Türk Kadın Sağlığı ve Neonatoloji Dergisi

To cite this article: Erdoğan K, Macit MS, Şanlıer NT, Engin Üstün Y. Coenzyme Q10: Current overview. Turk J Womens Health Neanotol 2022; 4(2): 77-86.

Review

Coenzyme Q10: Current Overview

Koenzim Q10: Güncel Genel Bakış

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Abstract

Coenzyme Q10 (CoQ10) is a lipid-soluble component from benzoquinones. The oxidized form of Coenzyme Q10 is ubiquinone, and the reduced form is ubiquinol. As well to its endogenous synthesis, Coenzyme Q10 is also included in the diet. Dietary sources of CoQ10 are meat, poultry, fish, oil, and nuts. Coenzyme Q10 has an important role in energy metabolism in the mitochondria. It also protects the phospholipids, proteins, and DNA from oxidative damage in the membrane. It is stated that CoQ10 has several positive effects on diseases due to its antioxidant capacity. In recent years CoQ10 intake has become widespread. There are several studies investigating the usage and dosage of CoQ10 in diseases such as cardiovascular, neurological disease, diabetes, and reproductive endocrinology. In the present study, it was aimed to evaluate the CoQ10 and its possible health effects.

Keywords: Coenzyme Q10; dietary supplements; health; nutrition

Öz

Koenzim Q10 (CoQ10), benzokinonlardan elde edilen lipitte çözünür bir bileşendir. Koenzim Q10'un oksitlenmiş formu ubiquinonedir ve indirgenmiş formu ubiquinoldür. Koenzim Q10, endojen sentezinin yanı sıra diyete de dâhildir. CoQ10'un diyet kaynakları et, kümes hayvanları, balık, yağ ve fındıktır. Koenzim Q10 in mitokondride enerji metabolizmasında önemli görevleri bulunmaktadır. Ayrıca membrandaki oksidatif hasardan fosfolipitleri, proteinleri ve DNA'yı korur. CoQ10'un antioksidan kapasitesi nedeniyle hastalıklar üzerinde birçok olumlu etkisi olduğu belirtilmektedir. Son yıllarda CoQ10 alımı yaygınlaştı. CoQ10'un kardiyovasküler, nörolojik hastalıklar, diyabet, kadın hastalıkları ve doğum vb. pek çok hastalıkta kullanım ve kullanım miktarını araştıran çalışmalar bulunmaktadır. Bu yazıda CoQ10 un metabolizması, etki mekanizmaları ile sağlık üzerine olan etkilerinin değerlendirilmesi amacıyla yapılmıştır.

Anahtar Kelimeler: Koenzim Q10; diyet takviyeleri; sağlık; beslenme

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DOI: 10.46969/EZH.1002286
Geliş tarihi: 30.09.2021 Kabul tarihi: 06.05.2022

