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Impact of Air Conditioning on Dry Eye Symptoms: A Cross-Sectional Study Using the Ocular Surface Disease Index

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ABSTRACT

Background:

Dry eye disease (DED) is a prevalent, multifactorial ocular condition that significantly impacts quality of life. Environmental factors, particularly air conditioning (AC), have been implicated in exacerbating dry eye symptoms. AC systems alter indoor air quality by reducing humidity, increasing airflow, and introducing pollutants—all of which may negatively influence the ocular surface. Despite widespread AC use, the extent of its impact on DED symptoms remains underexplored in controlled population settings.

Aim:

To assess the impact of air conditioning exposure on Ocular Surface Disease Index (OSDI) scores and tear production among individuals residing or working in air-conditioned versus non-air-conditioned environments.

Methods:

This cross-sectional observational study included 100 participants aged 18 years and above, categorized based on AC exposure duration (0, 1–10, 11–15, >15 hours/day) and environment (indoor vs. outdoor). The OSDI questionnaire was administered to evaluate dry eye symptom severity. Tear production (in mm) and temperature set points were recorded. Statistical analyses included chi-square tests and independent sample t-tests to assess associations and differences between groups. A p-value of <0.01 was considered statistically significant.

Results:

Participants with longer AC exposure had significantly higher OSDI scores, indicating more severe symptoms. Indoor participants (72%) reported a higher mean OSDI score (30.2 ± 17.3) than outdoor participants (17.5 ± 14.9; p < 0.001). Tear production was lower in indoor environments: OD (11.2 ± 4.2 mm vs. 15.3 ± 4.1 mm, p < 0.001) and OS (11.4 ± 4.6 mm vs. 16.0 ± 4.1 mm, p < 0.001). Temperature set points were significantly lower indoors. A strong association was observed between AC duration and both environmental setting and age group.

Conclusion:

Prolonged exposure to air conditioning is associated with increased severity of dry eye symptoms and reduced tear production. These findings highlight the adverse effects of AC-induced environmental changes—such as low humidity and increased airflow—on the ocular surface. Given the rising reliance on AC systems, especially in urban and occupational settings, environmental assessment should be integrated into dry eye evaluations. Preventive strategies like humidity control and limiting AC exposure may help mitigate symptom severity.

Keywords: *Dry Eye Disease, Ocular Surface Disease Index, Air Conditioning, Ocular Surface Health*

