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The Role of Coenzyme Q_{10} Supplementation as a Potential Adjunct in the Treatment of Autoimmune Diseases

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Abstract:
Autoimmune diseases are a heterogeneous group of afflictions whose etiopathogenesis is still incompletely understood. There is a great need to search for new treatment methods because of the difficulty of treatment, the numerous side effects of pharmacotherapy and the life-threatening complications associated with these diseases. The discovered role of mitochondrial dysfunction in the pathogenesis of these conditions and the associated oxidative stress, but also the contribution of coenzyme Q10 to normal mitochondrial function, provided the impetus for research into the use of coenzyme Q10 supplementation as an adjunctive therapy for autoimmune diseases. This review article summarises the role of coenzyme Q_{10} supplementation in the regulation of impaired processes involved in the pathogenesis of

autoimmune diseases and focuses on the potential benefits of coenzyme Q_{10} supplementation for patients with autoimmune diseases.
Key words: autoimmune diseases, Coenzyme Q_{10}, Antiphospholipid Syndrome, Systemic Lupus Erythematosus, Fibromyalgia, Rheumatoid Arthritis, Multiple Sclerosis, Type I Diabetes, Graves' Disease, Ulcerative Colitis, Psoriasis

Purpose of research:
This study includes an in-depth review of the scientific literature on mitochondrial disorders and associated oxidative stress in the pathogenesis of autoimmune diseases as well as the role of coenzyme Q_{10} in modulating the disrupted processes and the potential therapeutic benefits of supplementation with this antioxidant. A literature search was conducted using PubMed, focusing on peer-reviewed articles, clinical trials, and meta-analyses related to mitochondrial disorders and oxidative stress in autoimmune diseases and also the role and use of coenzyme Q_{10} in these conditions.
Results and conclusions:
Scientific studies have indicated that mitochondrial dysfunction, oxidative stress and inflammation are involved in the development of autoimmune diseases. Therefore, the role and potential benefits of coenzyme Q_{10} supplementation have begun to be considered. Preclinical as well as clinical studies that have been conducted to date indicate that coenzyme Q_{10} reduces oxidative stress and associated free radicals, and may also reduce inflammation, which has often translated into improvements in the clinical manifestations of autoimmune diseases. However, there is a further need for clinical trials on a larger patient population to fully understand the mechanisms of action of coenzyme Q_{10} and to determine the optimal dose of supplementation, but also to rule out the occurrence of severe side effects.

1. Introduction

Coenzyme Q_{10}, otherwise known as ubiquinone, is an organic compound from the quinone group, acting as an electron and proton transporter as part of the mitochondrial respiratory chain. In addition, it is involved in fatty acid β-oxidation, amino acid catabolism, pyrimidine biosynthesis. In a partially reduced form, it is found in all cell membranes, as well as in lipoproteins and serum blood [1]. In addition, ubiquinone has been found to affect gene expression, thereby influencing overall tissue metabolism [2]. Causes of reduced levels of coenzyme Q_{10} include: nutritional deficiencies (especially Vit B6 deficiency), genetic or acquired disorders of ubiquinone synthesis and utilisation, or increased tissue demand. In turn, ubiquinone deficiency may be associated with symptoms including: cerebellar ataxia, encephalopathy, isolated myopathy or Leigh syndrome [3,4]. It should not be forgotten that coenzyme Q_{10} levels decline with age, which is associated with some of the symptoms of ageing [5]. Ubiquinone has become the subject of numerous scientific research on its use in not only anti-aging therapy, but also in conditions such as neurodegenerative disorders, diabetes, cancer or autoimmune diseases due to its antioxidant properties [6].