Volume 4 Number 2 p: 77-86

1. Introduction

Coenzyme Q10 (CoQ10) is a lipid soluable benzoquinone (dimethoxy-5-methyl-6 deca pregnyl benzoquinone) (1,2). It was first isolated from the beef heart in 1957 (3). The oxidized form of CoQ10 is defined as ubiquinone, and the reduced form of ubiquinol (4). It is necessary to convert CoQ10 from oxidized form to reduced form to use it bioactively (5). Coenzyme Q10 has a similar structure with vitamin K. However, it isn`t defined as vitamin because of its de novo synthesis. It consists of hydro-benzoic acid derived from para-tyrosine structure, 10 isoprenyl units from (6). Coenzyme Q10 has functions in production of adenosine triphosphate in the cell membranes of the respiratory chain in mitochondria (7). It is involved in mitochondria for the electron transportation with benzoquinone ring (8). CoQ10 exist in golgi, lysosomes and cell membrane as well as mitochondria. It is responsible for the phosphorylation, however it acts as an antioxidant in the cell membrane (9). Coenzyme Q10 protects membrane phospholipids, mitochondrial membrane proteins, mitochondrial DNA and low density lipoproteins (LDL) from oxidative damage that give intracellular antioxidant properties (1). In particular, ubiquinone plays role in the regeneration of other antioxidants (tocopherol, ascorbate) (10). In addition, its importance has been reported to act on genes through gene transcription in recent years (9). Mitochondrial transcription factors have direct impact on the various genes. Coenzyme Q10 that has severals roles in this system, also effects gene expression (11). Coenzyme Q10 is synthesized in the tissues from farnesyl diphosphate and tyrosine and it is also obtaned with dietary intake (1,12). Heart, liver, kidney and pancreas have the higher levels of CoQ10 (10). After the age of 20, CoQ10 production decreases (13). There are several factors effecting the synthesis of CoQ10 except age in the body. Its levels may change during cancer, cardiovascular disease (CVD) and degenerative disease (6). Meat, milk, fish are the dietary sources of CoQ10 (1). Fats and seeds also include lower amount of CoQ10 (1,6). Dietary CoQ10 is 25% of the total CoQ10 (3).

Dietary CQ10 is absorbed in the small intestine, it is distributed to tissues after blood and lymph. Diet, dosage, lipoproteins may effect the bioavailability of CoQ10. Normal serum levels of CoQ10 is between 0.40-1.91 µmol/L (0.34-1.65 µg/mL) (14). Serum CoQ10 levels may decrease according to autosomal recessive mutations, oxidative stress due to aging, carcinogenesis, statin therapy, diabetes, and CVD (6,14).

2. Coenzyme Q10 metabolism

Coenzyme Q10 has low bioavailability due to its high molecul and large molecular weight (836.36 Da) and low solubility in water (5). Ubiquinol is the most common and active form of CoQ10. Ubiquinone is reduced to ubiquinol in enterocytes. Coenzyme Q10 is absorbed with lipids similar to vitamin E (2). For these reason, the absence of lipids in diet is important (15). It is transported from the epithelium and continues through passive transport (2). Its distribution to tissues happens with chylomicrons through the lymphatic system (15).

It is expressed that there is no spresific areas in the gut for the absorption of CoQ10 (2). However, it is also stated that the amount in the duedonum may be higher (16). Coenzyme Q10 is in the Class II drugs due to its low solubility and high permeability (17).

3. Coenzyme Q10 and oxidative stress

Oxidative stress is a process that the antioxidant defense system can´t response the increase in free radicals (18). Electron transport system including in CoQ10 in energy metabolism, is closely related to production of radical species (19). Electron transport system consists of 5 complexes. Complex I, is called as ubiquinone NADH dehydrogenase, transport of the electrons from ubiquinone to oxidized CoQ10 at this stage. In Complex II, succinate oxidized tomalat oxide via succinate dehydrogenase and electrons trasport to ubiquinone. In Complex I and II, ubiquinonetakes electrons, reduce to ubiquinol and electrons transport to Complex III. In Complex IV, H_2O and O_2 and than ATP are produced (20). Possible increase in the production of free radicals may cause degenerations in the metabolism of lipid, protein, and DNA. In the assesment of oxidative stress, it is necessary to evaluate antioxidan capasity as well as oxidative stress (18).

