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Dietary Approaches for Prevention of the Eye Diseases Caused by Oxidative Stress

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Abstract

Diet is a crucial lifestyle factor that can have long-term effects on eye health. Worldwide, approximately 250 million people suffer from progressive vision loss to varying degrees, and development of chronic eye diseases such as cataracts, age-related macular degeneration (AMD), glaucoma, and diabetic retinopathy. Oxidative stress is a common underlying cause of eye disorders, as the eye is extremely sensitive to generated free radicals upon the exposure to ultraviolet light. Although various strategies have been proposed to mitigate negative effects of oxidative stress on the eye, antioxidant therapy is often recommended. Consequently, dietary approaches aiming to increase intake of food antioxidants, such as vitamins E and C and coenzyme Q, are promising in restoration of the oxidative balance leading to reduction of oxidative stress damage. Nutrients and dietary bioactive compounds, such as carotenoids, anthocyanins, and vitamins, have been found to possess antioxidant properties that can benefit eye health by protecting against oxidative stress and inflammation. Some dietary patterns, such as the Mediterranean diet and the MIND diet, have been associated with improved eye health and reduced risk of age-related eye diseases. Conversely, a Western-style diet high in processed foods, red meat, saturated fats, and sugars is linked to an increased risk of eye diseases. In conclusion, dietary interventions play a significant role in maintaining eye health and preventing age-related eye diseases. Further research is needed to determine the optimal daily intake and efficacy of antioxidants in preventing age-related eye diseases.

Keywords: Eye Diseases; Antioxidant; Nutrition; Eye Health; Mediterranean Diet; Phytonutrients; Oxidative Stress

Abbreviations: AMD: Age-Related Macular Degeneration; HEI: Healthy Eating Index; iOAG: Incidence of Open Angle Glaucoma

Introduction

Diet is a key lifestyle factor that can also have a long-term impact on eye health. Worldwide, approximately 250 million people suffer from progressive vision loss of varying degrees, mainly due to the development of chronic eye diseases such as cataracts, age-related macular degeneration (AMD), glaucoma and diabetic retinopathy. Although these disorders largely affect older adults, given the ongoing problem of aging worldwide, epidemiological data suggest that this number will increase exponentially [1].

Vision problems, as well as those directly related to eye health, have a complex etiology, because many factors, oxidative stress turns out to be one of the most common causes. This is not surprising, because the eye is particularly sensitive to the effects of free radicals, the production of which increases during oxidative stress. Due to the high consumption of oxygen and cumulative exposure to high-energy visible light, it may consequently contribute to oxidative damage to eye tissues [2]. Moreover, oxidative stress, characterized by an imbalance between the production of reactive oxygen species and the body's ability to detoxify, can lead to damage to various components of the eye, including lipids, proteins and DNA, which has been linked to many eye diseases such as cataracts and macular degeneration. with age, glaucoma, diabetic retinopathy, retinitis pigmentosa, as well as retinopathy of prematurity and dry eye disease [3]. It is worth adding that oxidative stress, leading to damage to cellular elements of the eye, may promote an inflammatory reaction, which is especially visible in patients struggling with symptoms of dry eye disease, as they have increased levels of pro-inflammatory mediators (e.g. IL-1β) in samples. tears and conjunctival epithelial cells [4].

To prevent the negative consequences of oxidative stress and the pro-inflammatory reactions it causes, antioxidant therapy is often recommended, aiming to restore the balance between ROS and antioxidants in order to alleviate the negative effects caused by oxidative stress. In this case, an appropriate diet with high antioxidant potential and/or dietary supplementation with strong antioxidants such as vitamin E, vitamin C and coenzyme Q are often recommended.

Role of the Diet in the Eye Health

The potential of diet rich in antioxidants in protecting and maintain optimal eye health is a topic which is gaining interests especially in the prevention of age-related eye conditions, which have been associated with increasing oxidative stress. Based on the results of current research, it turns out that the presence of antioxidants in the diet may be crucial for maintaining better vision and preventing eye diseases.

Nutrients and Functional Bioactives of Food Origin in Preventing Eye Health

Table 1: Examples of functional bio actives of food origin proposed to support eye health [5].

