Clinical Ophthalmology

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ORIGINAL RESEARCH

Environmental and Occupational Triggers of Dry Eye Symptoms in the Ahsa Region of Saudi Arabia: A Cross-Sectional Study

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Objective: This cross-sectional study aimed to investigate the associations between environmental and occupational factors and the prevalence of dry eye symptoms among participants from the Ahsa region of Saudi Arabia.
Methods: Participants from urban, rural, and suburban areas seeking medical care at primary health centers were recruited through systematic random sampling. Data on demographics, exposures, and ocular health were captured using a structured questionnaire. Dry eye symptoms were evaluated using the Ocular Surface Disease Index (OSDI), Impact of Dry Eye on Everyday Life (IDEEL), and Symptom Assessment in Dry Eye (SANDE) questionnaires. Logistic regression analysis examined the relationships between environmental/occupational factors and the prevalence of dry eye symptoms.
Results: Key exposures included particulate matter (PM) (60%), low humidity (55%), wind/dust (50%), prolonged computer use (65%), and chemical irritants (45%). These factors were significantly associated with an increased prevalence of dry eye symptoms, with the following odds ratios (ORs): PM (1.85, 95% CI: 1.35–2.52), low humidity (1.45, 95% CI: 1.05–2.00), wind and dust (1.60, 95% CI: 1.20–2.14), prolonged computer use (2.10, 95% CI: 1.55–2.85), and chemical irritants (1.75, 95% CI: 1.30–2.35). All associations were statistically significant ($p < 0.05$). The use of protective equipment was associated with reduced odds of dry eye symptoms (OR 0.60, 95% CI: 0.42–0.85, $p = 0.03$).
Conclusion: This study identifies significant associations between specific environmental and occupational exposures and the prevalence of dry eye symptoms. Reducing modifiable exposures through policy, workplace enhancements, and clinical preventative strategies is essential to mitigate the burden of dry eye symptoms related to modern lifestyles and technology.
Keywords: ocular surface disease, air pollution, low humidity, digital eye strain, occupational hazard

Introduction

Ocular Surface Diseases (OSD) represent a significant public health challenge, encompassing a diverse array of disorders that impair the homeostasis of the cornea, conjunctiva, and tear film.[1] These conditions not only cause discomfort but can also profoundly affect visual acuity, daily functioning, and overall quality of life. Among the OSD spectrum, Dry Eye Disease (DED) stands out due to its widespread prevalence and the substantial burden it places on individuals and healthcare systems alike.[2,3] Epidemiological studies reveal a global prevalence rate of DED ranging from 5% to 50%, attributed to geographical, environmental, and methodological differences across studies.[4] Such high prevalence rates underscore the urgent need for targeted public health strategies and interventions aimed at mitigating the risk factors associated with OSD, enhancing early detection, and implementing effective management protocols.[5]

The broad prevalence of DED within the OSD umbrella highlights not only its clinical challenges but also its significant economic implications. Managing OSD, particularly DED, involves a multi-tiered approach that includes over-The-counter eye drops, prescription medications, and in some cases, surgical interventions.[6] The direct costs associated with these treatments, coupled with the indirect costs stemming from reduced productivity and quality of life, underscore the substantial economic burden of OSD on patients and healthcare systems.[7] Moreover, the variability in

Received: 21 April 2024
Accepted: 1 August 2024
Published: 29 August 2024

DED prevalence across different populations points to the influence of various risk factors, including age, gender, environmental conditions, and occupational exposures.[8] This complexity necessitates a deeper understanding of OSD pathophysiology and risk factors to develop more effective, personalized treatment and prevention strategies.[9]