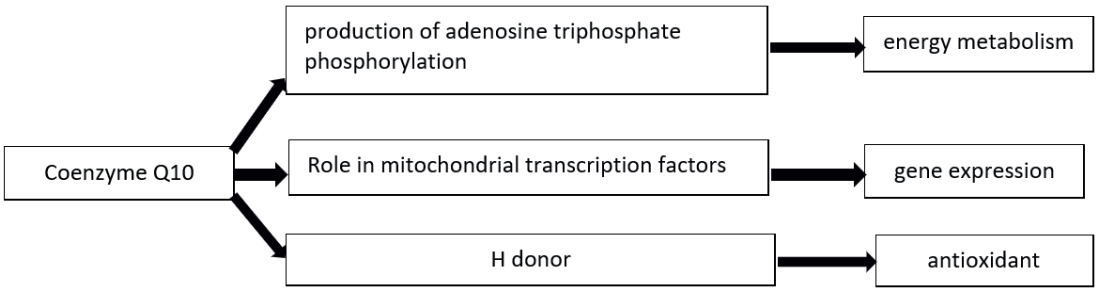

Figure 1. Possible benefits of CoQ10

Antioxidant capasity of CoQ10 is the most widely discussed topic to explain the relationship between CoQ10 and disease (7,21). Coenzyme Q10 is known as an antioxidant due to its protective effects on membrane lipids' protein, LDL from oxidative stress (22). Ubiquinol takes 1 or 2 electron easily and neutrelize the free radicals (20). Ubiquinol, is the only soluable antioxidant in mamalians. Besides, it is a H donor for other antioxidants. In this way it plays an important role to prevent hydroperoxidase lipid-mediated DNA and protein damage (23). In a study, CoQ10 supplementation (150 mg/gün) decreased interleukin-6 (IL-6) and oxidative stress in atherosclerosis patients (14).

4. Coenzyme Q10 and diseases

There are many studies investigating the relationship between CoQ10 and several disease, and health problems in diabetes, cancer, migraine and infertility (10,24-26).

4.1. Coenzyme Q10 and cardiovascular disease

Cardiovascular disease is a cause of death (27). Oxidative stress and impaired mitochondrial function may be associated with CVD (9). Mitochondria constitute 30% of the volume of cell in myocytes, and is responsinle for 90% of the energy production. Production of reactive oxygen species reach the higher levels in mitochondria (28).

The renin angiotensin system (RAAS) may be related to myocardial structure and function disorders. Increase in reactive oxygen species cause activation of p38 mitogen-activated protein kinase (MAPK) and c-Jun-N-terminal kinase (JNK) via apoptosis signal regulating kinase-1. In addition, cytokines may cause hypertrophy development with the increased oxidative stress (9,13). In particular, increase in the cytosolic and mitochondrial reactive oxygen species may cause mitochondrial dysfunction and cell death in heart failure (13). Coenzyme Q10 levels decrease in these patients. There are also studies reported low levels of CoQ10 in patients with CVD such as cardiomyopathy and ischemic heart disease. Coenzyme Q10 has positive effects on CVD by producing energy, preventing LDL oxidation, improving muscle contractility (6). In a study, patients with coronary artery disease recevied 150 mg/d CoQ10 supplement. It was found that malondialdehyde (MDA) was decreased which is an oxidative stress biomarker, antioxidant capacity biomarkers (superoxide dismutase (SOD) and catalase (CAT)) were increased (1). Superoxide dismutase and catalase play role in the protection of cell from the harmful effects of superoxide anion and H_2O_2. In this study, CoQ10 supplementation protected from oxidative stress by increasing levels of these enyzimes. In a meta-analyses study that included 13 studies investigating the relationship between CoQ10 (CoQ10 supplementation dosages between 50-300 mg/d) and chronic heart failure, it was reported that CoQ10 supplementation decrease ejection fraction by 3.7% (29). Endothelial dysfunction is a risk factor for the development of atherosclerosis and CVD. The relationship of CoQ10 and endothelial dysfunction is related to its effects to increase the antioxidant capacity and endothelial NO bioavailability. In a meta-analyses study, CoQ10 supplementation had positive effects on endothelial dysfunction (flow-dependent-endothelial-mediated dilation) (12).