2. Coenzyme Q_{10} and Autoimmune Diseases

Autoimmune diseases (AIDs) are a heterogeneous group of conditions where primary or acquired dysfunctions of the immune system result in a reaction against the body's own antigens (autoantigens). The etiopathogenesis of this group of diseases is not fully understood, and causes include: genetic disorders, environmental factors such as nicotinism, diet, exposure to infection or microbiota disorder [7]. It is estimated that 3-5% of the world's population struggles with an autoimmune disease. In addition, these conditions have a significant impact on morbidity and mortality rates and are sometimes extremely difficult to treat, making them a significant public health problem [8]. Current therapies are primarily based on immunosuppressive treatment, mainly with corticosteroids, which unfortunately is associated with a number of side effects that include increased risk of cardiovascular disease, diabetes, gastrointestinal bleeding, psychiatric disorders, infections and ophthalmic disorders [9]. There is therefore an obvious need to develop new and alternative treatments for autoimmune diseases. The potential role of coenzyme Q_{10} in the treatment of autoimmune diseases has begun to be explored due to the role of mitochondrial dysfunction in the inflammatory process [10]. It has been proved that patients with Sjogren's syndrome have changes in the ultrastructure of the mitochondria of salivary gland cells [11]. In addition, it has been noted that exposure of mitochondrial elements (especially mtDNA) enhances type 1 interferon production which promotes inflammation, which plays an important role in autoimmune diseases [12]. It is also important to note that coenzyme Q_{10} has low toxicity and no significant side effects have been found, making it appear promising for the treatment of autoimmune diseases [13].

3. Coenzyme Q_{10} and Antiphospholipid Syndrome (APS)

Antiphospholipid syndrome (APS) is a systemic connective tissue disease associated with the presence of antiphospholipid antibodies such as anti-β-2-glycoprotein 1 (anti-β2GPI), lupus anticoagulant (LA), and anticardiolipin antibodies (APLs). It manifests as vascular thrombosis and/or obstetric complications [14]. We can distinguish between primary APS and secondary APS, which is associated with infection, cancer or other immune-mediated diseases [15]. Mitochondrial dysfunction and oxidative stress have also been implicated in the pathogenesis of APS [16]. The treatment of antiphospholipid syndrome is mainly based on anticoagulant therapy, including vitamin K antagonists (VKA) and acetylsalicylic acid (ASA), which unfortunately is accompanied by side effects such as an increased risk of bleeding. In addition, VKA therapy is associated with frequent monitoring of INR levels and patients must be under

constant medical supervision [17]. Studies have begun to investigate the potential use of coenzyme Q_{10} as an alternative adjunctive treatment aid for this condition due to the potential involvement of oxidative stress in the pathomechanism of antiphospholipid syndrome. Perez-Sanchez et al. in prospective, randomized, placebo-controlled trial of ubiquinol supplementation at a dose of 200 mg/d for 1 month in patients with APS, found improvements in endothelial function and also reductions in inflammatory parameters and expression of pro-thrombotic mediators. An important aspect is that no significant side effects were noted during the study, highlighting the promising effect of coenzyme Q_{10} supplementation in addition to standard treatment [18]. This research study provides promising results regarding the potential benefits of coenzyme Q_{10} supplementation in the APS patient population. However, there is still a great need for further clinical studies, on a larger number of patients struggling with this disease, which will fully elucidate the mechanisms of action of coenzyme Q_{10} and also exclude the occurrence of severe side effects.

4. Coenzyme Q_{10} and Rheumatoid Arthritis (RA)

Rheumatoid arthritis (RA) is a chronic connective tissue disease that involves progressive, symmetrical inflammation of the joints, which can eventually lead to destruction of joint cartilage and bone and thus disability. The prevalence of RA in the general population varies between 0.4%-1.3% (with women being more commonly affected), making it one of the most common rheumatological diseases [19]. The pathomechanism of RA is not fully understood. It is based on an abnormal immune response of both cellular and humoral types, leading to the production of autoantibodies such as rheumatoid factor (RF) or anti-cyclic citrullinated peptide antibody (anti-CCP), which damage articular cartilage. Predisposing factors include genetic disorders or environmental factors such as nicotinism or infectious agents [20]. Furthermore, the structural elements of mitochondria may act as a stimulus for immune receptors and thus promote the development of inflammation. In addition, mitochondria are a source of reactive oxygen species, which promote the production of cytokines responsible for the symptoms found in RA [21]. Current therapy of rheumatoid inflammation is based on the use of disease-modifying drugs, including methotrexate, leflunomide and anti-TNF-α and also non-steroidal anti-inflammatory drugs (NSAIDs), glucocorticosteroids, surgery and supportive physiotherapy [22]. The treatment of rheumatoid arthritis is a challenge for both doctors and patients, because it is a long-term process, often unsuccessful, and is also associated with numerous sides. There is a constant need to look for new treatments due to the prevalence of RA in the population, the complications of this disease and also the therapeutic

