International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

The Rising Burden of Ocular Surface Disease Amongst Youth: Reviewing Pathophysiology and Evidence Based Preventive Approaches

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Abstract
Background: Ocular surface health is critical for maintaining clear vision and visual comfort, yet increasing evidence indicates a rising burden of ocular surface diseases (OSD), particularly Dry Eye Disease (DED) among children, adolescents, and young adults. Once predominantly associated with aging, DED is now frequently documented in younger populations due to a convergence of modifiable risk factors such as prolonged digital screen use, poor sleep hygiene, sedentary lifestyle, environmental pollution, and improper contact lens practices. This review synthesizes emerging evidence on the multifactorial etiology of DED and highlights preventive strategies rooted in physiology, lifestyle, and environmental management.
We explore the disruption of tear film homeostasis and the role of the lacrimal functional unit (LFU), redox imbalance, ocular surface perfusion, and microbiome alterations in the pathogenesis of DED. Furthermore, we examine how behaviours common in youth—such as extended screen time, insufficient outdoor activity, poor dietary patterns, and irregular sleep—adversely affect tear dynamics and ocular surface stability. Evidence-based interventions including omega-3 and vitamin D supplementation, physical activity, yoga, and structured sleep routines are shown to enhance ocular surface resilience. Environmental modifications, such as reducing exposure to outdoor and indoor air pollutants and adopting protective measures (e.g., eyewear, humidifiers), are emphasized alongside safe contact lens hygiene. The review also underscores the importance of early detection through advanced diagnostics and targeted screening in at-risk populations.
Overall, the review advocates a proactive, integrative approach to preserving ocular surface health among youth. Preventive strategies that combine lifestyle modification, environmental control, and early clinical intervention offer a promising path to reduce the growing ocular morbidity and enhance quality of life in younger demographics.

Keywords: Dry Eye Disease, Ocular Surface Disease, Oxidative Stress, Lifestyle, Air Pollution, Contact Lens Hygiene.

Introduction:

A functional unit comprising of ocular surface, tear film, main lacrimal gland and eyelids are responsible for maintaining the quality of refracting surface of the eye. The most important prerequisite for a clear image formation is to have a smooth wet ocular surface which includes Cornea and Conjunctiva primarily.

Cornea, being the major refractive structure, needs to maintain its transparency by keeping its surface wet. Though it is a challenge to maintain smooth, wet ocular surface as it is directly exposed to environment. Hence, effect of climatic condition both indoor and outdoor is incontestable in overall ocular surface health. However, the list of factors that can affect ocular surface health are more (Gipson, 2007).
The equilibrium between the amount of tear production and tear drainage is the key to sustain ocular surface health. This is known as homeostasis of tear film. Any disruption in this equilibrium leads to dry eye. Dry Eye Disease (DED) is currently among the most discussed ocular surface conditions and responsible for visual morbidity in different age groups.(Stapleton et al., 2017)
The aim of this review is to find out different sustainable ways to endure healthy ocular surface that can prevent dry eye disease at young age.

Dry Eye Disease Prevalence:

The recorded universal prevalence of dry eye disease using TFOS DEWS II diagnostic criteria was lowest in age group 50 which increase with age. The prevalence rises from 8.4% to 15% from age groups younger than 60 years to age groups 70-79 years and further rises to 20% in age groups older than 80 years. This data rises even more with increasing age in women compared to men. However, a cross-sectional study (Hu et al., 2021)of office employee in China have shown a high prevalence of more than 40% [95% confidence interval] in young and middle-aged population using video display terminal (VDT). A recent study on university students of Poland have documented a high prevalence of dry eye symptoms i.e. around 57% (Wróbel-Dudzińska et al., 2023). Similarly, a pool of evidence of elevated prevalence rates among young adults (18 to 25 years of age) [(Wróbel-Dudzińska et al., 2023), (Aćimović et al., 2022), (Talens-Estarelles et al., 2023)]is growing around the globe. Pediatric age group is also not an exception in a study showing elevated prevalence of 37% (Alrabghi et al., 2023). Though electronic screen usage for an extended period was associated. The American Academy of Paediatrics recommended 2 hours of non-schoolwork for children 6-17 years of age but there are no such specific recommendations for age groups beyond 17 years till 25 years i.e. young adults. However, screen time should not replace the time of adequate sleep, physical activity or other essential healthy activities (Policies on children and media by AAP 2/23/2021).
It has been reported that excessive screen time can affect the circadian rhythm leading to sleep disturbances (Foerster et al., 2019), since appropriate quantity and quality of sleep is important to maintain ocular surface health (Wagner et al., 2004). Lack of quality sleep disrupts redox homeostasis in the tear film leading to ocular discomfort and dry eye, (S. Li et al., 2022a). Though Dry eye disease (DED) is a common public health issue since decades (Craig et al., 2017), it has risen substantially after COVID-19 pandemic because of increased usage of digital screen (Ji et al., 2023). Sedentary lifestyle during lockdown and overall shift to Work from home (WFH) increased the digital screen usage in almost all age groups, however children and young adults were the majority (Trott et al., 2022). A case control study on Korean pediatric population by (Moon et al., 2016) has shown a rise of DED in urban children compared to rural children as the hour of usage of VDT (Visual Display Terminal) is more in urban children compared to rural children. The symptoms and signs of DED was improved after cessation of VDT for 4 weeks. The study has also denoted outdoor activity to be the protective factor for pediatric dry eye.
DED in young adults and pediatric population is a serious issue and economic challenge for many countries. But availability of studies in this age groups are inadequate. Hence, it is imperative to start more research focusing on the protective and preventive factors of DED in young age. Emphasis should be given