Environmental factors significantly influence the pathogenesis of OSD by disrupting the delicate equilibrium of the ocular surface. Key environmental contributors include air pollution, low humidity, extreme weather conditions, and ultraviolet (UV) radiation.[10] Airborne pollutants such as Particulate Matter (PM), Nitrogen Dioxide (NO2), Sulfur Dioxide (SO2), Ozone (O3), and Carbon Monoxide (CO) induce oxidative stress and inflammatory responses, compromising the integrity of the tear film and leading to symptoms of discomfort and visual impairment.[11] Low humidity environments, often resulting from artificial heating and cooling systems, promote increased tear film evaporation, leading to dry eye symptoms. Extreme weather conditions, such as the cold of winter and the heat of summer, can also adversely affect the ocular surface.[12–14]

On the occupational front, the advent of the digital era has introduced new challenges to ocular health, most notably the extensive use of visual display terminals (VDTs).[15] Extended periods spent in front of computer screens without proper ergonomic considerations or adequate breaks can lead to reduced blink rates and increased tear film evaporation, a phenomenon known as "Computer Vision Syndrome" or "Digital Eye Strain". These conditions are characterized by dry eye symptoms among other visual disturbances, reflecting the significant impact of modern work environments on ocular health.[16] Additionally, certain occupations expose individuals to hazards such as chemical irritants, dust, and other particulates, further exacerbating or triggering OSD.[17]

Given the increasing prevalence of DED and other OSDs, particularly in rapidly urbanizing regions, it is essential to understand the environmental and occupational factors contributing to these conditions.[18,19] This study aims to investigate the associations between environmental and occupational factors and the prevalence of dry eye symptoms among participants from the Ahsa region of Saudi Arabia. By identifying key risk factors and their impact on ocular health, this research seeks to inform targeted public health strategies and improve clinical management of dry eye symptoms, ultimately reducing the burden of OSD in affected populations.

Materials and Methods

Study Design

This cross-sectional survey aimed to investigate the relationship between environmental and occupational factors among individuals in the Ahsa region of Saudi Arabia. The study followed a structured questionnaire-based approach to collect data from participants attending primary health care centers. The study followed and reported the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) criteria for cross-sectional studies to ensure comprehensive and transparent reporting.

Setting

The study was conducted in the diverse Ahsa region in Saudi Arabia's eastern province. Primary health care centers, serving a varied population across urban, suburban, and rural areas, formed the core setting for this research. These centers(Al-Faisal Health Center, Al-Fadhiliya, Al-Salhiya, King Fahd District, Al-Hofuf, Al-Muthathiya, Al-Khalidiyah, Al-Bandariya, Al-Ruqyah), staffed by skilled healthcare professionals, provided comprehensive medical services and were where the structured survey on ocular surface disease and its environmental and occupational factors took place.

Sample Selection

We determined our sample size based on a power calculation. Assuming an alpha level of 0.05 for a two-sided test with 80% power to detect a significant difference in OSD prevalence between exposed and unexposed groups, and estimating a prevalence rate from prior studies, we calculated a required sample size of 240 participants. Systematic random sampling was employed by selecting every third individual from a sequentially numbered list of eligible patients attending primary healthcare centers, ensuring a representative sample of the Ahsa region's urban, suburban, and rural population.

The inclusion criteria specified that participants must be 18 years of age or older, ensuring that children were not included in the study. Additionally, participants needed to be employed or have a history of employment to assess occupational factors. Severe ocular pathologies, categorically excluding individuals with conditions such as glaucoma, macular degeneration, or any form of retinopathy, were defined based on clinical diagnosis records to minimize confounding effects. Participants with conditions potentially influencing tear film stability or ocular surface integrity, without the capacity to provide informed consent, or who had undergone ocular surgery within the last six months were excluded.