difficulties. Mitochondrial disorders may represent a promising therapeutic target for rheumatoid arthritis. The results of preclinical studies conducted in animal models of RA have shown a positive effect of coenzyme Q_{10} on reducing clinical symptoms as well as inflammation associated with this systemic connective tissue disease [23]. In addition, Bauerova et al. in their study showed that the addition of coenzyme Q_{10} to methotrexate, the most commonly chosen disease-modifying drug, inhibited the progression of RA in rats more than MTX supply alone [24]. Abdollahzad et al. in double-blind, randomized controlled clinical trial that included 44 RA patients supplemented with coenzyme Q_{10} at a dose of 100mg/day (n=22) or placebo (n=22) for a period of 2 months, showed a reduction in inflammatory markers (TNF-α, malondialdehyde, Il-6) and also oxidative stress levels [25]. In addition, Nachvak et al. in a randomised controlled trial involving 54 RA patients taking coenzyme Q_{10} at 100 mg/d (n=27) or placebo (n=27) for 2 months, found a significant decrease in serum metalloproteinase (MMP-1) levels, a reduction in the number of swollen and painful joints and a decrease in disease activity as measured by the Disease Activity Scale (DAS-28) and Visual Analogue Scale (VAS) in patients taking coenzyme Q_{10} [26]. These studies confirm the promising aspect of using coenzyme Q_{10} supplementation to reduce inflammation in RA patients and control symptoms and disease activity. However, additional clinical trials involving larger numbers of patients are needed to confirm the results of previous studies and to determine the safety profile of coenzyme Q_{10} supplementation in this patient group.

5. Coenzyme Q_{10} and Systemic Lupus Erythematosus (SLE)

Systemic lupus erythematosus (SLE) is a heterogeneous, chronic autoimmune disease that leads to dysfunction and damage of multiple tissues and organs. The incidence rate of this disease is 5.6 per 100,000 person-years in Caucasian and African-American populations, with women being more commonly affected [27]. Disorders of innate and acquired immunity that lead to the production of autoantibodies that attack and damage the body's own cells play a significant role in the pathogenesis of systemic lupus erythematosus [28]. Current therapy for SLE focuses on achieving disease remission and preventing organ damage. It is based on the use of immunosuppressive drugs such as antimalarials (hydroxychloroquine), glucocorticosteroids, azathioprine, mycophenolate mofetil. In more severe cases, cyclophosphamide, belimumab, rituximab may be considered [29]. Treatment is long-lasting and subject to the risk of side effects. Another important aspect is that SLE therapy is often ineffective, making it necessary to look for new treatments. In recent years, attention has been drawn to the potential role of mitochondria in the pathogenesis of SLE. Damage to these

organelles leads to the production of autoantibodies such as anti-mtDNA, anti-mitochondrial, anti-whole mitochondrial, mitochondrial-RNA which promotes organ damage. Furthermore, mitochondrial dysfunction is associated with the overproduction of free radicals that activate inflammation, which also contributes to the development of SLE [30]. These findings have helped to draw attention to the potential use of coenzyme Q_{10} in the treatment of this heterogeneous systemic connective tissue disease. Blanco et al. in preclinical study, which involved the administration of Idebenone (a synthetic quinone analogue of coenzyme Q_{10}) at a dose of 1g/kg to a lupus-prone mouse model for 8 weeks, observed reduced inflammation, improved renal function and also reduced mortality [31]. This research highlights the promising aspect of coenzyme Q_{10} supplementation in the treatment of systemic lupus erythematosus. Nevertheless, there is a need for additional clinical trials with people suffering from this disease to confirm the beneficial role and exclude possible side effects of coenzyme Q_{10} supplementation.