on preserving healthy ocular surface. This review aims to discuss about the preventive measures of DED which can inhibit the progression of DED at young age.

1. Natural Protective Mechanisms:

1.1 LFU:

The conception of lacrimal functional unit (LFU) (Stern et al., 1998), is the responsible theory on the pathophysiology of dry eye. The ocular surface (cornea, conjunctiva, and meibomian glands), the main and accessory lacrimal glands, and the neural network that connects them are the structures comprising LFU. The anti-inflammatory property of tear film prevents as well as repairs the damage of the ocular surface to environmental stress (wind, humidity, exposure to microorganisms etc.) (Stern et al., 1998). The conjunctival epithelial cells and goblet cells protect ocular surface by secreting mucin. Therefore, lack of normal tear production and inappropriate lubrication will trigger the risk of damage of the ocular surface. It is documented that androgen hormone helps in the normal functioning of lacrimal gland and meibomian gland (Sullivan, 2002). It also has anti-inflammatory properties. Insufficiency of androgen hormone in young age can be seen in case of Sjogren's syndrome or in case of people taking anti androgen medicines for precocious puberty etc (D. A. Sullivan et al., 2003).

1.2 Redox homeostasis:

The act of maintaining balance between the levels of antioxidant defence and cytotoxic reactive oxygen species (ROS) is known as redox homeostasis. These ROS cause oxidative stress which is known to contribute to the development of DED (Y. Chen et al., 2009). The biomarkers responsible for oxidative damage in ocular surface tissues include 8-hydroxy-2 deoxyguanosine (8-OHdG), 4-hydroxynonenal (HNE) and malondialdehyde (MDD) (Seen & Tong, 2018). These free radicals can be formed by different metabolic activities as well as other external substances like cigarette smoke, pesticides and ozone. On the other hand, antioxidative defences occur in the form of tear proteins such as lactoferrin and S100A proteins, and enzymes such as superoxide dismutase (SOD), peroxidase, catalase and mitochondrial oxidative enzymes (Seen & Tong, 2018). Thus, the balance is maintained. Though oxidative stress is part of aging process, however, diet, lifestyle, environmental conditions like pollution, radiation may cause uncontrolled oxidative stress at very young age. Practice of taking appropriate protective measures at early age like using goggles, healthy lifestyle etc. can delay DED. The ocular structures comprising of the tear film, the cornea, and the aqueous humor plays the key role in combating free radicals (Seen & Tong, 2018). Hence, maintaining healthy ocular surface is crucial to prevent or inhibit DED.

1.3 Ocular Perfusion Pressure:

Ocular Perfusion Pressure (OPP) refers to the pressure driving blood into the eye and is calculated by subtracting intraocular pressure (IOP) from the mean arterial pressure (MAP). Both MAP and IOP are dynamic physiological variables. Adequate OPP is crucial for maintaining proper blood flow through the eye's vascular system. The ophthalmic artery branches out to supply nutrients to the ocular surface, and stable OPP is necessary to meet the metabolic demands of these tissues and preserve ocular surface balance. When OPP is disrupted, it can lead to reduced blood supply and potential ocular surface complications.(Robert Weinreb et al., 2015)

1.4 Ocular surface microenvironment:

The ocular surface microenvironment comprises of cornea, conjunctiva, meibomian glands, lacrimal glands, neural network, immune cells, matrix cells, hormones and even microbiome. There are evidences which support the fact that the change in ocular surface microenvironment can affect the homeostasis of the ocular surface which eventually lead to the dysfunction of LFU and resulting in dry eye (X. Zhang et al., 2017). So, the goal of preventing DED is to maintain a healthy ocular surface microenvironment as well as redox homeostasis. Various pathological, environmental and therapeutic reasons are there that can alter the ocular surface microenvironment. For example, punctal occlusion can alter the tear film dynamics, and prolonged use of artificial tear with preservatives can induce epithelial damage and as a result the ocular surface microbiome can get altered. Therefore, special attention needs to be given for not altering the ocular surface microenvironment (X. Zhang et al., 2017).