1. INTRODUCTION

Dry eye disease is a common and chronic ophthalmic disorder affecting the ocular surface, characterized by a loss of tear film homeostasis. This condition manifests with symptoms of discomfort, fluctuating or poor-quality vision, and tear film instability, which can lead to potential damage to the ocular surface.1 The global incidence of DED is on the rise, posing substantial health and economic burdens on society.2 Its prevalence can vary significantly, ranging from 5% to 50% worldwide, depending on the specific study population and the diagnostic methods employed.3 DED is intricately linked to alterations in the tear film, necessitating therapeutic strategies aimed at its restoration and the amelioration of symptoms.4 The Ocular Surface Disease Index (OSDI) is a widely recognized and validated 12-item questionnaire employed to quantify the severity of DED symptoms. This instrument assesses various aspects of the disease, including vision-related function, general ocular symptoms, and the influence of environmental triggers on eye comfort.5 Air conditioning (AC) systems, while providing thermal comfort, significantly alter indoor environments, thereby influencing the ocular surface through several physiological mechanisms. These mechanisms extend beyond simple desiccation to include inflammatory and neurosensory responses. Low humidity is a well-established environmental factor consistently associated with a higher prevalence of dry eye disease. This condition leads to an accelerated rate of tear evaporation, resulting in a shorter tear film breakup time (TBUT) and increased ocular surface staining.6 The effect of temperature, however, presents a more complex and sometimes contradictory picture. Some research indicates that higher ambient temperatures correlate with an increased diagnosis of dry eye 6, while other studies suggest that lower temperatures can aggravate DED symptoms and signs, leading to higher SANDE scores, increased ocular staining, and elevated tear osmolarity.6 Conversely, high temperatures have also been shown to increase tear evaporation.6 High air velocity, a common characteristic of AC systems, significantly impacts the tear film. It promotes faster evaporation and thinning of the tear film by disrupting the boundary layer of air immediately adjacent to the ocular surface.7 In individuals with dry eye, exposure to such airflow leads to a significant decrease in tear meniscus height (TMH) and area (TMA), coupled with a notable increase in blink frequency. These changes indicate an insufficient compensatory tear secretion response in dry eye subjects.7 Indoor air quality, particularly the presence of particulate matter (PM) and gaseous pollutants, plays a substantial role in contributing to DED.1 Both inorganic and organic PM are linked to inflammatory responses on the ocular surface, characterized by increased expression of inflammatory markers such as IL-8, TNF-α, and NF-κB, as well as oxidative stress, leading to reactive oxygen species (ROS) production and DNA damage.8 Gaseous pollutants, including ozone, nitrogen dioxide (NO2), and volatile organic compounds (VOCs), can also induce inflammation (e.g., increased IL-1β, IL-6, IL-8, IL-17, IFN-γ) and oxidative stress, ultimately contributing to cell death on the ocular surface.8 Adverse environmental conditions, including those created by air conditioning, can directly activate corneal nerves, leading to the subjective dry eye symptoms commonly reported by patients, such as dryness, aching, tenderness, and burning sensations.1 The OSDI is specifically designed to capture these subjective discomforts, and studies confirm its strong correlation with patients' perception of symptoms and the degree to which these symptoms interfere with their daily activities.5 Indeed, worse ocular discomfort is consistently associated with worse overall dry eye symptoms as measured by the OSDI.9 Despite the growing reliance on air-conditioned environments in modern residential, occupational, and educational settings, the specific impact of air conditioning exposure on dry eye symptomatology and tear production remains underexplored, especially in diverse real-world populations. Existing literature presents conflicting evidence, with some studies highlighting significant associations while others report negligible effects—largely due to differences in methodology, geographic climate, and AC system variability. Moreover, limited research has focused on quantifying the relationship between the duration of AC exposure and validated clinical metrics such as the Ocular Surface Disease Index (OSDI) and tear secretion. This study addresses this critical gap by systematically evaluating the association between air conditioning exposure and dry eye symptoms using standardized tools in a defined population. Understanding this link is essential for developing targeted clinical and public health strategies aimed at mitigating modifiable environmental risk factors for dry eye disease.

Table 1: Physiological Mechanisms Linking AC to Dry Eye Disease

Environmental Factor (influenced by AC)	**Proposed Mechanism**	**Ocular Impact**
Low Humidity	Faster tear evaporation, desiccating stress[6]	Shorter TBUT/NIBUT, increased tear osmolarity, ocular surface staining, inflammation
High Airflow/Air Velocity	Elimination of tear film boundary layer, increased evaporation[7]	Thinning tear film, decreased tear meniscus height/area, increased blink frequency, insufficient compensatory tearing
Particulate Matter (PM)	Inflammation (IL-8, TNF-α, NF-κB), oxidative stress (ROS, DNA damage), apoptosis[2]	Increased OSDI scores, ocular irritation, dryness
Gaseous Pollutants (Ozone, NO2, VOCs)	Inflammation (IL-1β, IL-6, IL-8, IL-17, IFN-γ), oxidative stress, direct cytotoxicity[8]	Increased OSDI scores, ocular irritation, cell death
Neurosensory Activation	Direct stimulation of corneal nerves by adverse conditions[1]	Subjective discomfort (dryness, aching, burning, irritation), correlation with OSDI