6. Coenzyme Q_{10} and Fibromyalgia

Fibromyalgia is a condition characterised by chronic widespread musculoskeletal pain, which may be accompanied by mood and sleep disturbances, fatigue and bowel disorders. The values of fibromyalgia prevalence in the general population between 0.2% and 6.6%, which represents a significant population problem, especially as it is still a poorly understood and difficult to diagnose condition [32]. The causes of this condition are attributed to neurotransmitter disorders, i.e.: an increase in glutamate and substance P and a decrease in serotonin and norepinephrine at the level of descending antinociceptive pathways, as well as disturbances in dopamine and endogenous brain opioids [33]. Recently, it has also been noted that fibromyalgia sufferers have a deficiency of tissue coenzyme Q_{10} and mitochondrial dysfunction, leading to increased oxidative stress and inflammation [34]. Cordero et al. in a randomised, double-blind, placebo-controlled study evaluating the clinical effects of forty days of Q_{10} supplementation (300 mg/day) in 20 patients with fibromyalgia showed a reduction in pain and fatigue, but also a decrease in inflammation [35]. In another study, Cordero et al. showed a correlation between oxidative stress and reduced coenzyme Q_{10} levels and headache severity. Furthermore, they showed that coenzyme Q_{10} supplementation at a dose of 300 mg/d for 3 months significantly reduced pain symptoms in patients with fibromyalgia [36]. This research highlights the promising aspects of coenzyme Q10 supplementation in patients with fibromyalgia. There is therefore a further need for clinical studies on a larger population of patients suffering from this disease, which will fully

elucidate the mechanisms of action of coenzyme Q_{10} and also exclude the possibility of severe side effects.

7. Coenzyme Q_{10} and Multiple Sclerosis (MS)

Multiple sclerosis (MS) is a chronic autoimmune disease that affects the central nervous system, characterised by inflammation and demyelination leading to neuronal damage and gliosis. It most commonly progresses in the form of a flare-up, i.e.: neurological symptoms that persist for at least 24 h and are not associated with fever or other illness [37]. There are approximately 2.8 million people with MS worldwide and the prevalence of multiple sclerosis has increased in recent years, posing a significant public health problem [38]. The etiopathogenesis of this condition is complex and not fully understood. Autoreactive T-lymphocytes are involved in the development of this condition, which promotes the synthesis of antibodies, resulting in the destruction of myelin. Genetic disorders and environmental factors such as vitamin D deficiency, nicotinism or exposure to Epstein-Barr virus predispose to this disease[39]. Therapy for multiple sclerosis is mainly based on immunomodulatory drugs such as interferon beta (IFN-β) or glatimer acetate and also natalizumab and fingolimod, which will reduce the frequency of flares, but also corticosteroids, which are used for exacerbations of the disease [40]. These therapies are associated with side effects which limits their use and, in addition, their therapeutic capacity decreases with the duration of the disease [41]. There is therefore a need to search for new and alternative treatments. Mitochondrial disorders that exacerbate oxidative stress and inflammation have also been found to be involved in the pathogenesis of MS [42]. Coenzyme Q_{10} levels have been shown to be reduced in MS patients [43]. For this reason, researchers have begun to conduct studies on the use of ubiquinone supplementation in the treatment of multiple sclerosis. Preclinical studies have provided promising results. Soleimani et al. in study on an animal model of autoimmune encephalomyelitis in mice, showed that coenzyme Q_{10} administration at a dose of 10mg/kg/day for a period of three weeks significantly reduced inflammatory tumour necrosis factor-alpha (TNF-α) levels in the brain and furthermore observed an improvement in clinical symptoms [44]. Several clinical studies on coenzyme Q_{10} supplementation in MS patients have also shown benefits in terms of reducing oxidative stress and inflammation. Moccia et al. in open-label study involving 60 patients with the relapsing-remitting form of MS treated with IFN -β1α, showed that additional inclusion of coenzyme Q_{10} supplementation for a period of three months at a dose of 200 mg/day, significantly reduced levels of pro-inflammatory cytokines, oxidative stress markers and was also associated with lower scores on the Expanded Disability Status Scale (EDSS), Beck's

Depression Inventory (BDI), Fatigue Severity Scale (FSS) and Visual Analogue Pain Scale (VAS) [45]. In addition, Sanoobar et al. in randomised, double-blind, placebo-controlled clinical study, involving the administration of coenzyme Q_{10} at a dose of 500 mg/day for a period of three months, also showed a significant reduction in blood levels of inflammatory markers such as tumour necrosis factor-alpha (TNF-α) or interleukin-6 (IL-6) [46]. The authors of this studies emphasise that there is a need for further clinical trials with a larger patient population to confirm the beneficial effects of coenzyme Q_{10} and to fully elucidate the mechanism of action of this substance and exclude possible side effects.