1.5 Ocular surface microbiome:

Apart from corneal epithelium and tear film, conjunctival epithelium also forms a barrier to ocular infections (Petrillo et al., 2020). Ocular surface microbiome is the main responsible factor for this. It has been established that there are 24 genera of bacteria present in ocular surface which prevents the colonization of pathogenic species (Dong et al., 2011). Any alteration of this subtle ecosystem can affect the ocular homeostasis resulting in ocular surface diseases in future (Tanure et al., 2000). Long-term antibiotics usage can reduce the burden of ocular flora and increase the scope of opportunistic pathogenic microbe (X. Zhang et al., 2017). Thoughtful use of antibiotics can minimize such condition.

2. Healthy lifestyle:

2.1 Healthy diet:

Anti-inflammatory properties of Omega-3 fatty acids helps to reduce tear osmolarity and increase tear stability (Deinema et al., 2017). It also increases the quality of meibomian gland's oil which is the main source of lipid layer of tear film (Liu et al., 2016). Another important food group that is responsible for proper functioning of tear film is Vitamin D. Various studies have linked Vitamin D deficiency with dry eye [(Yildirim et al., 2016), (Bae et al., 2016)]. Importance of Vitamin A in eye health is very well known. It is an essential ingredient in dry eye treatment. It's property to increase cell turn over can help in case of loss or damage of corneal epithelial cells (W. Zhang et al., 2019). Lastly antioxidants and carotenoids rich diet prevent premature aging of ocular tissues by reducing oxidative stress (Khoo et al., 2019).

2.2 Healthy weight:

Healthy lifestyle can never be obtained without a healthy weight. Studies have shown that obesity may lead to sedentary habits which results in oxidative stress and eventually risk of dry eye. (Romieu I et al., 2017)

2.3 Exercise or physical activity:

Exercise can reduce oxidative stress and thus helpful in maintaining homeostasis. Sudden lockdown and shift to work from home, online mode of teaching and extracurricular activities after COVID-19 pandemic has imposed sedentary lifestyle among young population. Though there is no restriction in outdoor activities still flexibility of online mode has become a preferred choice among parents. As a result, children are confined to indoor activities more than outdoor activities. Studies have shown that physical activities or exercises can increase antioxidant activities in our body which help to reduce oxidative stress (JI et al., 1998). According to Centers for Disease Control and Prevention (CDC) of the United States, children ages 3-5 years should be physically active throughout the day and children from 6-17 years should have 60 minutes of moderate to intense physical activity every day. World Health Organization (WHO) has specific and detailed guidelines on physical activities for age groups starting from 0-3months till 18 years old and even more than 18 years old. See table 1.

Laughter exercises:

People who experience greater subjective happiness tend to report fewer symptoms associated with dry eye disease (Kawashima et al., 2015). A study also found that laughter exercises are just as effective as 0.1% sodium hyaluronic acid in alleviating the subjective discomfort of dry eye (J. Li et al., 2024). The lacrimal glands, responsible for producing the watery component of tears, and the meibomian glands, which secrete the oily layer, are primarily regulated by the parasympathetic nervous system. During laughter—particularly when involving deep abdominal breathing—respiratory muscle activity stimulates the autonomic nervous system, activating both sympathetic and parasympathetic pathways. This autonomic stimulation, in turn, enhances tear production and helps relieve dry eye symptoms [(Sakuragi et al., 2002; Sano et al., 2015)].