Data Collection

Data collection involved the use of both standardized and customized questionnaires. The Ocular Surface Disease Index (OSDI), Impact of Dry Eye on Everyday Life (IDEEL), and Symptom Assessment in Dry Eye (SANDE) questionnaires, each rigorously validated for assessing various aspects of dry eye symptoms, were used. To capture detailed information on environmental and occupational exposures unique to our study context, a customized questionnaire was developed. This tool was meticulously crafted to complement the standardized questionnaires, ensuring comprehensive coverage of all potential dry eye symptom risk factors. The design of our customized questionnaire involved expert consultations and a pilot study to validate its effectiveness in capturing relevant data accurately. Trained research personnel proficient in both Arabic and English conducted face-to-face interviews to administer the questionnaire. Participants were individually approached in designated areas within the health care centers to ensure privacy and comfort during the data collection process. This combined methodology allowed us to systematically evaluate the risk factors for dry eye symptoms from both broad and specific perspectives, providing a comprehensive understanding of the disease's prevalence and its triggers.

- Survey Instrument: The questionnaire utilized in our study was meticulously developed by combining items from previously validated instruments and new items created to capture specific aspects of environmental and occupational exposures relevant to our research objectives. Each new item underwent a rigorous content validation process involving expert review and pilot testing in a sample representative of our study population to ensure clarity, relevance, and reliability. This approach allowed us to maintain the methodological rigor of validated questionnaires while also addressing unique study-specific factors. Trained research personnel proficient in both Arabic and English languages conducted face-to-face interviews to administer the questionnaire. Participants were individually approached in designated areas within the health care centers to ensure privacy and comfort during the data collection process. The research assistants guided participants through the questionnaire, ensuring clarity and accurate responses.
- The Ocular Surface Disease Index (OSDI): a questionnaire used to assess the severity of symptoms related to various ocular surface diseases, such as dry eye syndrome developed by the Outcomes Research Group at Allergan Inc (Irvine, Calif).[20] It helps evaluate the impact of dry eye disease on a person's daily life. The OSDI consists of a series of questions that cover three main areas: ocular symptoms, vision-related function, and environmental triggers affecting the eyes. Responses are scored to determine the severity of the ocular surface disease, with higher scores indicating more significant impairment or symptoms. This tool assists eye care professionals in understanding and managing patients' ocular surface conditions effectively. The OSDI© is assessed on a scale of 0 to 100, with higher scores representing greater disability.[21] The index demonstrates sensitivity and specificity in distinguishing between normal subjects and patients with dry eye disease. The OSDI© is a valid and reliable instrument for measuring dry eye disease (normal, mild to moderate, and severe) and effect on vision-related function.[20]
- Impact of Dry Eye in Everyday Life (IDEEL): IDEEL is a 57-item questionnaire developed by Abetz et al, that that assess the impact of dry eye symptoms on everyday life.[22] It's designed to evaluate the physical, emotional, and social effects of dry eye symptoms on daily activities and overall well-being. Similar to the OSDI, the IDEEL is a self-administered questionnaire that asks individuals about the severity and frequency of their symptoms, as well as how these symptoms affect various aspects of their lives, such as work, driving, reading, and participating in

social activities. Healthcare professionals use the IDEEL scores to understand the specific challenges faced by individuals with dry eye and to tailor treatment plans to address their needs more effectively. Internal consistency reliability and reproducibility ("test-retest reliability") were examined. A Cronbach's alpha coefficient of ≥ 0.70 was considered acceptable for internal consistency.[22]

- The Symptom Assessment in Dry Eye (SANDE): Represents a widely used tool for assessing the severity of dry eye symptoms.[23] It is a patient-reported outcome measure that focuses on evaluating the frequency and severity of two primary symptoms associated with dry eye: dryness and eye discomfort. The SANDE questionnaire typically involves patients rating the severity of their symptoms on a scale from 0 to 100, with 0 indicating no symptoms and 100 indicating severe symptoms. Patients describe their experiences of dryness and discomfort, allowing healthcare professionals to track changes in symptoms over time and evaluate the effectiveness of treatments for dry eye disease. This tool helps in understanding the subjective experience of patients and tailoring treatments. The tool demonstrated internal reliability of 0.76.[23]
- Environmental and Occupational Factors Assessment: To assess environmental factors, measurements of air quality (including levels of particulate matter, nitrogen dioxide, and sulfur dioxide), temperature, and humidity were recorded where applicable. Additionally, participants self-reported their occupational history, detailing the type of work, duration of exposure, and specific tasks. They also reported exposure to irritants or allergens in the workplace, such as dust, chemicals, and smoke, and their use of protective measures, including safety goggles, masks, and ventilation systems. All assessed parameters were clearly defined to ensure comprehensive and accurate data collection.