Hyperlipidemia is a major risk factor for CVD and 3-hydroxy-3-methyl-glutaryl coenzyme A (HMG CoA) is used in its treatment. Statins decrease the cholesterol synthesis with the downstream of mevalonate which is a pre-cursor of CoQ10. For this reason, statins decrease the CoQ10 level as well as cholesterol (22). On the other hand, CoQ10 deficiency due to statin treatment poses risk for myopathy. In a study, rats received statin therapy, CoQ10 supplementation (30, 90 and 270 mg/kg) prevented the negative effects of statin (30). However, in another study patients with statin myalgia, no association was found of CoQ10 supplementation (600 mg/d) (31).

4.2. Coenzyme Q10 and hypertension

It is widely known the effects of NO and reactive radicals on hypertension. NO has blood pressure lowering effects, however it may increase the reactive oxygen sprecies (9). In some hypertensive patients, production of free oxygen species increase and activate NO (14). In these patients, CoQ10 levels tend to be low (9). For this reason, CoQ10 supplementation may protect NO and effect blood pressure positively (14). Another mechanism about this effect is that CoQ10 prevents platelet aggregation by stimulating production of prostacyclins (6). In a meta analyses, it was reported that CoQ10 lower blood pressure by 17 mmHg (32). Besides, it was also stated that CoQ10 may decrease the number of antihypertensive drugs (6).

4.3. Coenzyme Q10 and diabetes

Diabetes is one of the important chronic disease with is increasing prevelance. There are several reason in the progress of diabetic complications (8). One of these reasons, oxidative stress, involves in the pathogenesis of diabetes and poses risk for CVD (33). In type II diabetic patients, reactive species levels increase, however CoQ10 levels both decrease and increase (34,35). Hyperglycemia induced oxidative stress one of the characteristic properties of diabetes and is a risk factor for diabetic complications (8, 20). Ateş et al. found that MDA levels incerased, serum CoQ10 levels decreased in patients with proliferative diabetic retinopathy (34). Mitochondrial dysfunction is an another mechanism that occurs with obesity and diabetes. Obesity induced ongoing transition of food

substrates to mitochondrial causes an increase in the amount of free fatty acids. This condition, may be responsible for the insulin resistance as well as increasing reactive oxygen species. These complications compansate for the pathogenesis of type II diabetes (20). In diabetic patients, glycerol-3-phosphate dehydrogenase (G3PD) enzyme damages which is in charge of the electron transport. It is known theoretically that CoQ10 increases G3PD activation in islets (10). In a study, diabetic patients recieved CoQ10 supplementation for 12 weeks, antioxidant capacity incerased, HbA1c and lipid profiles improved (35). In a meta analyses study, results showed that CoQ10 supplementation was not related with diabetes however, effective to decrease trigliserit levels (10). In another study, the form of CoQ10 was assesed and rats were divided into 2 groups, one group was taken ubiquinone-10 and the other group as taken ubiquinol-10. Ubiquinone-10 group had lower levels of serum blood pressure and glucose, ubiquinol-10 groups´ serum blood glucose improved only 2th week of the study. MDA levels decreased in both 2 groups (8).

The form of CoQ10 and age are effective in activation in CoQ10. After the age of 40, deteriorations may occur in convertion of ubiquinone to ubiquinol. In this case, CoQ10 supplementation becomes an important approach (20).

4.4. Coenzyme Q10 and neurological-psychiatric diseases

Oxidative stress involves in the pathogenesis of disease such as Parkinson, Huntington´s disease, bipolar disorder and Alzheimer (36). In particular, mitochondrial dysfunction induced oxidative and nitrosative stress may effect progress of these disease (11). Coenzyme Q10 protects from oxidative stress with its potential antioxidant capacity (36,37). Patients who take CoQ10 supplementation have positive developments on cognitive capacity (38).

Parkinson disease is a common neurological disease occuring with the environmental and genetic factors. Oxidative stress, microglial activation, neuroinflammation, and mitochondrial dysfunction are possible pathophysiological pathways of the disease (39). Coenzyme Q10 has protective properties for parkinson disease (36). In these patients, CoQ10 levels are lower than healthy subjects (40,41). In a study, it was found that CoQ10 supplementation with creatinin delayed the deterioration in cognitive function (39).