2.4 Sleep cycle:

One of the important determinants of health and quality of life is quality of sleep. Many studies have shown that lack of good quality of sleep and its short duration can reduce quality of life [(Augner, 2011), (X. Chen et al., 2014)]. There are different guidelines available (WHO, CDC etc.) where age-appropriate required amount of quality of sleep is mentioned (Table 1 and 2). Sleep disturbances and dry eye disease (DED) are two prevalent health concerns that often intersect, especially among young adults. Their bidirectional relationship—where poor sleep can worsen dry eye symptoms and dry eye can, in turn, disrupt sleep—makes it important to understand how they influence each other and how they can be managed together. A recent study has shown how poor sleep quality is linked with dry eye irrespective of age and sex (Magno et al., 2021). However, longitudinal studies are required to comment on improvement of dry eye with the improvement of sleep cycle. American Academy of Sleep Medicine and Sleep Research Society have collaboratively recommended minimum 7 hours of sleep per night on regular basis for young adults. There are many proven factors responsible for sleep disturbances in young adults which can be improved with proper awareness and motivation (Cavic et al., 2021; Kumar et al., 2019; Memon et al., 2021). To address both sleep disturbances and dry eye disease, young adults should adopt the following strategies:

Consistent Sleep Regimen: A consistent circadian rhythm is supported by going to bed and waking up at the same time each day.

Limit Screen Use Before Bed: Avoiding digital devices at least an hour before sleep helps melatonin production.

Practice Stress Management: Techniques like meditation, exercise, and journaling can improve both sleep quality and eye comfort.

Optimize Sleep Environment: Keep the room cool, dark, and quiet which assist deeper sleep and reduce nighttime eye discomfort.

Follow Dry Eye Treatments: Use prescribed eye drops or warm compresses to alleviate symptoms that may disrupt sleep.

2.5 Yoga:

Yoga plays a valuable role in promoting ocular surface health and improving sleep quality through its holistic effects on the body and mind. Regular practice of yoga, particularly breathing exercises (pranayama) and relaxation techniques, helps reduce stress and inflammation, which are key contributors to dry eye disease. Certain yoga postures and eye exercises can enhance blood circulation around the eyes, support tear production, and alleviate eye strain caused by prolonged screen use. Additionally, yoga helps regulate the autonomic nervous system, promoting relaxation and better sleep quality by reducing anxiety and encouraging a consistent sleep pattern. Cortisol and other stress chemicals rise when sleep is reduced. Lower parasympathetic tone, noradrenalin, and adrenalin (S. Li et al., 2022b), which results in less lacrimal tear production and tear hyperosmolarity. Additionally, a decrease in systemic testosterone levels brought on by sleep loss might suppress meibomian gland secretions [(Schmid et al., 2012), (B. D. Sullivan, 2002), (Krenzer et al., 2000)]. A recent study shows that the Sudarshan Kriya Yogic (SKY) breathing technique improves the quality of sleep for healthy persons of all ages and genders. The greatest noticeable long-term advantages of SKY were seen with regular practice (Kanchibhotla et al., 2021). In reaction to stressful situations, the adrenal cortex releases cortisol and β-endorphin (βE) simultaneously after being stimulated by the adrenocorticotropic hormone (ACTH). Physiological stress triggers the release of cortisol, and physical activity has a significant effect on plasma cortisol levels and sympathetic nervous system activation to promote the production of the adrenocorticotropic hormone, which in turn causes the circulation to release cortisol (Drăgoi et al., 2024). According to a 2013 study that was published in the Indian Journal of Psychiatry, a validated yoga module dramatically reduced cortisol levels and eventually maintained the production of lacrimal tears (Thirthalli et al., 2013).

Studies have shown a significant decrease in Ocular Perfusion Pressure (OPP) in both eyes immediately following yogic practices (Schmid et al., 2012). One such technique, the Mind Sound Resonance Technique (MSRT)—a yoga-based relaxation method—was shown in a study at SVYASA University to reduce blood pressure, heart rate, and anxiety after just one session. These findings suggest that guided yoga can help maintain healthy OPP, thereby supporting ocular surface health (B. D. Sullivan, 2002). Furthermore, incorporating yoga, meditation, a balanced diet, weight management, and lifestyle changes can help address modifiable risk factors and therefore can support both visual comfort and restful sleep.

2.6 Screen Time:

WHO have recommended (Table 1) screen time which is age appropriate. Screen time beyond the recommended level can disturb sleep cycle and increase sedentary time which is not at all acceptable especially for young adults. Therefore, less screen time is utmost important to maintain healthy lifestyle.

Table 1: WHO recommendations on physical activity, screen time and sleep time.

