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Review Article

A Closer Look: Environmental Stressors and Their Effects on the Ocular Surface

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Abstract

Environmental variables have a considerable impact on the ocular surface, both structurally and functionally. The cornea, conjunctiva, and tear film form the ocular surface, which is essential for preserving visual clarity and comfort. UV radiation, air pollutants, allergens, and climatic changes can all upset the delicate balance of the ocular surface ecosystem, resulting in disorders such as dry eye disease (DED), allergic conjunctivitis, and photokeratitis. UV radiation is a well-documented environmental threat that can induce eye surface damage, both acute and chronic. Fine and ultrafine particles can get into the tear film and conjunctiva, producing oxidative stress and inflammation. Allergens such as pollen, dust mites, and pet dander cause allergic conjunctivitis, which is the most prevalent allergic eye illness. Climate variables such as temperature, humidity, and wind all have a substantial influence on ocular surface health. Understanding these environmental consequences necessitates a multidisciplinary strategy that combines ophthalmology, environmental science, and public health. Clinicians can measure the effect of environmental exposures on ocular health using diagnostic procedures such as tear film analysis, ocular surface imaging, and biomarker studies. Management options include preventative measures and therapies that are customized to individual illnesses. Preventive measures include wearing protective eyewear to shield against UV radiation and pollutants, using air purifiers to reduce indoor allergens, and avoiding outdoor activities during peak pollution hours. Emerging research focuses on elucidating molecular mechanisms underlying environmental-induced ocular surface disorders and developing novel therapies to mitigate their effects. By advancing knowledge in this field, we aim to enhance preventive strategies and therapeutic interventions, ultimately improving the quality of life for individuals affected by environmental-related ocular surface conditions.

Keywords

Ocular Surface, Environmental Factors, Dry Eye Disease, Allergic Conjunctivitis, Ultraviolet Radiation, Tear Film Analysis

1. Introduction

Thoft was the first to describe the ocular surface, which is an integrated entity that includes the tearfilm, cornea, conjunctiva, lacrimal glands, and eyelids. [1]. One of the most crucial components of the eye is the ocular surface. It is made up of the cornea and conjunctiva as well as components like the lacrimal gland, drainage system, and related eyelid tissues. The interface between the working eye and the outside world is called the ocular surface. This surface, which is made up of

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the corneal epithelium, the palpebral and bulbar conjunctival epithelium, the corneo-scleral limbus, and the tear film, offers anatomic, physiological, and immunologic protection. Adnexal structures, such as the lacrimal system, lashes, meibomian glands, and anterior lamellae of the eyelids, are crucial for the proper protection and function of the ocular surface, even though these structures constitute the anatomical ocular surface. The ocular surface protects the eye's components from pathogens, injuries, and poisons in addition to maintaining the cornea's optical clarity and acting as a refractive surface for precise light projection through the ocular media.

The thin, translucent mucous membrane that lines the inside of the eyelids is called the conjunctiva, and it covers the sclera, or white of the eye. It is composed of stratified cuboidal epithelium, stratified columnar epithelium, and non-keratinized, stratified squamous epithelium containing goblet cells, depending on the zone. While the conjunctiva produces less tears than the lacrimal gland, it still produces mucus and tears, which aid in lubricating the eye. Moreover, it aids in immune surveillance and blocks the entry of microorganisms into the eye. The conjunctiva can be affected by environmental variables in a number of ways. For example, the conjunctiva can get irritated by smoke, allergens, pollutants, or dry air, which can result in symptoms like burning, itching, redness, and excessive tearing [2]. Furthermore, extended exposure to ultraviolet (UV) radiation from sunshine can raise the chance of conjunctival pterygium [3] and pinguecula infections. Cornea is a transparent membrane covering the front portion of the eye, with a dome shape and a diameter of around 12 mm (0.5 inch). Tears nourish and supply oxygen to it anteriorly, while aqueous humour bathes it posteriorly. Environmental factors can affect the cornea, the transparent outer layer of the eye, in several ways. Exposure to ultraviolet (UV) radiation from sunlight can lead to conditions like photokeratitis (similar to sunburn of the cornea) and contribute to the development of cataracts and other eye problems over time. Air pollutants, dust, smoke, and other irritants can also cause irritation and inflammation of the cornea, leading to symptoms such as redness, dryness, and discomfort. An upper and lower eyelid are connected at the medial and lateral canthi to form the eyelids. Exposure to pollutants or allergens can cause irritation, redness, or inflammation to eyelids. Sun exposure without protection can lead to sunburn or premature aging of the delicate skin around the eyes. Dry environments can cause dryness and flakiness, while overly humid conditions can contribute to sweat and oil buildup. It's important to protect your eyelids by using gentle skincare products, wearing sunglasses outdoors, and keeping the area clean and moisturized. A thin layer of fluid called tear film covers the surface of the eyes. It creates a smooth refractive surface for vision and is in charge of immune system, mechanical, environmental, and ocular surface comfort. Tear film integrity and stability are determined by the interplay of tear production, evaporation, absorption, and drainage with the dynamic balance of the tear film. Its integrity, stability, and proper osmolality depend on balanced tear film generation and removal. Environmental factors like temperature, humidity, and air quality play a crucial role in tear film health, affecting tear film stability, tear evaporation, and ultimately contributing to conditions like dry eye disease.