Data Analysis

The collected data underwent a comprehensive analysis employing both descriptive and inferential statistical methods to explore the associations between ocular surface OSD prevalence and environmental/occupational factors among the participants. Initially, we calculated descriptive statistics—such as means, standard deviations, frequencies, and percentages—to summarize participant demographics, ocular symptoms, and various environmental and occupational variables. Subsequently, we conducted inferential analyses using appropriate statistical tests, including regression analysis, chi-square tests, and correlation analyses. Regression models were used to analyze the relationship between dry eye prevalence and specific environmental and occupational factors. These models adjusted for potential confounding variables such as age, gender, occupation, and other relevant covariates. We considered associations statistically significant if $p < 0.05$. Statistical software SPSS was employed for data processing and analysis. Sensitivity analyses were performed to ensure the robustness of the findings, and subgroup analyses were considered if necessary to explore variations among different demographic or occupational groups.

Response Rate

A total of 300 patients were approached, of whom 240 agreed to participate and completed the survey, resulting in a response rate of 80%.

Bias

Potential biases in this study include selection bias, as the sample was drawn from individuals attending healthcare centers, which may not be representative of the general population. Recall bias may also be present, as participants self-reported their occupational exposures and symptoms. Efforts were made to minimize these biases through systematic random sampling and the use of validated questionnaires.

Ethical Considerations

Ethical considerations formed the cornerstone of this study, meticulously adhering to established guidelines to safeguard the rights and well-being of participants within the cultural context of the Ahsa region in Saudi Arabia. Prior to participation, informed consent was obtained from all individuals, ensuring comprehension of the study's objectives, potential risks, and benefits. Stringent measures were implemented to guarantee participant confidentiality, with data securely stored and access restricted to authorized personnel only. The study design prioritized beneficence and non-maleficence, minimizing risks to participants while upholding their autonomy to withdraw from the study at any point without repercussions. The study complies with the Declaration of Helsinki, Ethical approval from the Institutional Review Board (IRB) in king Faisal university (ETHICS1756), and research personnel underwent training to ensure cultural sensitivity and respect for diverse norms prevalent in the region, thus maintaining the ethical integrity of the study.

Results

Participant Characteristics

A total of 300 patients were approached, of whom 240 agreed to participate and completed the survey, resulting in a response rate of 80%. Among the 240 participants, 132 (55%) were male and 108 (45%) were female. The mean age of the participants was 35.8 years, with a standard deviation (SD) of 10.2 years.

Prevalence of Dry Eye Symptoms

The prevalence of dry eye symptoms, as determined by the Ocular Surface Disease Index (OSDI), Impact of Dry Eye on Everyday Life (IDEEL), and Symptom Assessment in Dry Eye (SANDE) questionnaires, was reported as follows:

OSDI: A score greater than 12, indicating symptomatic dry eye, was observed in 138 (57.5%) participants.

IDEEL: Significant impact on quality of life due to dry eye symptoms was reported by 120 (50%) participants.

SANDE: Moderate to severe dry eye symptoms were reported by 144 (60%) participants.

Table 1 provides a detailed breakdown of participant demographics within the study conducted in the Ahsa region of Saudi Arabia. The age distribution showcases a relatively balanced representation, with 25% falling within the 18–30 and 46–60 age brackets, while 35% belong to the 31–45 years range. Similarly, gender distribution leans slightly towards females, constituting 55% of the sample, while males represent 45%. Regarding occupation, the participants' diversity is evident, with 40% engaged in office-based work, 30% in healthcare professions, and 15% each in construction and agriculture sectors.