Age Group	Specific Age	Recommended Physical Activity Duration	Type of Activity	Recommended Sleep Duration (hours/day)	Recommended Screen Time
Infants (<1 year)	0–3 months	≥30 minutes/day in prone position while awake	• Interactive floor-based play under caregiver supervision• Sedentary time should include reading or storytelling• Should not be restrained (e.g., prams, carriers, highchairs) for >1 hour at a time	14–17 hours	Not recommended
	4–11 months	Same as above	Same as above	12–16 hours	Not recommended

Age Group	Specific Age	Recommended Physical Activity Duration	Type of Activity	Recommended Sleep Duration (hours/day)	Recommended Screen Time
Toddlers (1–2 years)	1 year	≥180 minutes/day accumulated over the day	• A mix of light, moderate, and vigorous intensity activities• Sedentary time should include reading or storytelling under adult supervision• Restraint/sitting should be limited to <1 hour at a time	11–14 hours	Not recommended
	2 years	Same as above	Same as above	Same as above	≤1 hour/day
Preschoolers (3–4 years)	3–4 years	≥180 minutes/day; ≥60 minutes moderate-to-vigorous	• Activities of varying intensity, with at least 60 minutes of moderate-to-vigorous activity• Sedentary time should involve supervised reading or storytelling• Should not be restrained or seated >1 hour at a stretch	10–13 hours	≤1 hour/day
Children & Adolescents	5–17 years	≥60 minutes/day across the week	•Primarily moderate-to-vigorous aerobic physical activity• Include vigorous-intensity and muscle-strengthening activities ≥3 days/week• Minimize sedentary time (no fixed duration defined)	Not specified	Less is better (no defined limit)
Adults	18–64 years	150–300 minutes/week (moderate) or 75–150 minutes/week (vigorous)	• Aerobic physical activity of moderate-to-vigorous intensity• Include muscle-strengthening activities ≥2 days/week involving major muscle groups	Not specified	Less is better (no defined limit)

Table 2: CDC (Centers for Disease Control and Prevention) guidelines on physical activity for Americans

Age Group	Recommended Physical Activity	Recommended Sleep Duration
3–5 years	Should engage in physical activities consistently throughout the day to support healthy growth and development.	Not specifically defined
6–12 years	Minimum of 60 minutes per day of moderate-to-vigorous intensity physical activity. Activities should include aerobic exercises, along with muscle and bone-strengthening exercises at least 3 days per week.	9 to 12 hours per day
13–18 years	Minimum of 60 minutes per day of moderate-to-vigorous intensity physical activity. Should incorporate aerobic, muscle-strengthening, and bone-strengthening activities on at least 3 days per week.	8 to 10 hours per day
Above 18 years	Encouraged to move more and reduce sedentary behaviour. Should accumulate 150–300 minutes per week of moderate-intensity aerobic activity, or 75–150 minutes per week of vigorous-intensity activity. Muscle-strengthening activities should be performed on at least 2 days per week.	Not specifically defined

3. Pollution Control:

Air pollution is a major concern for overall health worldwide. Ocular surface health is not excluded from that. With increased urbanization and industrialization our eyes come in contact with the polluted air both outdoors as well as indoors (Mo et al., 2019). According to World Air Quality report 2023 by IQ Air, India is the third most polluted country in the world and New Delhi is the city which is contributing the most followed by Kolkata, Mumbai and Chennai. World Health Organization (WHO) has reported Particulate Matter, Carbon Monoxide, Ozone at ground level, Nitrogen dioxide and Sulfur dioxide as key air pollutants.

3.1 Outdoor Air Pollution and Dry Eye Disease:

Ambient exposure to air pollutants, including particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), ozone (O_3), and sulphur dioxide (SO_2), has been correlated with an elevated risk and increased severity of dry eye disease (DED) (Kai et al., 2024a). These pollutants may trigger oxidative stress and inflammatory responses on the ocular surface, leading to tear film destabilization and epithelial cell damage(Novaes et al., 2010a). It has been reported that there is a significant influence of ambient air pollution on dry eye symptoms (Kai et al., 2024b). Additionally, research indicates that lower temperatures combined with higher levels of PM2.5, O_3, and NO_2 exacerbate ocular symptoms and increase tear osmolarity, further contributing to DED pathogenesis(Kim et al., 2020a).

3.2 Indoor Air Pollution and Dry Eye Disease:

Indoor environments can also harbor pollutants detrimental to ocular health (Torricelli et al., 2011). Volatile organic compounds (VOCs) are among the most prevalent indoor air pollutants, emitted from building materials and furnishings, as well as particulate matter from cooking and heating sources(Yang et al., 2023). These hazardous agents induce ocular surface irritation and inflammation including DED. Moreover, interventions aimed at improving indoor air quality, such as the use of air purifiers and humidifiers, have shown potential in alleviating DED symptoms, underscoring the importance of environmental modifications in disease management (Vijayan et al., 2015).