Huntington´s disease is an autosomal inherited disease which is characterized by dystonia, neuropsychiatric symptoms and cognitive functional decline. In studies to clarify the spesific dosage for Huntington´s disease, 600, 1200, 2400 ve 2600 mg/d CoQ10 were given to patients. 21 patients of 33 received the maximum dosage 3600 mg/d. Gastrointestinal side effects of CoQ10 occured after 1200 mg/d, and there was no side effects exceed 2400 mg/d. It was reported that 2400 mg/d was safe and tolerable dosage for Huntington´s disease (42).

Bipolar disorder is a psychiatric disorder that the mood can´t be controlled. In these patients, mood ranged from mania, hypomania and depression (43). In a study with geriatric bipolar patients, CoQ10 supplementation (720 mg/d -4 weeks, 1040 mg/d- 8 weeks) was found to be benefical on depressive state. Changes in the activity of CoQ10 due to aging process may be effected positively with the supplementation (37).

Alzheimer disease is a neurological disease characterized by oxidative stress. Coenzyme Q10 is expressed to have positive effects on the progress of disease by decreasing oxidative stress (14). In a study, amiloid plaques were reduced in rats that took CoQ10 (36). Similary, there were studies about CoQ10 neuroprotective activity of CoQ10 (44,45). However, CoQ10 is stated that it may play an active role in the prevention of these diseases rather than treatment (46).

Migraine prevalence has reached 303 million, and it has higher rate in women (70%) than men (30%). Oxidative stress involved in the progression of disease (47). Coenzyme Q10 has been associated with migraine, its one of the acute nutraceuticals in the prophylactic treatment of migraine (48,49). In a study, migraine attacks decreased in patients who received 200 mg/d supplementation (50). In a similar study, CoQ10 supplementation reduced hedache in 50% of patients, vomiting in 47.6% patients (51). American Academy of Neurology, reported that CoQ10 had postive effects (C level evidence) to prevent migraine (52). Canadian Headache Society, CoQ10 admit effects of CoQ10 in migraine as low level evidence, however strongly recommends 300 mg/d CoQ10 supplementation in these patients (53). Besides, due to migraine prevelance is high in children (54), it is stated that CoQ10 supplementation may be beneficial in pediatric population (25). Spinocerebellar ataxia is an autosomal dominant inherited, cerebellum degenerative disease. In a study, CoQ10 supplementation (600 mg) improved scores of Scale for the Assessment and Rating of Ataxia (SARA) (55).

4.5. Coenzyme Q10 and fibromyalgia

Fibromyalgia is mostly seen in females with its increasing prevelance (56). American College of Rheumatology published diagnostic criteria in (57), and updated this criteria in 2010 (58). According to this, fibromyalgia is characterized by widespread pain and pain after digital palpation. Different symptoms such as sleep disorders, and depression are also involved in the progress of disease (59).

Oxidative stress may involve in the pathogenesis of fibromyalgia as well as other disease (60,61). In a study, CoQ10 was found to be lower in the fibromyalgia patients (62). This suggests that CoQ10 supplements may be positive in patients with fibromyalgia. In a study, CoQ10 supplementation (100 mg/ dubiquinol) had no effects on oxidative stress in children, however had positive effects on fatigue (61). In another study, depression scores were found to be higher in fibromyalgia patients and CoQ10 supplementation improved the scores (63).

4.6. Coenzyme Q10 and cancer

Coenzyme Q10 is an important component due to its effects in energy metabolism and apoptosis. Increased oxidative stress, decreased antioxidant capacity in cancer patients may be associated with CoQ10. Besides, increased oxidative stress may change the activity of chemotherapeutic drugs (6). Coenzyme Q10 intake may be beneficial in disease response by improving immun system (14). It is known that cancer patients have lower levels of CoQ10 (64). In a study, breast cancer patients´ CoQ10 levels were lower (65). In another study, CoQ10 was also found to be lower in patients with melanoma. In particular, patients with the metastasis had the lowest levels of CoQ10 (66). In a rat study, CoQ10 supplementation supressed lipid peroxidation, prevented the decrease in activity of glutathione and superoxide dismutase, decreased the levels of TNF-α ve NO (67). However in another study, CoQ10 levels and breast cancer showed a positive correlation (68). There exist limited number of studies between cancer and CoQ10 to compare the results.

