiac function and pronounced increase of survival show that therapy with CoQ10 is remarkably beneficial due to correction of CoQ10 deficiency in mechanisms of bioenergetics<sup>45</sup>.



#### COENZYME Q-10 INCREASES HEART EFFICIENCY & BALANCES BLOOD PRESSURE

A systematic review of effect of coenzyme Q10 in physical exercise, hypertension and heart failure [show that it lowers blood pressure in hypertension, heart patients taking Coenzyme Q-10 increase exercise time and lower pathological heart failure symptoms](#). Rosenfeldt et al (2003) identified eleven studies in which CoQ10 was tested for an effect on exercise capacity, six showed a modest improvement in exercise capacity with CoQ10 supplementation but five showed no effect. CoQ10 in hypertension: They identified eight published trials of CoQ10 in hypertension. Altogether in the eight studies the mean decrease in systolic blood pressure was 16 mm Hg and in diastolic blood pressure, 10 mm Hg. Being devoid of significant side effects CoQ10 may have a role as an adjunct or alternative to conventional agents in the treatment of hypertension. They performed a randomised double blind placebo-controlled pilot trial of CoQ10 therapy in 35 patients with heart failure. Over 3 months, in the CoQ10 patients but not in the placebo patients there were significant improvements in symptom class and a trend towards improvements in exercise time<sup>46</sup>.

#### COENZYME Q-10 IMPROVES PERFORMANCE

Researchers report [a modest 4% increase in the maximal cycling workload increase](#) after 8 weeks of Coenzyme Q10 supplementation compared to placebo, although measures of aerobic power were not increased<sup>47</sup>. Malm et al (1997) also found significantly greater improvement in measures of [anaerobic](#) performance after supplementation with a placebo compared to coenzyme Q10.

<sup>45</sup> Langsjoen et al (1985, 1990, 1997).

<sup>46</sup> Rosenfeldt et al (2003).

<sup>47</sup> Bonetti et al (2000).

Laaksonen et al (1995) likewise found significantly greater improvement in measures of [aerobic](#) exercise performance after supplementation with a placebo compared to coenzyme Q10.

## SUMMARY

- Coenzyme Q-10 biosynthesis 17-step process requires 9 vitamins and several trace elements for the body to make its own stores.
- Coenzyme Q-10's deficiency preventative dose is 30 mg per day, whereas 3 times that amount is required for active subjects to prevent deficiency<sup>48</sup> symptoms.
- Coenzyme Q-10 deficiency predictably occurs proportionate to metabolic activity rate.
- Coenzyme Q-10 is a fat-soluble compound primarily synthesized by the body but replaced sparingly from foods. Huge portions of food is required to provide only 30 milligrams of Coenzyme Q-10:
  1. 1 pound sardines
  2. 2 pounds beef
  3. 2.5 pounds of peanuts
- Coenzyme Q10 exerts beneficial therapeutic effects reducing defects in energy metabolism and oxidative damage play a role in the pathogenesis of neurodegenerative diseases.
- Coenzyme Q10 supplementation reduces the degenerative symptoms of cardiovascular diseases, neurodegenerative diseases, cancer, diabetes, and metabolic deficiencies.
- Coenzyme Q10 supplementation has been shown to be a useful adjunct to conventional medical therapy for congestive heart failure.
- Coenzyme Q10 is required for mitochondrial ATP synthesis and functions as an antioxidant in cell membranes and lipoproteins.
- Coenzyme Q-10 is required for efficient cellular energy metabolism.
- Coenzyme Q-10 is required for maximal antioxidant effects during energy metabolism.
- Coenzyme Q-10 oral dose increases plasma, lipoprotein, blood vessel and tissue levels.
- Coenzyme Q-10 supplementation has resulted in clinical and metabolic improvement in some patients with hereditary mitochondrial disorders.
- Coenzyme Q-10 regenerates Vitamin E's antioxidant potential.
- Coenzyme Q-10 supplementation of 1 milligram per kilogram (example 70 mg for 154 lb athlete) more than doubled plasma CoQ10 concentrations.
- Coenzyme Q10 supplementation improves athletic performance in some studies while in others it does not. The question of whom it may benefit appears to be in those whose diets are deficient or in those who are deficient due to pathological or metabolic deficits.

**CONCLUSION:** Coenzyme Q-10 is always depleted in cardio pathological disorders or during endurance exercise resulting in high levels of superoxides (free radicals) in fatty tissue sites. It takes large amounts of foods to replace Coenzyme Q-10. It also takes 9 vitamins and several trace substrates to replace Coenzyme Q-10. Chronic Coenzyme Q-10 deficiency may occur from exercise-induced expenditures. When Coenzyme Q-10 is supplemented, mitochondria energy metabolism dependant upon this metabolite appear to rebound subtly, improving cardiovascular ejection

**fraction, survival rate, energy metabolism efficiency, anaerobic threshold, aerobic threshold, VO2 Max, and lactate clearance, all of which exert a beneficial therapeutic effect in both pathological patients and endurance athletes.**

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**DISCLOSURE:** One product manufactured by the [author's employer](#) contains 30 mg Coenzyme Q-10. The author, an endurance athlete, has been taking Coenzyme Q-10 before, during, or after exercise for 17 years. During that time period, performance gains were associated with coenzyme Q-10 dose, though placebo periods fasting coenzyme Q-10 periods were less than those utilizing COQ10. The author discloses his bias without completely eliminating the placebo effect.

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