Table 3: Air Pollutants and their impact on ocular surface

Type of Air Pollutant	Impact on Ocular Surface	Type of Ocular Discomfort
Particulate Matter (PM2.5 / PM10)	Causes oxidative stress, inflammation, and tear film instability	Dryness, burning, foreign body sensation
Nitrogen Dioxide (NO_2)	Induces inflammation and irritation of conjunctival and corneal cells	Redness, itching, irritation
Ozone (O_3)	Damages epithelial cells and reduces mucin secretion	Grittiness, tearing, sensitivity to light
Sulphur Dioxide (SO_2)	Lowers tear pH, causing ocular surface irritation	Stinging, watery eyes, eye pain
Volatile Organic Compounds (VOCs)	Disrupt tear film stability and irritate the conjunctiva	Eye strain, burning, blurred vision
Carbon Monoxide (CO)	Reduces oxygen delivery to ocular tissues	Fatigue, mild eye discomfort (indirect effects)
Indoor Particulate Matter (e.g., from cooking, smoking)	Enhances inflammation and destabilizes tear film	Irritation, dryness, worsening of pre-existing dry eye
Formaldehyde	Triggers allergic reactions and ocular inflammation	Redness, tearing, itching

Exposure to high levels of environmental air pollution has been associated with several adverse changes on the ocular surface. Tear film stability decreases due to oxidative stress and inflammation caused by pollutants like PM2.5, ozone, and nitrogen dioxide, which disrupt the tear film's lipid and mucin layers [(Novaes et al., 2010a), (Kim et al., 2020b)]. Tear film osmolarity tends to increase under polluted conditions, indicating a hypertonic tear environment that promotes ocular surface irritation and inflammation [(Torricelli et al., 2011; Yang et al., 2023).

Moreover, in goblet cell hyperplasia an increase in mucin-secreting cells has been observed as a compensatory response to chronic irritation from air pollutants. While initially protective, prolonged exposure can impair goblet cell function and worsen dry eye symptoms ((Novaes et al., 2010b)). Together, these changes reflect the significant role of air pollution in the development and progression of dry eye disease. Understanding the relationship between environmental pollutants and DED is crucial for developing effective prevention and management strategies. Measures to reduce exposure to harmful pollutants like using protective eyewear (wrap-around sunglasses), preservative-free lubricating eye drops to maintain tear film and flush out irritants, face masks, avoid rubbing eyes, air purifiers for indoor usage etc. alongside traditional therapeutic approaches, can play a vital role in mitigating the burden of DED.

4. Contact Lens overuse and lack of hygiene:

Contact lens uses for refractive error is highly prevalent among young adults (18-30 yrs), due to cosmetic preference, convenience, and active lifestyles [(Ezinne et al., 2022; Rhee et al., 2022; RILEY & CHALMERS, 2005). However, inconsistent or extended wear patterns are common due to academic demands, screen-based activities, social events, and travel, which lead to prolonged daily use and sometimes overnight wear [(Bashir et al., 2024), (Markoulli & Kolanu, 2017)]. Common Wear Habits (‘Centers for Disease Control and Prevention’ USA, n.d.) in Young Adults are: wearing lenses for more than 12–14 hours/day, sleeping or napping with lenses on, infrequent replacement of lenses beyond recommended schedule, reusing or topping off disinfectant solution in lens cases, skipping cleaning steps due to time constraints or lack of awareness, using tap water or saliva to rinse lenses in emergencies, incomplete blinking and decreased tear production during screen time.

These patterns reflect a general underestimation of risk and lack of adherence to safe wear guidelines among young adult users which increases the risk of microbial keratitis, inflammatory events, and meibomian gland dysfunction further associated with manifestations of dry eye and ocular irritation (Table 4). Inflammatory mediators released during these conditions further damage the epithelial barrier, perpetuating the disease cycle.

Table 4: Behavioural Risk Factors and Management Strategies in Contact Lens Wear Among Young Adults

Wear Habits of Young Adults	Potential Risks and Complications	Preventive Strategies
Wearing lenses for more than 12–14 hours/day	Dry Eye & Ocular Surface Disease (tear film instability, dryness, irritation)	Limit lens wear to 8–12 hours/day
Sleeping or napping with lenses on	Hypoxia & Corneal Edema (decreased oxygen supply, corneal swelling)	Avoid overnight lens wear
Infrequent replacement of lenses beyond the recommended schedule	Allergic Reactions & Giant Papillary Conjunctivitis (immune response, discharge, lens intolerance)	Emphasize compliance with replacement schedules
Reusing or topping off disinfectant solution in lens cases	Microbial Keratitis (serious infections like Pseudomonas keratitis, risk of vision loss)	Educate on proper lens care and hygiene; use fresh solution each time