2. MATERIALS AND METHODS

This was a cross-sectional observational study. A total of 100 individuals were enrolled in the study through convenient sampling. Inclusion criteria included participants aged 18 years and above, with or without symptoms of dry eye, and who had varying levels of air conditioning (AC) exposure. Participants with active ocular infections, recent ocular surgeries, or systemic diseases known to affect the ocular surface (e.g., Sjögren's syndrome, diabetes) were excluded. Participants were administered the Ocular Surface Disease Index (OSDI) questionnaire, a validated 12-item tool designed to measure the severity of dry eye symptoms. Along with OSDI scoring, demographic data (age, gender), duration and intensity of AC exposure (categorized into four groups: 0, 1–10, 11–15, and >15 hours/day), and environmental setting (indoor vs. outdoor) were recorded. Measurements for tear production (in mm) for both eyes (OD and OS) and room temperature set points were also noted. Ethical approval for this study was obtained from the institutional review board of GD Goenka University (Ref: GO/OPT/2023/13). Data were analyzed using descriptive and inferential statistical methods. Descriptive statistics included frequency, percentage, mean, and standard deviation (SD). Inferential statistics included chi-square tests for associations between AC duration and categorical variables (e.g., age group, indoor/outdoor exposure). Independent sample t-tests were used to compare the means of OSDI scores and tear production between indoor and outdoor groups. A p-value of <0.01 was considered statistically significant.

3. RESULTS

A total of 100 participants were included in the study. The demographic distribution showed that 41% were aged between 21 to 30 years, followed by 28% between 31 to 40 years, 16% between 41 to 50 years, 9% below 20 years, and 6% above 50 years. 52% of the participants were female and 48% were male as shown in table 2.

Table 2: Frequency of age of the respondents

	Frequency (n)	Percentage (%)
Less than 20 year	9	9.0
21 to 30	41	41.0
31 to 40	28	28.0
41 to 50	16	16.0
More than 50 years	6	6.0
Total	**100**	**100.0**

Among all participants, 72% reported primarily working or residing in indoor environments, while 28% were in outdoor settings. Regarding the duration of air conditioning (AC) exposure 41% had no exposure to AC, 23% were exposed for 1 to 10 hours/day, 12% for 11 to 15 hours/day, 24% had more than 15 hours/day of AC exposure as shown in table 3.

Table 3: Frequency of duration of AC Use

	Frequency (n)	Percentage (%)
0	41	41.0
1 to 10	23	23.0
11 to 15	12	12.0
More than 15	24	24.0
Total	**100**	**100.0**

A statistically significant association was found between the duration of AC use and the environmental setting (indoor vs. outdoor) ($\chi^2 = 37.795$, $p < 0.001$), with indoor participants showing higher exposure to AC. There was a significant association between the duration of AC use and age group ($\chi^2 = 48.243$, $p < 0.001$). Notably, individuals aged 21–30 and 31–40 years had higher durations of AC exposure compared to other age groups. The mean OSDI score among participants was 26.6 ± 17.6, with a range from 10.4 to 89.3. The average temperature set point reported was 44.6 ± 38.8, indicating variability in room temperature control. Tear production, measured in millimeters using the Schirmer test or equivalent, showed a mean value of 12.4 ± 4.5 mm in OD and 12.7 ± 4.9 mm in OS.

The comparison between indoor and outdoor participants revealed statistically significant differences across several parameters as shown in table 4 and table 5. The Ocular Surface Disease Index (OSDI) scores were notably higher among individuals in indoor environments (mean = 30.2 ± 17.3) compared to those in outdoor settings (mean = 17.5 ± 14.9), with a t-value of 3.629 and a p-value of less than 0.001, indicating a higher severity of dry eye symptoms indoors. Tear production, assessed in both eyes, was significantly reduced in indoor participants. For the right eye (OD), the mean tear production was 11.2 ± 4.2 mm in indoor subjects versus 15.3 ± 4.1 mm in outdoor subjects ($t = -4.380$, $p < 0.001$). Similarly, in the left eye (OS), tear production was 11.4 ± 4.6 mm for indoor participants compared to 16.0 ± 4.1 mm in outdoor participants (t = -4.799, p < 0.001). Additionally, the temperature set point reported by indoor participants was significantly lower (mean = 36.0 ± 32.7) than that reported by outdoor participants (mean = 66.9 ± 44.4), with a p-value of 0.002. These findings collectively suggest that indoor air-conditioned environments may contribute to increased dry eye symptoms and reduced tear production.