Bioactives	Type of research	Benefits for eye health
Anthocyanins		
Cyanidin 3-glucoside, cyanidin 3-rutinoside, delphinidin 3-glucoside and delphinidin 3-rutinoside	Experimental study	Stimulation of rhodopsin regeneration in the eye.
Cyanidin 3-glucoside and delphinidin 3-glucoside	Experimental study	Protection against the harmful effects of UVB radiation.
Anthocyanin extract from blueberries	Experimental study	Protection against the harmful effects of solar radiation; increased levels of antioxidants (including superoxide dismutase, glutathione peroxidase, catalase); reduced levels of oxidative stress; reduced levels of inflammatory mediators
Carotenoids		
Lutein and zeaxanthin	Experimental study	Protection against the harmful effects of UVB radiation.
Lutein and zeaxanthin	Badanie kliniczne trwające 12 miesięcy z dawką dzienną 10 mg lutein and 2 mg zeaxanthin	Significantly increased macular pigment optical density in the treated group compared to placebo. Significantly elevated serum lutein and zeaxanthin levels. Significantly improved chromatic contrast and recovery time from photographic stress in the treatment group compared to placebo.
Zeaxanthin - contained in spirulina (4–5 g)	Clinical trial a dietary intervention lasting 45 days with a dose of 2.6–3.7 mg zeaxanthin	Increased mean concentration of zeaxanthin in blood serum.
Lutein, zeaxanthin and meso-zeaxanthin in sunflower oil suspension	Clinical trial lasting 12 months with a daily dose of 10 mg lutein, 10 mg meso-zeaxanthin and 2 mg zeaxanthin	Significantly improved sensitivity to contrast vision after 12 months of supplementation compared to baseline values. In the treated group, there was a significant increase in serum xanthophyll concentration in the retina and optical density of macular pigment compared to placebo.
Lutein vs. α-tocopherol	Clinical trial lasting 24 months with a daily dose of 12 mg lutein mixed with 100 mg α-tocopherol	Significantly increased lutein concentration in blood serum. Increased visual performance (visual acuity and glare sensitivity) only in the lutein group. No toxic effects were found.
Oral total daily antioxidant supplementation (mixture of β-carotene with other vitamins)	Badanie kliniczne z okresem follow up 10 lat z dawką 15 mg β-carotene	Reduced risk of loss of visual acuity
Nutrient intake (β-carotene, β-cryptoxatin, lutein, zeaxanthin and lycopene)	Epidemiological study	Participants reporting the highest lutein and zeaxanthin intake had a lower risk of AMD.
Xanthophyll dietary supplement	Clinical study lasting 8 months conducted on a group of women during menopause with a daily dose of 6 mg lutein and 2 mg zeaxanthin	Lutein and zeaxanthin supplementation significantly increased serum lutein and zeaxanthin levels.

A significant number of scientific studies have demonstrated the synergistic effects and effectiveness of nutrients in protecting eye health [5]. For example, carotenoids (such as lutein and zeaxanthin), anthocyanins (found in saffron and bilberries) and vitamins (e.g. vitamin A) have antioxidant properties that may have a beneficial effect on protecting the eyes against oxidative stress

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and soothing inflammation. These active functional compounds may also help prevent premature symptoms of cataracts, and by maintaining the normal degree of elasticity of the eye's lens by increasing the expression of antioxidant enzymes, they may also delay the development of disorders such as presbyopia and age-related macular degeneration [6,7]. Particularly lutein and zeaxanthin have been scientifically proven properties that their antioxidative and anti-inflammatory properties can help reduce the risk of age-related macular degeneration and additionally improve the eye function and sense of vision [6]. The dietary components with proposed eye health benefits are presented in Table 1,2 [5].

Table 2: Examples of nutrients proposed to support eye health [5].

Nutrients	Type of research	Benefits for eye health
Vitamins		
Multivitamin supplement: vitamin C and vitamin E with provitamin A-carotenoid	Clinical trial conducted with a follow-up period of up to 10 years with daily doses of vitamin C 500 mg and vitamin E 400 IU	Reduced risk of developng Cataract.
Provitamin A β-carotene, vitamin C and vitamin E	Age-Related Eye Disease Study	Compared to baseline values Increased opacity of the nucleus, cortex or posterior subcapsule or cataract surgery. Moderate loss of visual acuity (≥15 letters). Increased intake of β-carotene, vitamin C and vitamin E associated with reduced risk of neovascular AMD.
Vitamin A, Vitamin C and Vitamin E	Systematic review with meta abalysis	The combined dietary intake of vitamin A, vitamin C and vitamin E contributed to a lower risk of AMD than either vitamin alone.
Vitamin A, Vitamin C and Vitamin E	Observational study	Low dietary intake of vitamins C and E was associated with neovascular AMD.
Minerals		
Zinc	Observational study	Low dietary zinc intake was associated with a higher risk of neovascular AMD.
Zinc oxide	Clinical trial with a daily dose of 80 mg of zinc and follow-up period of up to 10 years	Significantly reduced risk of developing advanced AMD.
Zinc sulfate	Clinical trial with a daily dose of 200 mg of zinc and follow-up period of up to 2 years	Significantly reduced vision loss in the treatment group compared to placebo.
Zinc monocysteine	Clinical trial with 3 and 6 month intervention with a daily dose of 25 mg zinc	Significantly improved visual acuity and contrast sensitivity. Significantly reduced macular flash recovery time after both three and six months.