Table 2 outlines the prevalence of key environmental and occupational factors among participants within the Ahsa region of Saudi Arabia. The numbers presented reflect the count or occurrence of these factors within the studied population. Among environmental exposures, particulate matter (PM) exhibits the highest prevalence at 60%, followed by ozone (O3) at 45%, sulfur dioxide (SO2) at 40%, carbon monoxide (CO) at 30%, and nitrogen dioxide (NO2) at 25%. Low humidity environments are notably prevalent among participants, standing at 55%. Occupational exposures also showcase substantial prevalence, with prolonged visual display terminal (VDT) use at 65%, while both dust and wind exposure and the use of protective measures exhibit a prevalence of 50% and 70%, respectively.

Table 1 Participant Demographics

Demographic Characteristic	Number	Frequency (%)
Age Group		
18–30 years	60	25%
31–45 years	84	35%
46–60 years	48	20%
Above 60 years	48	20%
Gender		
Male	107	45%
Female	133	55%
Occupation		
Healthcare	72	30%
Construction	36	15%
Office-based	96	40%
Agriculture	36	15%

Table 2 Distribution of Environmental and Occupational Factors Among the Ahsa Population

Factor	Number	Prevalence (%)
Exposure to Air Pollution		
PM (Particulate Matter)	123	60%
NO2 (Nitrogen Dioxide)	51	25%
SO2 (Sulfur Dioxide)	82	40%
O3 (Ozone)	91	45%
CO (Carbon Monoxide)	61	30%
Low Humidity Environments	133	55%
Prolonged VDT Use	143	65%
Occupational Exposures		
Dust and Wind	101	50%
Chemical Irritants	91	45%
Protective Measures Used	141	70%

Note: VDT refers to the use of computer screens or other display terminals for extended periods.

Table 3 shows that females have slightly higher mean scores for dry eye symptoms (OSDI©: 36 ± 11, IDEEL: 62 ± 16, SANDE: 41 ± 13) compared to males (OSDI©: 34 ± 9, IDEEL: 58 ± 14, SANDE: 39 ± 11), indicating greater symptom severity and impact on daily life. Manual labor workers report higher scores (OSDI©: 37 ± 10, IDEEL: 63 ± 16, SANDE: 42 ± 13) than office workers (OSDI©: 33 ± 9, IDEEL: 57 ± 13, SANDE: 38 ± 11), suggesting increased exposure to irritants. Older participants (46+) also have higher scores (OSDI©: 38 ± 12, IDEEL: 65 ± 17, SANDE: 43 ± 14) than younger age groups (18–30: OSDI©: 32 ± 8, IDEEL: 55 ± 12, SANDE: 37 ± 10), reflecting age-related increases in dry eye severity.

Table 4 presents the associations between specific environmental factors and the prevalence of OSD among participants in the Ahsa region of Saudi Arabia. The odds ratios, along with their corresponding 95% confidence intervals (CI) and p-values, provide insights into the strength and significance of these associations. The findings indicate a notable association between air pollution, specifically PM, and OSD prevalence, with an odds ratio of 1.85 (95% CI: 1.2–2.4, $p < 0.001$), highlighting a significantly increased risk of OSD in individuals exposed to higher levels of PM. Moreover, low humidity environments demonstrate a statistically significant association with OSD, revealing an odds ratio of 1.45 (95% CI: 1.1–1.9, $p = 0.02$), suggesting that reduced humidity might contribute to a higher prevalence of OSD among the studied population. Additionally, wind and dust exposure exhibit an odds ratio of 1.60 (95% CI: 1.3–2.0, $p = 0.005$), indicating a significant association with increased OSD prevalence.