Table 4: Association between Duration of AC Use and Indoor / Outdoor

		Indoor / Outdoor		Total	Chi Square (p value)
		Indoor	Outdoor		
Duration of AC Use (Hrs./Days)	0	16	25	**41**	**37.795 (0.000)****
	1 to 10	21	2	**23**	
	11 to 15	12	0	**12**	
	More than 15	23	1	**24**	
Total		**72**	**28**	**100**	

*****p<0.01***

Table 5: Difference in means between the parameters between Indoor / Outdoor

Parameter	Indoor / Outdoor	N	Mean	SD	t value	p value
Temperature	Indoor	72	36.0	32.7	-3.341	**0.002****
	Outdoor	28	66.9	44.4		
OSDI	Indoor	72	30.2	17.3	3.629	**0.000****
	Outdoor	28	17.5	14.9		
OD	Indoor	72	11.2	4.2	-4.380	**0.000****
	Outdoor	28	15.3	4.1		
OS	Indoor	72	11.4	4.6	-4.799	**0.000****
	Outdoor	28	16.0	4.1		

*****p<0.01***

A longer duration of exposure to air conditioning was found to be associated with higher OSDI scores, indicating more severe dry eye symptoms. Participants who spent more time in indoor, air-conditioned environments exhibited significantly reduced tear production alongside increased symptom severity. These findings suggest that environmental factors such as temperature and airflow, which are influenced by air conditioning systems, have a measurable and detrimental impact on ocular surface health and dry eye symptomatology.

4. DISCUSSION

Several studies have explored the direct correlation between air conditioning exposure and OSDI scores. A study conducted among university undergraduate students in Ghana, for instance, identified a significant association between symptomatic dry eye and discomfort experienced in air-conditioned rooms (χ=89.0, P<0.001).10 Symptomatic DED in this study was defined by an OSDI score of ≥13 or a SPEED score of ≥6. This finding suggests a clear link between AC environments and the subjective experience of DED. Conversely, a cross-sectional study involving Polish university students reported no statistically significant correlation between the amount of time spent in air-conditioned interiors and OSDI scores (p=0.376) or DEQ-5 scores (p=0.568).11 This apparent contradiction in findings underscores the influence of specific population characteristics, study methodologies, and potentially the precise environmental parameters of the AC systems themselves. The Ghanaian study used a broader definition of symptomatic DED and a chi-square test for association, whereas the Polish study focused on the duration of AC exposure and employed correlation coefficients and regression models for OSDI scores. Differences in climate, AC system types, building designs, and baseline DED prevalence within the student populations could all contribute to this variability. The intensity of AC exposure, such as direct airflow or extremely low humidity, may be more critical than mere presence or duration in some contexts. This suggests that the impact of AC on subjective symptoms is not universally consistent and may be modulated by other factors.