4.7. Coenzyme Q10 and physical activity

Physical activity has important effects on health by influencing physiological and psychological parameters (69, 70). There are several studies on coenzyme Q10 and exercise (70, 71). In a study, CoQ10 supplementation had positive effects on exercise-induced injury of the muscle (72). It was stated in another study that participants with higher physical activity had lower levels of CoQ10 (70). Coenzyme Q10 is pointed out with its benefits on physical activity via oxidative stress mechanisms (72).

4.8. Reproductive Endocrinology

Lee et al. demonstrate that Coenzyme Q10 stimulates differentiation of ovarian surface epithelium-derived ovarian stem cells (73). The addition of CoQ10 and L-carnitine significantly reduced the number of reactive oxygen species in semen (74). The use of CoQ10 in PCOS patients significantly reduces serum fasting plasma glucose and HOMA-IR (75). Age-related decline in oocyte quality and quantity can be reversed with CoQ10 administration. Decreased expression of Pdss2 and Coq6, the enzymes responsible for CoQ production, was seen in oocytes of aged females in both mice and humans. It has been reported that the age-related decline in oocyte quality and quantity can be reversed with CoQ10 administration. It leads to a decrease in ovarian reserve in animals with oocyte-specific Pdss2 deficiency. This is reported to cause premature ovarian failure, which can be prevented by maternal dietary administration of CoQ10 (76). Healthy eating patterns are clearly associated with a lower risk of abnormalities in parameters such as better sperm quality and sperm count, sperm concentration and motility, and lower sperm DNA fragmentation. Minerals such as zinc and selenium, omega-3 fatty acids and antioxidant vitamins play a role in minimizing oxidative stress and inflammation. The inclusion of carnitine supplements and coenzyme Q10 in therapeutic interventions also looks promising. Therefore, a varied and balanced diet based on the Mediterranean diet is recommended (77). It was determined that infertile men aged 20-40 who took 150 mg/ day ubiquinol supplement for 6 months increased the sperm count by approximately 53% and sperm motility by 26% (78). It has been found that supplementing men with 200-300 mg of ubiquinol for 26 weeks improves sperm quality, density, motility and morphology. In addition, it was determined that serum follicle-stimulating hormone levels decreased and increased inhibin B levels (79). In another study, it was found that giving 600 mg of CoQ10 for 12 months increased sperm quality and additionally pregnancy rates (80).

Several placebo-controlled studies have shown that sperm motility is increased by approximately 4-6% with CoQ10 supplementation (81). In a study on elderly animals, it is reported that treatment with compounds such as CoQ10 can improve reproductive performance by protecting against oxidative stress (82). The follicular environment of patients with endometriosis severely affects the maturation of oocytes. It is emphasized that in vitro maturation in the presence of coenzyme Q10 is important for the protection of oocytes exposed to such follicular environments (83). CoQ10 supplementation during in vitro maturation is said to increase oocyte maturation rates and reduce post-meiotic aneuploidies for older women (84).

It is reported that combinations of selenium, coenzyme Q10 and L-carnitine + acetyl-L-carnitine, folic acid + zinc and EPA + DHA are beneficial in the treatment of male infertility. However, better- designed clinical studies are needed to generalize the treatment of infertility (85). While zinc is seen as the most common and important component of nutritional supplements, it is followed by selenium, arginine, coenzyme Q, and folic acid. Although the importance of some nutritional supplements in improving sperm parameters has been reported, the actual effectiveness of these supplements is still debated (86). Since

CoQ10 is synthesized in the body, the amount to be taken with the diet is not clear. However, the optimal amount of intake has been determined as 200-300 g per day (87). In addition, it has been reported that plasma samples of adolescent PCOS patients have lower amounts of Gamma-Tocopherol and higher amounts of CoQ9, a product of deficient CoQ10 biosynthesis (88).