8. Coenzyme Q_{10} and Type 1 Diabetes (T1D)

Diabetes mellitus is a group of metabolic disorders of varying etiology and course, the essence of which is hyperglycemia, resulting from a defect in insulin secretion or action. The disease represents a significant public health problem, as 451 million people were reported to have diabetes in 2017 and it is further estimated that this figure could rise to 693 million in 2045 [47]. Type 1 diabetes mellitus is an autoimmune disease in which there is destruction of pancreatic beta cells by circulating antibodies such as: autoantibodies against insulin (IAA), autoantibodies against insulinoma-associated antigen-2 (IA-2), autoantibodies against glutamic acid decarboxylase (GAD), autoantibodies against zinc-transporter 8 (ZnT8), and islet cell antibodies (ICA), resulting in insulin deficiency, hyperglycaemia and complications [48]. Both genetic factors and environmental factors such as viral infections (especially Coxackie B virus), dietary factors (cow's milk, vitamin D3 deficiency, cereals) are involved in the etiopathogenesis of this condition [49]. It has also been noted that oxidative stress and the associated overproduction of free radicals disrupts normal glucose metabolism by damaging pancreatic beta cells, disrupting insulin signal transduction, reducing GLUT-4 gene expression or increasing inflammation [50]. Currently, intensive insulin therapy remains the main treatment for patients with type 1 diabetes, and in a selected patient population: pancreas transplantation or isolated pancreatic islets [51]. There is a great need for further research into new treatments because of the ever-increasing number of new cases of the disease, the risk of serious complications and the limitations of treatment, which include the risk of life-threatening hypoglycemia, but also due to the insufficient number of organs available for transplantation. Research has begun on the use of coenzyme Q_{10} in adjunctive therapy for diabetes or its complications due to the involvement of oxidative stress in the pathogenesis of type 1- diabetes. Preclinical studies have provided promising results. Sourris et al. in a study on the effects of ubiquinone on mitochondrial dysfunction in a mouse model of diabetic

nephropathy, showed that supplementation with coenzyme Q_{10} at a dose of 10 mg/kg/day for 10 weeks led to a reduction in free radicals production in renal mitochondria as well as improvements in biochemical exponents of nephropathy such as a reduction in urinary albumin concentration and albumin/creatinine ratio [52]. The beneficial effects of ubiquinone are also confirmed by clinical studies. Brauner et al. in study evaluating the effects of coenzyme Q_{10} on antimicrobial peptides and NK cells (components of innate immunity involved in the pathogenesis of diabetes and its complications), showed that ubiquinone supplementation at a dose of 100 mg twice daily for 12 weeks resulted in a significant reduction in human beta-defensin-2 (hBD2) and also improved NK cell activity in patients with type 1 diabetes [53]. In addition, Montano et al. in study evaluating the effects of coenzyme Q_{10} on disease progression and oxidative status in patients with type 1 and type 2 diabetes, showed that ubiquinone supplementation at a dose of 100 mg twice daily for 12 weeks was associated with reduced oxidative stress, improved lipid profile and also a trend towards improved metabolic control as assessed by glycated hemoglobin (HbA1c) regardless of type of diabetes [54]. The results of the above studies highlight the potential of ubiquinone supplementation as an adjunctive treatment for T1D. However, there is still a deficit of clinical trials involving larger populations of patients with type 1 diabetes that would definitively clarify the mechanism of action and confirm the safety of coenzyme Q_{10} supplementation.