Wear Habits of Young Adults	Potential Risks and Complications	Preventive Strategies
Skipping cleaning steps due to time constraints or lack of awareness	Increased risk of infections and inflammation due to poor hygiene	Educate users and simplify routines where possible
Using tap water or saliva to rinse lenses in emergencies	Exposure to harmful microorganisms (e.g., Acanthamoeba), leading to serious infections	Never use tap water/saliva. Carry sterile saline or backup lenses
General non-adherence to wear and hygiene guidelines	Multiple complications including MGD, infection, hypoxia, dryness	Recommend daily disposables for poor compliance; schedule regular eye exams to monitor ocular health

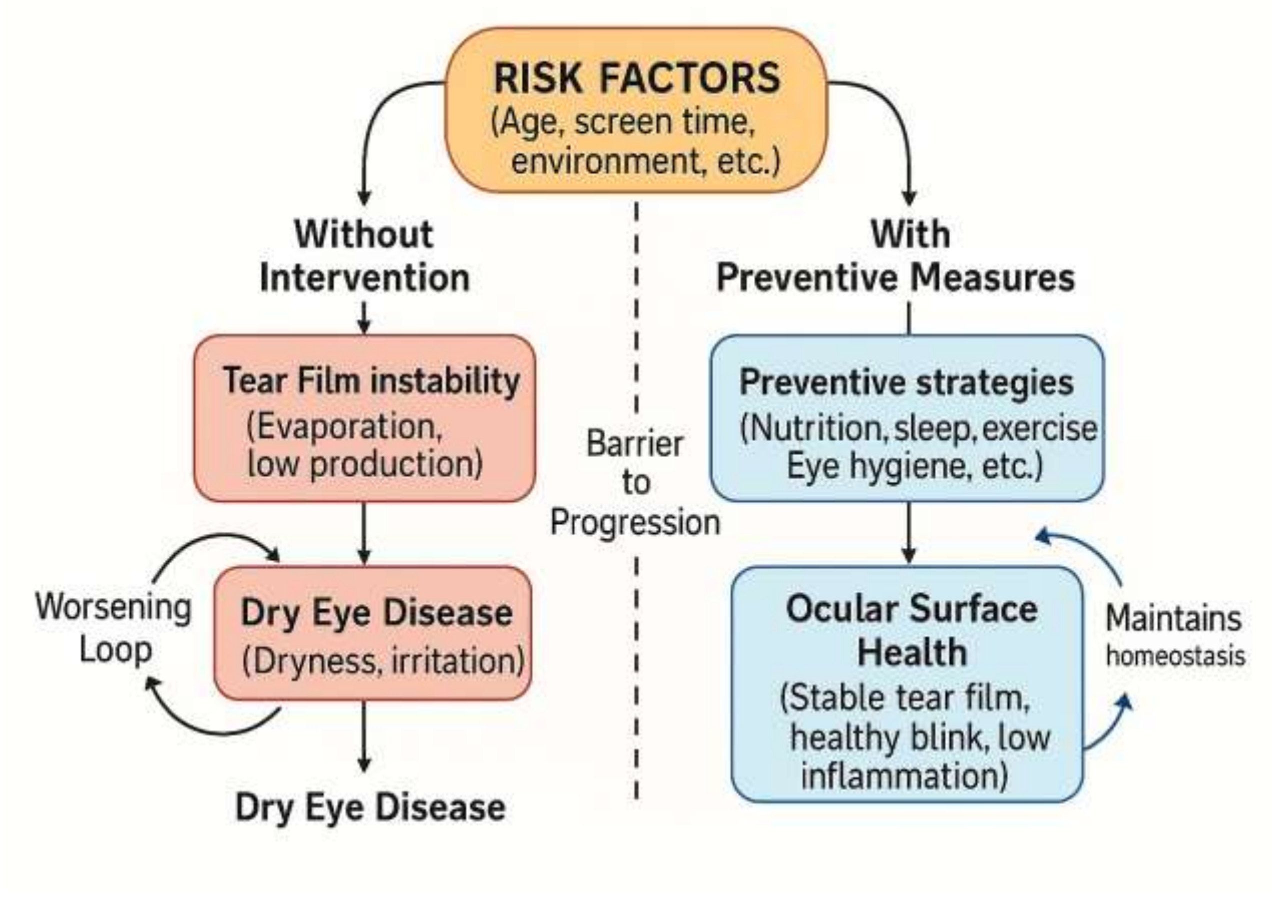
5. Early diagnosis:

Early diagnosis of ocular surface disease (OSD), especially in young individuals, is critical for preventing long-term damage and preserving visual comfort and quality of life (Baral Pawan et al., 2024). OSD including conditions like dry eye disease, meibomian gland dysfunction and allergic conjunctivitis, often begins subtly with symptoms such as mild dryness, itching, or intermittent irritation. These early signs are frequently overlooked or misattributed to fatigue, screen use or environmental factors, leading to delays in appropriate care.