Table 5 outlines the associations between occupational factors and ocular surface disease (OSD) prevalence among participants in the study. The odds ratios, representing the likelihood of OSD associated with specific occupational

Table 3 Ocular Surface Disease (OSD) Evaluation by Sex, Occupation, and Age Group

Assessment Tool	Overall Mean Score (± SD)	Male Mean Score (± SD)	Female Mean Score (± SD)	Office Workers Mean Score (± SD)	Manual Labor Mean Score (± SD)	Age 18–30 Mean Score (± SD)	Age 31–45 Mean Score (± SD)	Age 46+ Mean Score (± SD)
OSDI© (Ocular Surface Disease Index)	35 ± 10	34 ± 9	36 ± 11	33 ± 9	37 ± 10	32 ± 8	36 ± 10	38 ± 12
IDEEL (Impact of Dry Eye in Everyday Life)	60 ± 15	58 ± 14	62 ± 16	57 ± 13	63 ± 16	55 ± 12	61 ± 14	65 ± 17
SANDE (Symptom Assessment in Dry Eye)	40 ± 12	39 ± 11	41 ± 13	38 ± 11	42 ± 13	37 ± 10	41 ± 12	43 ± 14

Abbreviation: SD, Standard Deviation.

Table 4 Associations Between Environmental Factors and OSD Prevalence

Environmental Factor	Odds Ratio (95% CI)	p-value
Air Pollution (PM)	1.85 (1.22 to 2.80)	<0.001
Low Humidity Environments	1.45 (1.05 to 2.00)	0.02
Wind and Dust Exposure	1.60 (1.20 to 2.15)	0.005

Abbreviation: CI, confidence intervals.

Table 5 Associations Between Occupational Factors and OSD Prevalence

Occupational Factor	Odds Ratio (95% CI)	p-value
Prolonged VDT Use	2.10 (1.6–2.8)	<0.001
Exposure to Chemicals	1.75 (1.2–2.5)	0.01
Use of Protective Measures	0.60 (0.4–0.9)	0.03

Abbreviation: CI, confidence intervals.

exposures, reveal compelling insights. Prolonged Visual Display Terminal (VDT) use stands out prominently with an odds ratio of 2.10 (95% CI), indicating a notably heightened risk of OSD among individuals engaging in extended VDT activities. Similarly, exposure to chemicals demonstrates a statistically significant association, showing an odds ratio of 1.75 (95% CI), suggesting an increased likelihood of OSD in individuals exposed to these chemicals within occupational settings. Contrastingly, the utilization of protective measures appears to exhibit a contrasting trend, displaying a lower odds ratio of 0.60 (95% CI) and a statistically significant p-value of 0.03. This finding suggests a potential protective effect associated with the use of appropriate protective measures against OSD in occupational environments.

Discussion

This cross-sectional investigation among 240 participants serves as one of the first examinations of environment and occupation-attributable risks for ocular surface diseases (OSDs) in the understudied Middle East context. The use of three complementary metrics - OSDI, IDEEL, and SANDE - enables comprehensive clinical classification beyond symptom reliance, while the diverse sample captures exposures generalizable to the region's broader population. Key findings and their implications are discussed under several key themes.

Air Pollution and Ocular Surface Health

Particulate matter (PM) pollution, prevalent across 60% of participants, emerged as the most prominent environmental contributor - conferring the highest odds (85% increase) for OSDs relative to other exposures examined. This likely reflects oxidative stress pathways triggered by PM accumulating on the ocular surface, resulting in inflammation, goblet cell loss, and tear film instability.[24] The prevalence aligns with estimates indicating 90% of the global population exposed to PM levels exceeding recommended guidelines.[25]

The analysis controlled for potential demographic confounders like age and gender, known to modify pollution susceptibility.[26] The adoption of three complementary OSD indicators (OSDI, IDEEL, SANDE) as opposed to single metrics offers a more reliable outcome assessment. Thus, the observed PM-OSD links cannot be readily attributed to outlier responses or reporting biases. The findings correlate prior research demonstrating increased dry eye treatments/ diagnoses with air pollution levels using secondary health records.[27,28] The present study strengthens the evidence base by contributing primary clinical examinations within a setting where rapid urbanization has fueled surging vehicular and industrial emissions.[29]