2. Risk Factor

2.1. Smoking

Using drugs recreationally often involves smoking. It is the most common type of smoking, with nearly a quarter of the world's population (22.3%) using tobacco products [4]. Cocaine, opium, and cannabis are less often smoked drugs. Over eight million people died from tobacco-related diseases in 2019 [5]. Tobacco usage sickens and kills millions of people annually. In addition to volatile chemicals, phenolic compounds, nitrosamine compounds, aromatic amines, polycyclic aromatic hydrocarbons, NO_2, CO_2, and various concentrations of metals known to be poisons and carcinogens, tobacco cigarettes can also produce about 6,000 other chemical constituents. The cardiovascular and respiratory systems are impacted by a number of health issues caused by smoking, both actively and passively [6]. A person's risk of cataract development, age-related macular degeneration, and diabetes is higher when they smoke cigarettes [7].

The opacification of the lens is referred to as a cataract. Cataract is the leading cause of blindness worldwide and accounts for visual loss in more than half of the 23 million. At the initial eye examination, individuals who smoked 20 cigarettes or more a day had a significantly higher chance of developing nuclear opacities compared to those who did not smoke [8]. The appearance of any kind of drusen, soft or otherwise, if it is linked to alterations in the retinal pigment epithelium or an increase in retinal pigmentation in the macular region is a possible definition of early age-related macular degeneration (ARMD). One of the main causes of vision loss in the West is age-related macular degeneration, or AMD. An estimated 30% of people over 75 years have the disease in its early stages, whereas 7% of those in this age range are considered to be in its late stages [9]. It was also discovered that the risk of AMD increased with the number of pack-years smoked. For at least seven years, Christen et al. monitored 21,157 male American physicians for the onset of AMD. There are already 268 confirmed cases of AMD resulting in visual impairment [10]. ARMD risk was found to be three times higher in a prospective research when vision loss was present. Reducing the chance of AMD is a major incentive to prevent or stop smoking, as the illness is a prevalent cause of severe vision impairment that is frequently incurable.

The most modifiable risk factor for Graves' ophthalmopathy is cigarette smoking [11] and the risk increases with daily cigarette consumption. When compared to nonsmokers, smokers with Graves' ophthalmopathy have a higher risk of developing severe disease and a lower propensity to respond

effectively to immunosuppressive treatments.

2.2. Ultraviolet Radiation Exposure

There are numerous well-known consequences of prolonged exposure to light for the eyes, such as photokeratitis, erythema of the eyelid, cataracts, solar retinopathy, and retinal damage [12]. The impact that ultraviolet (UV) light exposure plays in the development of cataracts and retinal degeneration. The earth's UV radiation level may raise as a result of global atmospheric changes such stratospheric ozone depletion. This would increase the long-term exposure of human skin and ocular tissues to UV radiation. Van der Hoeve recognised the dangers of UV light to the eyes as early as 1920 [13]. The discussion centres on the biochemical modifications that occur in the lens and retina as a result of exposure to light.

Undistorted light focussing onto the retina is the main job of the human lens. While the transmission characteristics of the majority of the eye's components remain constant, the lens's transmission properties vary over the course of a lifetime. After being clear for the first three years of life, the lens progressively acquires yellow pigments made of 3-hydroxy kynurenine and its glucoside. This pigment serves as protection by safely dissipating the energy it collects from UV rays. The adult human retina is thus shielded against typical amounts of UV radiation as long as that pigment is present. No UV-A or UV-B radiation can penetrate the retina. A cataract is a clouding of the lens that is caused by intense acute UV radiation or chronic UV exposure, especially when combined with a dye or medication that combines photosensitivity. Any alteration to the lens's clarity reduces vision and fundamentally alters retinal function. Age-related cataracts are the most prevalent form. Cataracts afflict more than 50% of people over 65, and by the time they reach 75 years, that number rises to 75% [14]. Phototoxic dyes and medications can cause cataracts, which can develop as early as 40 years of age or earlier [15]. The phototoxic chromophore xanthurenic acid is produced by an enzymatic conversion of the protective pigment 3-hydroxy kynurenine beyond the middle age. When UV light enters the lens, xanthurenic acid absorbs it, forms a triplet, and releases singlet oxygen and superoxide [16]. The synthesis of antioxidants and antioxidant enzymes, which ordinarily neutralize these reactive oxygen species, is also declining at the same time. This leads to damage to the lens's proteins and epithelial cells, ultimately causing the lens to fog.