9. Coenzyme Q_{10} and Graves' disease

Graves' disease is an autoimmune disease characterised by the presence of autoantibodies directed against the thyrotropin receptor (TRAb), which damage the thyroid gland and lead to an overproduction of hormones, associated with troublesome symptoms such as gastrointestinal disorders in the form of diarrhoea, a feeling of heart palpitations, anxiety, insomnia and heat intolerance [55]. The prevalence of Graves' disease in the population is estimated to be approximately 3% of women and 0.5% of men [56]. The pathogenesis of this condition is not fully understood and the causes are thought to be genetic predisposition and environmental factors such as nicotinism, stress, infections, vitamin D and selenium deficiency [57]. It has also been noted that thyroid hormones affect mitochondrial function and thus regulate cellular energy metabolism [58]. The increased triiodothyronine levels that occur in Graves' disease are associated with excessive oxidative stress and thus lead to increased free radical production [59]. Current treatment of this condition focuses on symptom relief and prevention of complications and is based on pharmacotherapy with antithyroid drugs (thiamazole, propylthiouracil), radioiodine therapy and thyroidectomy in

more severe cases [60]. Unfortunately, these therapies are often ineffective and have numerous side effects. Therefore, there is a need to search for new treatments. Suzuki et al. in study to determine the relationship between coenzyme Q_{10} levels and cardiac function in thyroid disease found reduced coenzyme Q_{10} levels in patients with thyrotoxicosis. Furthermore, they noted that coenzyme Q_{10} supplementation at a dose of 120 mg/day for 1 week in 12 patients with hyperthyroidism, resulted in improvements in cardiac function [61]. In another publication, Moncayo and Moncayo described an effective method to increase serum levels of coenzyme Q_{10} in patients with thyroid disease by supplementing ubiquinone at a dose of 60 mg/day until a serum value of >1200 µg/l was achieved [62]. The above studies show the promising effect of coenzyme Q_{10} in adjunctive therapy for Graves' disease, but there is a need for further clinical studies involving a larger number of patients to fully explain the mechanism of action of coenzyme Q_{10} and exclude severe side effects of supplementation.

10. Coenzyme Q_{10} and Ulcerative colitis (UC)

Ulcerative colitis (UC) is a disease belonging to the inflammatory bowel diseases, which is characterised by diffuse inflammation of the rectal mucosa or of the rectum and the rectum and colon, manifested by: diarrhoea mixed with blood, weakness, weight loss, and in more severe cases leading to complications such as: megacolon toxicum, perforation of the colon, haemorrhages from the colon [63]. The incidence of this condition is estimated at 9 to 20 cases per 100 000 people per year, with a trend towards increasing incidence [64]. The etiopathogenesis of ulcerative colitis is not fully understood. The causes are attributed to genetic predisposition, but also to environmental factors such as "westernization" of the diet, exposure to environmental pollutants, and disruption of the intestinal microbiome [65]. Current therapy for ulcerative colitis is based on a remission induction strategy using 5-aminosalicylic acid (5-ASA) and glucocorticosteroids as well as immunosuppressive drugs (azathioprine, cyclosporine), biologic drugs (infiximab, adalimumab) or surgical treatment when drug therapy is ineffective or complications develop [66]. There is a need to search for new treatments for the condition due to the ever-increasing incidence, the often ineffectiveness of treatment and its side effects, but also the risks associated with the development of colorectal cancer [67]. In recent years, it has also been noted that mitochondrial dysfunction, resulting in abnormal energy production and increased free radicals, is also involved in the pathogenesis of inflammatory bowel disease [68]. Research into the use of coenzyme Q_{10} as an adjunctive therapy has begun for this reason. Preclinical studies have provided promising results. Shastri et al. in study to determine the effect of