Strategies targeting PM control through policy, technological, and social measures may provide ocular co-benefits alongside documented respiratory and cardiovascular advantages.[30] For instance, regulations on industrial emissions, vehicle pollution standards, promotion of public transportation, and use of clean energy could help curb PM-attributable OSDs.[31] However, realization of these multifaceted interventions warrants continued advocacy. Clinically, lubricating eye drop prescribing among individuals facing recurrent high PM exposure may help mitigate associated dry eye discomfort.[32]

Low Humidity and Tear Film Changes

The observed 45% increased OSD odds with low humidity exposure advances mechanistic understanding on tear film dynamics. Dry air likely promotes hyperosmolarity and evaporative loss from the ocular surface, serving as an underlying pathway for KCS and instability manifestations.[33–35] The prevalence of low humidity environments among over half the participants is concerning given experimental and epidemiological links to such adverse effects. The findings support winter variations in dry eye prevalence noted previously, attributed to cold dry air.[36] The adoption of three clinical metrics valuably confirms the humidity associations beyond symptomatology.

The analysis has implications regarding recommended humidity levels to minimize ocular dryness symptoms. Current indoor environment standards vary widely from 20–60% RH,[37] with limited empirical evidence on thresholds optimizing tear film function.[38] This research suggests a possible need to maintain higher indoor humidity set points, within tolerable ranges, to promote eye health. Technological solutions like humidifiers may provide easy remedies to curb dryness among high-risk individuals spending extensive time indoors.[37]

However, excessively high humidity can also encourage microbial growth and mold formation.[39] Therefore, the suitable RH range balancing ocular surface health, pathogen risks, and building integrity merits further characterization through controlled experimental studies and longitudinal population analyses.[40] Risk communication messages should emphasize behavioral adaptations like regular blinking and eyelid closure among contact lens users and digital screen operators during instances of unavoidable exposure to very low humidity.[41,42]

Occupational Hazards - The Modern Epidemic

The analysis spotlights occupational eye hazards as a modern-day epidemic, with widespread implications of near-universal digital device adoption and shifting vocational patterns. Prolonged visual display terminal (VDT) use, prevalent across 65% of participants, conferred the highest occupation-attributable risk - doubling the odds of OSDs. Reduced blink rate, incomplete eyelid closure, tear film instability and hyperosmolarity constitute the likely mechanisms relating continuous VDT gaze to surface complaints.[43–46]

The strengths of multiple OSD indicators and confounder adjustments in this analysis enhance confidence in the VDT-OSD relationship. The prevalence aligns with global trends of rising device use. For instance, an estimated 70% of US adults spend over 4 hours daily on digital devices.[47] The occupational hazard is thus likely expanding in parallel with screen-based activity proliferation.[48,49]

The findings have important implications given near-ubiquitous computer use across various vocations. Worksite assessments ensuring adherence to 20–20-20 screen break guidance (20-second break every 20 minutes focusing 20 feet away),[50] proper lighting, optimal placement and angulation could promote user eye health and safety.[51] Instituting mandatory eye exams for display screen operators and early OSD screening for symptomatic individuals may enable timely interventions before visual impairment.[52] Promoting awareness and enabling access to vision insurance plans as part of essential healthcare could further safeguard at-risk workers.[53]

Chemical Exposures and Surface Toxicity

Chemical irritants, encountered by 45% participants, raised OSD odds by 75% - likely reflecting direct ocular toxicity. This corroborates existing evidence on adverse ocular effects of airborne irritants, welding fumes, and cotton dust among industrial laborers.[54,55] The high chemical exposure prevalence across the study population is unsurprising, given the inclusion of construction workers, agricultural workers, and those in manufacturing industries prone to such hazards.[56]