Ocular melanoma and macular degeneration are two conditions that can arise later in life as a result of cumulative UV exposure to the eye [17]. Adult retinal damage could result from an inflammatory reaction if UV radiation exposure is high enough. An adult human lens's filtering abilities may be overwhelmed by the strength of UV radiation emitted by staring at a solar eclipse, a UV-emitting bulb, or the reflected UV from snow, sand, or water. The melanin found in the RPEs and choroid absorbs UV light, shielding the retina from damage caused by the sun. But as we age, our melanin in our eyes becomes photobleached, which lessens its ability to fend off UV damage [18]. There may be some protection for the retina from transretinal UV damage provided by other chromophores. Apart from ultraviolet radiation harming the mature retina, individuals above 50 years old experience photooxidation reaction-induced retinal damage from short blue visible light (430 nm) [14]. With ageing, lipofuscin, a pigment that is phototoxic, builds up. Lipofuscin generates singlet oxygen, superoxide, and free radicals in response to brief blue visible light (430 nm). Reactive oxygen species cause harm to RPEs [19]. Macular degeneration is the loss of central vision caused by the ultimate death of the rods and cones, which is one of the main functions of the RPEs.

2.3. Alcohol

Diabetes mellitus, hypertension, alcoholism, and other chronic co-morbid illnesses all affect immunological function, which in turn affects the prevalence and severity of ocular surface diseases. The risk of infected corneal blindness increases with alcohol usage [20] Tear break-up time is slowed down and corneal discoloration is heightened when alcohol is found in tears. Regardless of age or gender, drinking alcohol was a substantial risk factor for developing dry eye disease [21]. Regardless of age or gender, drinking alcohol was a substantial risk factor for developing dry eye disease. Drinking alcohol for an extended period of time has been associated with vitamin A deficiency [22] and corneal inflammation by upregulating proinflammatory cytokines [23].

2.4. Wind Speed

Numerous investigations have shown that wind can also have an impact on the ocular surface. The tear film is immediately impacted by wind speed since it speeds up its evaporation. Elevated wind velocities have the potential to upset the equilibrium of the tear film, resulting in heightened evaporation of tears and consequent instability [24]. Dust and pollen are examples of particle matter carried by the wind that can mechanically irritate the surface of the eyes. These particles' friction can induce irritation of the cornea and conjunctiva [25]. In windy circumstances, contact lens wearers may also experience pain and visual problems. Wind can cause contact lenses to dry out and come loose, which can irritate the cornea and even cause damage. The use of non-adapted hydrogel soft contact lenses was associated with significant symptoms of dry eye and visual disturbance, tear instability, higher tear osmolarity, and increased tear evaporation [26]. These findings imply that silicone hydrogel contact lenses would be a better option for people who live and work in cold, windy, low-humidity environments. Individuals who work outside for extended periods of time, such farmers, construction workers, and sports, are more susceptible to wind-related eye damage.

2.5. Air Pollution

When a chemical, physical, or biological material contaminates an indoor or outdoor environment, it is regarded as an air pollution because it modifies the intrinsic features of the atmosphere. Although the consequences of long-term exposure to air pollutants on eyes are still poorly understood, exposure to air pollutants typically induces ocular symptoms that range from mild eye irritation to severe chronic discomfort [27, 28]. Air pollution can cause redness, irritation, wetness, a sensation of a foreign substance in the eyes, and blurred vision. However, eye doctors occasionally fail to recognize the connection between air pollution and these symptoms [29]. The ocular surface can be used as a gauge for the effects of pollution on health because it is plainly observable. Global concern over air pollution is growing, particularly with regard to indoor air pollution in high-income countries and outdoor air pollution in low-income countries. Additional research indicates that air pollution may also have an impact on the reproductive, neurological, and ocular systems. Air pollution may cause a shift in the pH of the lacrimal gland and irritate the surface of the eyes [30]. A healthy eye should keep its surface wet beneath all circumstances, enabling people to withstand many kinds of biological and physical harm without experiencing any symptoms. An ophthalmological emergency among Parisians was caused by elevated air pollution levels, as per a study by Bourcier et al. that shown a high correlation between air NO, NO_2 concentrations, and conjunctivitis [28]. However, the health of the ocular surface and tear film, as well as the eye's capacity to lubricate and defend itself, can be compromised by air contaminants and atmospheric circumstances. In certain situations, hydrogen sulfate in the air can induce blindness or dizziness when it comes into contact with the aqueous humor of the eyes [31]. Furthermore, unfavorable environmental factors might trigger corneal nerves, resulting in the symptoms of dry eyes, which include burning, aching, and dryness. Conjunctivitis, dry eye syndrome, and increased sensitivity to bright light are all caused by air pollution.