5. Coenzyme Q10 deficiency

Several enzymes play role in the synthesis of CoQ10. Important parf of the synthesis process is in mevalonate pathway in citosol with the production of polyisopren ring. 4-hydroxybenzoate is the precursor in qionon group. This structre becomes complex with the enzymes. There are 13 genes in the CoQ10 synthesis (89). Coenzyme Q10 deficiency is a heterogen mithocondrial disease (90). This deficiency was first decribed in 1989 (91). Coenzyme Q10 has a large clinical fenotype. Five basic fenotypes are defined as encephalon myopathy, cerebellar ataxia, infantile multisystem form, nephropathy and isolated myopathy (92). Assesment of genes that involved in the CoQ10 biosynthesis is necessary to detect the genetical defects. There are 8 genes associated with this deficiency for now (89). Especially, mutations in PDSS1, PDSS2, COQ2, COQ4, COQ6, ADCK3, ADCK4 and COQ9 may be related to CoQ10 deficiency. These patients usully have positive responses to the supplementation (93). However, there is no spesific recommendation due to limited number of controlled trials, differences in the bio-availablity of CoQ10 and no data of the dosage (89).

Coenzyme Q10 deficiency may occur in patients with mitochondrial disorders. In a study, it was found that patients with mitochondrial depletion had CoQ10 deficiency (94). In another study, no response was obtained to supplementation (95). It is important to define CoQ10 deficiency in an early stage for the disease progression (94). Coenzyme Q10 may also occur as secondary disease due to ataxia and metilmalonic asiduri (14, 93). Lactic asidosis, stroke, neurodegenerative diseases are the other reasons for secondary CoQ10 deficiency (23). Yubero et al. (2014) stated that GLUT1 deficiency is a CoQ10 deficiency in their case (96).

In healthy subjects CoQ10 deficinecy is rarely with the sufficient endogen synthesis. However, supplementation is stated as benefical to provide physiological needs in patients with deficiency due to primary or secondary reasons (15).

6. Dietary and supplementary intake of coenzyme Q10

Meat and fish are the richest sources of CoQ10 due to their muscle and mitochondria content. Fat, seed, vegetable and fruits also include a smaller amount of it. Dietary intake is between (ubiquinone) 3-6 mg (23). 25% of total CoQ10 comes from dietary intake (3). Absorbtion of dietary intake of CoQ10 is low due to its large molecule size and more than 60% of it excretes with feces (5). Coenzyme Q10 absorbtion is similar with lipids such as vitamin E (97). Absence of lipids affect the absorbtion of CoQ10 (3). Cooking methods also affect the CoQ10 content. In a study, different methods (cooking, frying and in vitro digestion) were assesed in beef meat and higher CoQ10 content was found in boiled meat (98).

Coenzyme Q10 supplementation has became widespread with its potential benefits (99). CoQ10 supplement (ubiquinol) are usually obtained from yeast fermentation (5). This form of CoQ10 is similar with the CoQ10 in tissues. Otherwise, extraction from animal tissues and chemical sythesis are other wats to produce CoQ10 (97). Intake of CoQ10 with food increase the absorbtion (14).