Young people today face unique risk factors for OSD including excessive screen time, exposure to digital devices, environmental pollution, and contact lens overuse (Jones et al., 2023). These exposures can alter tear film composition, destabilize ocular surface homeostasis, and increase the risk of chronic inflammation (Y. Chen et al., 2009). Early diagnosis allows for timely interventions, such as improving tear film stability, managing environmental triggers, and promoting lifestyle changes (e.g., screen breaks, proper hydration, and improved blink patterns). Moreover, addressing subclinical disease can reduce progression to more severe forms of dry eye or corneal damage.

Modern diagnostic tools like tear break-up time (TBUT), ocular surface staining, osmolarity testing, and meibography enable clinicians to detect early changes in the ocular surface before significant symptoms develop. Patient education and routine screening in at-risk groups, especially young adults in academic or urban settings, are essential strategies for prevention.

Figure 1: Impact of Risk Factors and Preventive Strategies on Ocular Surface Health



Conclusion:

Ocular Surface Disease (OSD), particularly Dry Eye Disease (DED), is emerging as a significant yet under-recognized health burden among young individuals. Once considered a condition of older age, DED is now increasingly documented in school-aged children, university students, and young professionals—largely driven by prolonged screen exposure, urban environmental stressors, sedentary behaviour, poor lifestyle choices, and improper contact lens use. The subtle onset and multifactorial nature of OSD demand a proactive and holistic approach grounded in evidence-based preventive strategies.

This review synthesizes growing scientific evidence supporting a range of strategies that target modifiable risk factors. Digital eye strain and screen-induced tear film instability, for example, can be mitigated through behavioural modifications such as looking at something 20 feet away every 20 minutes for 20 seconds, conscious blinking, and use of screen filters or blue light-blocking glasses. Clinical studies have demonstrated that supplementation with omega-3 fatty acids, vitamin D, and antioxidant-rich diets can help reduce inflammation and enhance meibomian gland function, which is essential for maintaining tear film stability.

Consistent physical and outdoor activity have been shown to enhance systemic antioxidant capacity, regulate circadian rhythms, and reduce digital overexposure—factors crucial for ocular surface homeostasis. Sleep hygiene, too, is backed by evidence linking adequate rest to improved tear quality and redox balance. Yoga, particularly pranayama and relaxation techniques, has demonstrated effectiveness in regulating autonomic function, reducing cortisol levels, and even improving tear secretion, making it a promising non-pharmacological adjunct in DED prevention.

Equally important is the emerging recognition of the ocular surface microbiome and its disruption due to long-term antibiotic use or preservative-containing eye drops. Judicious prescribing practices and preference for preservative-free formulations are supported by both in-vitro and clinical data to preserve microbial balance and epithelial health.

Environmental interventions such as improving indoor air quality through humidifiers and air purifiers, as well as using protective eyewear in high-pollution areas, are supported by epidemiological studies linking particulate matter and gaseous pollutants to ocular surface inflammation and oxidative stress.

Furthermore, structured educational programs targeting young contact lens users are critical. Evidence from clinical audits and observational studies shows that adherence to recommended wear schedules, proper hygiene, and regular eye check-ups significantly reduce complications such as microbial keratitis and meibomian gland dysfunction—both major contributors to DED.

Lastly, the role of early diagnosis cannot be overstated. Advanced diagnostic modalities like tear film osmolarity testing, meibography, and non-invasive tear break-up time (NIBUT) have made it possible to identify preclinical or subclinical DED, allowing for early intervention. Incorporating routine screening in high-risk populations, such as students and office workers, is an evidence-supported recommendation from multiple expert consensus reports.

In summary, addressing OSD and DED in young people requires a paradigm shift—from reactive treatment to proactive, evidence-based prevention. Multi-disciplinary engagement, including eye care professionals, educators, public health authorities, and families, is essential to implement and sustain these strategies. By integrating lifestyle, environmental, nutritional, and clinical approaches, we can build a resilient framework for lifelong ocular surface health.

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