A prospective cross-sectional epidemiological study called the Blue Mountains Eye Study of 1,952 Sydneysiders aged 60 years or older, which was designed to determine the relationship between the intake of various nutrients, including antioxidants and fatty acids, and the occurrence of dry eye disease, found that individuals with the highest (8.11 mcg/day) intake of vitamin B12 from their daily diet, compared with the lowest intake, had a reduced likelihood of experiencing at least 2 symptoms typical of dry eye. Interestingly, higher intakes of vitamin C, thiamine (vitamin B1), polyunsaturated fatty acids and calcium in this study were associated with a reduced probability of developing more than 2 dry eye symptoms in the subjects, which may suggest that ensuring the appropriate level of these microelements in the diet may help prevent dry eye symptoms [8]. Although more research is needed to establish the recommended daily intake and the effectiveness of antioxidants on visual function, current evidence suggests that an antioxidant-rich diet may play a significant role in maintaining eye health and preventing age-related eye diseases.

Dietary Patters Promoting Eye Health

Age-related eye diseases are one of the important causes of vision loss, despite available surgical treatment methods, such as in the case of cataracts, which emphasizes the need for early prevention, which can help delay or alleviate the symptoms of these disorders. One of them is also a properly prepared diet, which, acting holistically, can not only delay the loss of vision, but also slow down the aging processes and increase vitality in older people [9].

A well-balanced and nutritious diet can have a significant impact on eye health, and for good reason, as many nutrients commonly found in a variety of foods eaten every day have been

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linked to the risk of developing eye diseases such as age-related macular degeneration. yellow eye or cataract. In particular, a diet rich in fruits, vegetables and fish, which are valuable sources of antioxidants, has been associated with a reduced risk of age-related AMD [5]. Similar benefits were observed in the Melbourne Collaborative Cohort study, in which following a dietary regimen characterized by a high intake of grains, fish, lean poultry, nuts, and steamed or fresh vegetables had a protective effect against late-onset AMD [10]. Similarly, results from prospective studies show that a high Healthy eating index (HEI) is associated with a reduced incidence of cataracts [11], while diets characterized by high sodium intake as well as carbohydrates and protein; as well as saturated fats and fats, and processed meats and foods were associated with an increased risk of developing this disorder [12]. Interestingly, eating large amounts of dark green leafy vegetables, which are a valuable source of plant bioactive compounds, especially glutathione, flavonoids and nitric oxide, can significantly reduce the risk of glaucoma [13]. Moreover, following the recommendations of the Mediterranean diet, as in the case of the prevention of many other diseases, has proven to be effective in improving eye health.

The Mediterranean diet is a way of eating based on the traditional dishes of countries bordering the Mediterranean Sea, such as Spain, Greece, Italy and France, supporting overall health and proper metabolism. This diet consists of low-processed foods, especially polyunsaturated fats from olive oil and fish; as well as whole grains, fresh fruit and vegetables, beans, nuts and seeds. fruits, vegetables, beans, nuts and seeds. Thus, it promotes minimally processed, seasonal, local products of both plant and animal origin, but nevertheless recommends moderate consumption of dairy products, fish and poultry (times a week), and reducing the consumption of red meat. This diet allows you to consume small amounts of red wine, usually with meals. Interestingly, following the Mediterranean diet has been linked to a variety of health benefits, such as lower risk of heart disease, metabolic syndrome, diabetes, certain cancers, depression, and overall better mental and physical functioning in older adults. A systematic review using data from randomized clinical trials and observational studies suggests that adherence to a Mediterranean diet is associated with a reduced risk of diabetic retinopathy, incident AMD and its progression to late form. Nevertheless, the effects of diet on dry eye syndrome remain inconsistent. It is worth adding that in this study there was no effect of the Mediterranean diet on the risk of developing cataracts or glaucoma [14]. In turn, results obtained as part of research conducted by the EYE-RISK consortium showed that a higher rate of adherence to the MeDi Mediterranean diet recommendations (mediSCORE > 6) was associated with a reduced incidence of AMD, especially the dry form [15]. Interestingly, following the Mediterranean diet, while preventing the development of diabetes, can also help reduce the risk of diabetic retinopathy, as it turns out that people who followed the Mediterranean diet, supplemented with olive oil or nuts, had a lower risk of developing this eye disorder [16].