There are several approaches to incerase the bioavailability of CoQ10. Production of $CoQ10H_2$ is one of these. This formulation is more hydrophilic than CoQ10. Coenzyme Q10 supplements differ between 20-400 mg (23). Fortified food with CoQ10 is an another approach. Fruit products, dairy are some of the fortified food. The form of CoQ10 in these food is stated as stable. Form and dosage of supplementation become important due to increasing usage of it. Studies provide information for different dosages 50-3000 mg (1,22). Coenzyme Q10 is reported as

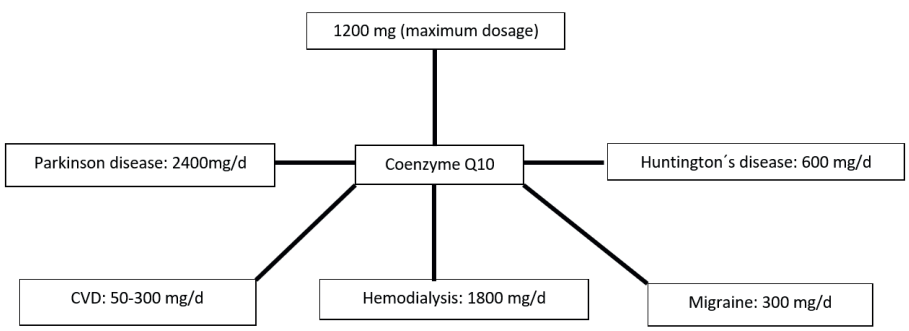

Figure 2. CoQ10 supplementation dosages according to study results

tolarable even in high dosages. However, gastrointestinal side effets (abdominal discomfort, vomiting, nausea, diarrhea, anorexia) may ocur (14). For this reason, it is necessary to clarify a spesific dosage (98). Maximum dosage is reported for 1200 mg/d for CoQ10 (84). Recommended dosage differs according to disease (42). For congestive heart failure 50-300 mg/d, for mitochondrial disease and muscle dystrophy 100-200 mg/d, for Parkinson disease 2400 mg/d, for Huntington's disease 600 mg/d are the dosages that given in the studies as safe (10). In a study, 1800 mg/d was reported as safe dosage for hemodialysis patients (90).

The safety of the supplements is another subject that focused on as well as the dosage. In a study, 58 supplements from European countries assesed with HPLC, it was found that 1 to 3 had less CoQ10 content than 70% in tha label. This suggests that obligatory assesments are necessary to provide safe products for consumers.

7. Conclusion

CoQ10 is a lipid soluable component from the benzoquinones. Studies focus on its possible roles in energy metabolism, antioxidant capacity, and protective effects on cell membrane. Particularly, several studies pointed out the relationship between disease such as CVD, diabetes, and neurological disease. In these studies different dosages were given to patients. The dosage for the CVD differs between 50-300 mg/d, for neurological diseases 100-3000 mg/d, for migraine patients 300 mg/d is recommended. High intakes of CoQ10 may cause gastrointestinal side effects, nevertheless it is stated as tolerable. However, there exist a maximum intake for CoQ10 as 1200 mg/d and no other side effects are reported except gastrointestinal side effects. There are many studies about CoQ10, however some of them have contradictory results. In addition, the differences between dosages and forms also make it harder to compare the results. For this reason, there need to be longitidunal studies to show the long term effects of supplementation and spesific dosage recommendations for different disease.

Author contribution

Study conception and design: KE, SM, NTS, and YEÜ; data collection: KE, SM, and NTS; analysis and interpretation of results: KE, SM, NTS, and YEÜ; draft manuscript preparation: KE, SM, NTS, and YEÜ. All authors reviewed the results and approved the final version of the manuscript.

Funding

The authors declare that the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

Yazar katkısı

Araştırma fikri ve tasarımı: KE, SM, NTS ve YEÜ; veri toplama: KE, SM ve NTS; sonuçların analizi ve yorumlanması: KE, SM, NTS ve YEÜ; araştırma metnini hazırlama: KE, SM, NTS ve YEÜ. Tüm yazarlar araştırma sonuçlarını gözden geçirdi ve araştırmanın son halini onayladı.

Finansal destek

Yazarlar araştırma için finansal bir destek almadıklarını beyan etmiştir.

Çıkar çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını beyan etmiştir.

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