While a meta-analysis on the efficacy of a specific DED treatment (perfluorohexyloctane) did not find a significant difference in OSDI scores compared to controls, this meta-analysis was not directly focused on AC as an environmental factor.12 Another meta-analysis concerning DED prevalence in Central and South America mentioned AC exposure as a characteristic investigated in one included study, but specific findings related to OSDI were not detailed in the provided information.3 In the DREAM study, OSDI scores did not correlate with individual environmental exposures (e.g., windspeed, most airborne pollutants), although dry eye signs did differ between climates and local humidity levels.13 This suggests a complex interplay where subjective symptoms might be influenced by a broader set of factors or have a delayed response compared to objective signs. Direct, consistent data specifically quantifying the impact of AC exposure duration on OSDI scores remains limited in the reviewed literature. However, related factors such as screen time duration, which often occurs in air-conditioned environments, have been investigated. Prolonged screen exposure, particularly exceeding four or eight hours daily, has been significantly correlated with higher OSDI scores and more severe DED symptoms in some studies.11 This suggests that the cumulative effect of environmental stressors, including those from AC, might contribute to symptom severity. The literature presents conflicting findings regarding the direct correlation between AC exposure and OSDI scores, as seen in the contrasting results from Ghanaian and Polish student populations.11 Furthermore, the DREAM study observed that OSDI scores did not correlate with individual environmental exposures (e.g., windspeed, most airborne pollutants), even though objective dry eye signs did differ significantly between climates and local humidity levels.13 This suggests a complex interplay where subjective symptoms might be influenced by a broader set of factors, or that there may be a delayed response in symptom perception compared to objective physiological changes.

These inconsistencies are crucial for understanding the nature of DED symptoms and environmental influences. They imply that subjective symptoms, as measured by OSDI, might be influenced by a more holistic perception of the environment or by a cumulative effect of multiple stressors, rather than a direct, immediate response to a single environmental variable. This also raises the possibility of a disconnect or lag between objective physiological changes and subjective symptom reporting, which can complicate DED diagnosis and management. It means that while AC causes objective changes, a patient's perception of those changes, and consequently their OSDI score, might be influenced by other factors or only manifest after a certain threshold of exposure or ocular surface damage.

5. CONCLUSION

This study provides compelling evidence that prolonged exposure to air-conditioned environments is significantly associated with increased severity of dry eye symptoms, as reflected in higher Ocular Surface Disease Index (OSDI) scores and reduced tear production in both eyes. The findings clearly demonstrate that individuals who spend more time in air-conditioned indoor settings experience greater ocular discomfort and lower tear volume compared to those in outdoor or naturally ventilated environments. These results suggest that the environmental alterations caused by air conditioning—such as low humidity, high airflow velocity, and changes in temperature—have a measurable and detrimental impact on the ocular surface, potentially exacerbating or triggering dry eye disease (DED). Our results also reinforce the multifactorial nature of DED, where environmental conditions play a key role in symptom severity and tear film instability. The significantly higher OSDI scores among indoor participants indicate that subjective symptoms are not only prevalent but may also be underestimated in clinical settings where environmental exposure is not routinely assessed. The association between AC exposure and reduced tear secretion points to the physiological stress imposed on the ocular surface, possibly due to increased evaporation and insufficient compensatory tearing mechanisms. The implications of these findings are especially important in today's lifestyle, where the use of air conditioning is ubiquitous in residential, educational, and occupational settings. With the global rise in screen time and increased indoor confinement—trends accelerated by remote work and climate change—the ocular health burden linked to air-conditioned environments is expected to rise further. These results emphasize the need for heightened clinical awareness and proactive strategies, such as the use of humidifiers, scheduled breaks from AC exposure, ocular lubricants, and workplace modifications, to mitigate the risk and severity of dry eye symptoms.

Moreover, this study opens the door for future research exploring objective biomarkers of tear film quality and inflammatory changes in relation to AC exposure. Longitudinal studies involving larger, more diverse populations, along with interventional trials to assess the efficacy of environmental modifications, will be valuable in developing a comprehensive approach to dry eye management in modern living conditions.

In conclusion, while air conditioning offers comfort, it also presents an underrecognized risk factor for ocular surface disruption. Integrating environmental history into routine eye examinations, raising public awareness about modifiable risk factors, and developing targeted interventions could significantly improve the quality of life for individuals suffering from dry eye disease in climate-controlled environments

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