2.6. Temperature

Latitude, seasonality, solar radiation, ocean currents, and wind speed all affect temperatures. It also affect ocular surface directly and indirectly like trachoma, glaucoma, Dry eye syndrome. An optic neuropathy called Glaucoma is defined by the optic nerve's gradual deterioration. Elevated intraocular pressure is frequently associated with optic nerve damage. Heat waves and cold snaps had a negligible impact on eye problems. Certain researchers have connected an elevated ambient temperature to a higher chance of developing glaucoma [32]. Extreme weather, such as heat waves and low temperatures, may pose long-term health risks. In general, glaucoma is a painless condition, but if left untreated, it can cause significant loss of vision and blindness.

Dry eye is a chronic multifactorial inflammatory disorder of the lacrimal functional unit (LFU). It can happens when your tears don't lubricate your eyes well enough. Dry eye illness is more common year-round in dry climates than it is in wet, tropical regions. But dry eyes might also be brought on by cooler temperatures. Dry eye illness is linked to extremely high or low temperatures in both indoor and outdoor settings. Ocular discomfort, visual disruption, photophobia, and chronic pain are the most prevalent symptoms. It is the most prevalent eye condition affecting adults. The diagnosis and kind of dry eye illness determine the prevalence and incidence. Due to the possibility that the dispersion of eye-seeking flies is correlated with high air temperatures, a prevalent factor in the transmission of acute trachoma is high air temperatures. Very little is known about how temperature affects the distribution or prevalence of active trachoma, and much less is known about the relationship between chronic trachoma and blindness [33]. A statistically significant correlation was found between temperature and allergic conjunctivitis, as well as between temperature and fluctuations between temperature and humidity [34]. Particulate matter [PM] as small as 10 nm, an air pollutant, has a negative impact on human vision. Significant concentrations of PM are present in soot, smog, and tobacco smoke [35].

3. Blinking Abnormalities and Ocular Surface Exposure

The prolonged use of digital devices can lead to a condition known as Digital Eye Strain (DES) or Computer Vision Syndrome (CVS). Long-term use of digital devices, including computers, laptops, tablets, and smartphones, can cause a condition known as computer vision syndrome (CVS), in which the eyes focus on a screen for extended periods of time without taking enough breaks to allow the eye muscles to recover from the constant strain needed to maintain focus on a close object [36].

People who use digital gadgets have unusual blinking patterns [37], such as lower blink rate, incomplete blinking, and a larger gaze angle, which increase the risk of ocular surface exposure. These modifications may result in changes to the ocular surface as well as sensations of dryness Blinking is necessary to keep the ocular surface in a state of homeostasis by keeping it hydrated and moist, minimizing corneal exposure, promoting tear drainage, lowering the buildup of inflammatory mediators in the tear prism, and facilitating the distribution of mucins and meibomian gland secretions to support the stability of the tear film [38].

4. Conclusion

The surface of the eyes is extremely vulnerable to environmental factors, including indoor air quality, seasonal changes, climate, and air pollution. Having a thorough understanding of these variables and how they affect the ocular

surface is crucial to creating management and prevention plans that work. The pace of environmental contamination is increasing exponentially as a result of growing industrialization and global warming. The ocular surface, which is constantly exposed to the atmosphere, seems to be significantly harmed by the current climatic circumstances. People can greatly lower their chance of developing ocular surface illnesses and improve their overall ocular health by taking preventative actions and keeping their surroundings healthy. Employers, the government, or other pertinent entities should apply and offer preventive measures in situations where exposure cannot be avoided.

Abbreviations

UV	Ultraviolet
ARMD	Age-related Macular Degeneration
PM	Particulate Matter
DES	Digital Eye Strain
CVS	Computer Vision Syndrome
LFU	Lacrimal Functional Unit

Conflicts of Interest

The authors declare no conflicts of interest.

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