idebenone (a coenzyme Q_{10} analogue) in a mouse model of sodium dextran sulphate-induced ulcerative colitis, found that idebenone administered at 200 mg/kg significantly reduced clinical symptoms, prevented weight loss, improved Disease Activity Index (DAI) and intestinal histopathology [69]. In addition, Ewees et al. in study determining the protective effect of coenzyme Q_{10} in a rat model of ulcerative colitis, showed that coenzyme Q_{10} supply at a dose of 30mg/kg/day also improved intestinal histopathology, reduced myeloperoxidase activity, malondialdehyde content and nitrate/nitrite production [70]. These studies have provided promising results for further clinical trials. Farsi et al. in double-blind, randomised controlled trial involving coenzyme Q_{10} supplementation at a dose of 200 mg/day for 8 weeks, showed significant reductions in blood pressure and disease severity as assessed by the Simple Clinical Colitis Activity Index Questionnaire (SCCAIQ) and improvements in quality of life as measured by the Inflammatory Bowel Disease Questionnaire (IBDQ-32) in patients with this inflammatory bowel disease [71]. The authors emphasise that there is a need for further clinical studies, on a larger population of patients with ulcerative colitis, which will clarify the exact mechanism of action of coenzyme Q_{10} and furthermore confirm the safety of this substance.

11. Coenzyme Q_{10} and Psoriasis

Psoriasis is a chronic inflammatory autoimmune skin disease characterised by itching, soreness and burning of the skin. The prevalence of this condition is estimated at 2- 3% depending on the geographical region (more common in wealthier countries and with older populations [72]. In addition, psoriasis is often accompanied by comorbidities such as psoriatic arthritis, cardiometabolic diseases, gastrointestinal and renal diseases, infections or malignancies and mood disorders in the form of depression, anxiety and suicidal thoughts [73]. The etiology of this condition is multifactorial and incompletely understood, involving genetic disorders, but also environmental factors such as infections, drugs and trauma [74]. It has also been noted that mitochondrial dysfunction and the associated increase in reactive oxygen species levels leads to the increased proliferation, apoptosis and inflammation present in psoriasis [75]. Currently, psoriasis therapy is based on topical treatment with corticosteroids, vitamin D analogues, calcineurin inhibitors, phototherapy and, in more severe cases, biological drugs such as: TNF-α inhibitors, IL-23 and IL-17 inhibitors [76]. Despite the presence of numerous treatments, they are not without side effects and there is a group of patients who do not respond to therapy. There is therefore a need for further research into new methods. The use of coenzyme Q_{10} as an adjunctive therapy has begun to be investigated due to the association of mitochondrial disorders in the pathogenesis of psoriasis. Kharaeva et al.

in double-blind, placebo-controlled clinical trial assessing the effect of supplementation with selected antioxidants on the improvement of clinical and biochemical parameters in patients with psoriasis, found that supplementation with coenzyme Q_{10} at a dose of 50 mg/d together with selenium and vitamin E for a period of 30 days significantly reduced levels of oxidative stress markers and also contributed to clinical improvement compared with placebo [77].

In addition, Al-Oudah et al. in prospective double-blind controlled study assessing the effect of coenzyme Q_{10} supply at a dose of 100 mg/day for 12 weeks on Psoriasis Area Severity Index (PASI) and Dermatology Life Quality Index (DLQI) in patients with psoriasis receiving concomitant biological treatment (adalimumab) found significant improvements in quality of life and reduced disease severity compared to placebo [78]. The above studies are promising for the use of coenzyme Q_{10} as an adjunctive treatment for psoriasis, but clinical trials on a larger patient population are still lacking to definitively elucidate the mechanism of action of coenzyme Q_{10} and assess the safety profile of this therapy.

Conclusion

Autoimmune diseases are a group of conditions whose etiopathogenesis is still incompletely understood. Nevertheless, it has been proven that mitochondrial disorders and the associated oxidative stress are involved in the development of these conditions. Coenzyme Q_{10}, known for its antioxidant properties, has long been used in the cosmetic industry in anti-aging therapies. With time, its potential role in the treatment of various conditions, including autoimmune diseases, began to be explored. In this review article, both preclinical and clinical studies cited confirm the beneficial effects of coenzyme Q10 supplementation on reducing oxidative stress and inflammation, which resulted in improvements in biochemical and clinical exponents of the disease, making it an important adjunctive treatment method for this group of patients. An additional advantage is its low toxicity and lack of serious effects. Nevertheless, there is still a deficit of randomised controlled trials and a need to conduct them on a larger population of people with autoimmune diseases that will authenticate the promising effects from coenzyme Q_{10} supplementation.

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