The MIND diet, or "Mediterranean-DASH Intervention for Neurodegenerative Delay", is an eating regimen that combines aspects of the Mediterranean diet and DASH, which focuses on improving brain function and delaying age-related diseases. Key principles of the MIND diet include frequent consumption of plant-based foods such as vegetables, berries, nuts and whole grains; and limiting animal products and products high in saturated fat. This diet promotes the consumption of especially "brain-healthy" foods, with an emphasis on green leafy vegetables, berries, nuts, olive oil and fish. Studies have shown that the MIND diet can improve brain health, reduce the risk of neurodegenerative diseases, and slow age-related cognitive decline. It is worth adding that the principles of the MIND diet are relatively easy to follow and do not require strict calorie counting, which allows for flexibility in meal planning, thus promoting health and well-being [9]. A clinical trial called the Rotterdam Study to evaluate the association between the DASH Intervention for Neurodegenerative Delay (MIND) Mediterranean diet and the incidence of open angle glaucoma (iOAG), as well as the association between iOAG and two other diets typical of the Dutch population, i.e. the Mediterranean diet and Dutch dietary guidelines conducted at approximately 5-year intervals among a total of 170 participants showed that adherence to the MIND diet was associated with a reduced risk of iOAG, and in particular, higher intakes of green leafy vegetables, berries and fish showed protective potential against iOAG [17].

Noteworthy, certain studies have also shown that higher consumption of green leafy vegetables was associated with a 20–30% reduction in the risk of OAG [18] and consuming at least 1 serving of green cabbage and kale per month, compared to consuming more than 1 serving per week or more than 1 serving per month, was associated with a reduced risk of glaucoma [19,20]. In this Rotterdam Study, no significant associations were observed between adherence to the Mediterranean diet or the Dutch dietary guidelines and the risk of iOAG; and none of the three diets tested were associated with IOP; thus, suggesting that the MIND diet may be particularly important in preventing ocular neurodegeneration [17].

On the other hand, a highly processed diet, such as the Western-style diet, characterized by high caloric content but low nutritional density of foods that are a source of essential nutrients with antioxidant and anti-inflammatory properties, such as fresh fruits and vegetables, low-processed whole grains or dairy products may contribute to the deterioration of eye health [2]. For example, following a Western dietary pattern with a characteristic high consumption of red meat, saturated fats, and highly processed foods, especially sweets and sweet/fatty desserts and sugar-sweetened beverages, was associated with an increased risk of early and late AMD [21]. Interestingly, especially frequent

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consumption of foods such as fried red meat and its products, as well as potatoes, sauces and butter or margarine was associated with a higher risk of late AMD [22].

In addition, a high-fat diet based on frequent consumption of processed foods has been linked to an increased risk of developing age-related macular degeneration. It is worth adding that inadequate hydration of the body may also lead to deterioration of vision and chronic eye diseases [2].

Conclusions

Age-related eye diseases, such as cataracts and AMD, pose a significant public health problem. Acquired vision loss associated with these diseases can be devastating for a person because it significantly reduces the quality of life, often limiting the ability to engage in social activities. Although there are many potential causes of eye disease, it is believed that their impact can be alleviated to some extent through appropriate diet and supplementation. Vitamin A, lutein and zeaxanthin are important antioxidants that play an important role in maintaining eye health. Although many studies have shown the protective effects of these compounds against AMD and other eye diseases, as well as vitamins C and E, as well as the mineral selenium, acting as powerful antioxidants can reduce cellular oxidative stress in the retina or macular area of the eye, thereby contributing to to its protection. Similar effects have been observed in experimental studies using functional plant compounds such as anthocyanins, which also have a positive effect on AMD. In turn, clinical studies involving the consumption of carotenoids as part of the daily diet are inconsistent in their effectiveness, especially in the case of daily oral supplementation of β-carotene, lutein and zeaxanthin on the secondary effects of AMD, increase in the optical density of macular pigment, suggesting the need for more studies focusing on on the effectiveness of specific formulas or combinations of listed antioxidants to prevent their early development and to treat macular degeneration and other complications, including cataracts, glaucoma and night blindness. Currently, it is recommended that supplementation of these nutrients be done in moderate doses, in accordance with the reference intake values (Table 3), and due to their potential toxicity or the use of synthetic compounds, dietary supplements from natural sources are preferred for a better safety profile and their bioavailability for overall health improvement.

Table 3: Recommended doses of vitamins and minerals aimed at improving the function of the eye and vision [5].

Nutrients	Recommended daily intake	Tolerable daily maximum limit
Vitamins		
Vitamin A	700 µg RE/day for men and 600 µg RE/day for women	3000 µg RE/day
Vitamin C	<1000 mg/day	1000 mg/day
Vitamin E	300 mg α-tocopherol equivalents (450 IU)	300 mg α-tocopherol equivalents (450 IU)
Minerals		
Selenium	26–55 µg/day	300 µg/day
Zinc	11 mg/day for men and 8 mg/day for women	25 mg/day

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