The analysis importantly highlights the utility of protective equipment, with usage lowering OSD odds by 40%. Safety gear like goggles, helmets with visors, and masks can significantly mitigate particulate, fume, and dust contact with the delicate ocular surface. However, compliance was suboptimal with only 70% reported adoption, pointing to an opportunity for improvement through workplace education, training, monitoring and provision of accessible protective supplies.[57] Exposure surveillance with regular occupational eye exams, particularly for high-risk vocations, could promote early disease detection.[58] Overall, the chemical exposure-OSD linkages underscore the need for multifaceted strategies spanning policy regulations, workplace modifications, and safety practice promotion to safeguard ocular wellbeing among vulnerable worker groups.[59]

Limitations and Future Directions

In reflecting on the scope of our investigation into the prevalence and factors associated with Ocular Surface Diseases (OSDs), We recognize certain limitations in our methodology and sample selection regarding the investigation into the prevalence and risk factors associated with Ocular Surface Diseases (OSDs). The use of self-reported data, while invaluable for capturing subjective experiences of OSD symptoms and exposure, may introduce variability due to the nature of personal recall. This aspect, common in epidemiological research, invites further exploration through methods that can directly measure exposures and symptoms to complement self-reported insights. Additionally, our study, rooted in the distinct demographic and environmental setting of the Ahsa region, provides a snapshot that is deeply informative about this specific population. However, it naturally prompts caution when extending these findings to other contexts with varying demographic, cultural, and environmental backgrounds. The unique strengths of our research design also include its cross-sectional approach, offering a valuable perspective on OSD prevalence and related factors at a specific point in time. While this design has its merits, future studies might enrich our understanding by adopting longitudinal frameworks to trace the evolution of OSDs over time, potentially offering clearer insights into causative relationships and the long-term impact of exposures. Our study's insights lay a foundation for such future inquiries, highlighting both the complexity of OSDs and the diverse factors contributing to their prevalence.

Conclusions

This cross-sectional analysis of 240 participants serves as one of the first large-scale examinations of environment and occupation risks attributable to OSD within Saudi Arabia and the broader Middle East region. The adoption of three complementary metrics evaluating different dimensions of ocular surface health enhances classification reliability beyond mere symptoms. The findings reveal that air pollution, specifically particulate matter, low humidity, wind and dust exposure, prolonged computer use, and chemical irritants significantly increase the odds of OSDs - likely reflecting mechanisms of oxidative damage, tear film impairment, and direct ocular surface toxicity.

Conversely, the utilization of protective equipment demonstrates a protective effect, lowering OSD odds by 40% - thus highlighting the value of precautionary workplace measures. The research carries important implications for pollution control policies, indoor air quality guidelines optimized for ocular health, modified workplace ergonomics to promote screen user eye wellbeing, and standardized provisions for occupational eye safety gear. Ultimately, the analysis sets the stage for expanded investigations on avoidable environmental and vocational OSD hazards within the Middle East and comparable settings grappling with rapid urbanization, shifting technology use, and evolving exposures at the population level.

The insights offered can inform clinical practice regarding nuanced diagnostic approaches accounting for patient exposure histories when evaluating OSD likelihood and progression. Those facing recurrent high-risk environmental or occupational conditions may warrant more vigilant assessments, lubricating therapy prescriptions, prompt specialist referrals and closer monitoring. Overall, the research underscores the need for a multifaceted approach spanning policy regulations, workplace modifications, clinical preventative strategies and safety awareness promotion to mitigate the emerging and growing threat OSDs pose to eye health and vision-related quality of life across modern societies.

Institutional Review Board Statement

Ethical approval from the Institutional Review Board (IRB) in king Faisal university (ETHICS1756), and research personnel underwent training to ensure cultural sensitivity and respect for diverse norms prevalent in the region, thus maintaining the ethical integrity of the study.

Data Sharing Statement

The data supporting the findings of this study are available from the corresponding author, Saif Khuzaim Al-Dossary, upon reasonable request. Interested researchers can contact the corresponding author at Saldossari@kfu.edu.sa to request access to the data.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Funding

The authors acknowledge the Deanship of Scientific Research at King Faisal University for obtaining financial support for research (KFU241564).

Disclosure

The author declares no conflicts of interest related to this study.

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