Clinical Ophthalmology

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ORIGINAL RESEARCH

Prevalence and Determinants of Symptomatic Dry Eye Disease Among Adult Urban Residents of High-Altitude Areas of Southwest Saudi Arabia – A Survey

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Purpose: To estimate the prevalence and determinants of Ocular Surface Disease Index (OSDI) score based dry eye disease (DED) among the adult urban population of four cities located at high altitudes in Southwest Saudi Arabia.

Methods: This cross-sectional survey was held in 2023. OSDI questionnaire was used to collect the responses of the adult participants. The score was further graded into none, mild, moderate, and severe DED to estimate age-sex-adjusted DED prevalence. The OSDI score was correlated to demographic (age group, gender, education, occupation, city) and risk factors like smoking and co-morbidities.

Results: Of the 401 adults, 388 (response rate of 97.8%) participated. The age-sex-adjusted prevalence of mild, moderate, and severe DED was 21.7%, 13.1%, and 32%, respectively. The median ODSI score was 22.9 [Interquartile range (IQR) 10.4; 47.9)]. The score was significantly higher in females (Mann–Whitney *U*-test P = 0.038), residents of Taif city (KW P = 0.05), those with primary/middle school education (Kruskal–Wallis P = 0.004), comorbidities like hypertension, asthma (KW P < 0.001) and risk factors like past refractive surgeries, arthritis (KW P = 0.013). Education status (P <0.001) [B = −9.0 95%] and presence of comorbidity (P = 0.022), [B = −0.823] were significant predictors of DED.

Conclusion: The prevalence of DED and severe grade was high. The level of education and presence of comorbidities significantly influenced DED in the adult urban Saudi population of cities at high altitudes.

Keywords: dry eye disease, Ocular Surface Disease Index

Introduction

Dry eye disease (DED) is a rapidly evolving health issue globally. Its prevalence ranges from 5% to 50%.[1] People suffering from DED complain of irritation, stinging, dryness, ocular fatigue, and fluctuating visual disturbances.[2] DED negatively affects person's health-related quality of life and causes an economic burden on the health care system and society.[3] Both environmental and personal factors cause DED. They include advancing age, female sex, low humidity environments, systemic medications, and autoimmune disorders.[4]

During Covid 19 pandemic, restriction of outdoor activities, use of face masks and exposure to excessive screen time by using visual display terminals, and non-availability of eye care in need further increased the problem of DED both in adults and children.[5,6]

For effective public health intervention and better preventive and therapeutic care to the identified persons with DED, information on the magnitude and determinants are crucial. The health services including medications are provided free

Received: 22 June 2023
Accepted: 30 August 2023
Published: 11 September 2023

of cost by the government to the Saudi citizen. As a part of VISION 2030, the Kingdom periodically reviews the need and implements revision of services.[7] Being a large country with nearly 30 million population in 215,000 KM^2, DED is likely to vary in different parts. Most of the KSA has a dry and hot climate for nearly 10 months of the year. But in the southwest part of the Kingdom, provinces are hilly, and the climate is relatively humid with different vegetation compared to the rest of northern and central regions of the kingdom.[8] The eastern and western provinces although have coastal areas, the hot climate, and humidity affect a limited part adjoining the sea. Several studies on the prevalence and risk factors of DED are conducted in these provinces.[9–13]

To the best of our knowledge, the magnitude and determinants of DED in the adult population residing in cities at high altitudes in Saudi Arabia are not studied.

We conducted a survey targeting the adult population of Abha, Taif, Al-Baha, and Khamis Mushait cities in southwest Saudi Arabia to determine the prevalence of DED and its determinants. We also compared the rates noted in the literature to study differences in altitude on DED.

Methods

Ethical Issues

The Scientific Research Ethics Committee at King Faisal Medical Complex in Taif approved this study. (2022-A-29). The participants were informed about the purpose of the study, in accordance with the Declaration of Helsinki.

Study Site

Abha, Taif, Al-Baha, and Khamis Mushait (1.3 million as per census 2020) cities were study sites. These cities are situated more than 6000 feet above sea level. The average humidity is 30% (range 27% to 53%).[14]

Inclusion and Exclusion Criteria

The 18 year and older population of four cities invited to participate in this study.[14] Those agreeing to participate were surveyed. Those declining or responding to less than two questions regarding symptoms of dry eye were excluded from the analysis.

Sample Size Calculation

To calculate the sample size, we assumed that the prevalence of DED in study areas is like the global prevalence of 50% in the adult population.[15] To achieve a 95% confidence interval and 8% accepted error margin to the study and clustering effect of 2, we need to survey randomly selected at least 301 participants. To compensate for the nonparticipation, we added a 10% sample. Thus, the final sample was 330. We used Openepi software to calculate the sample for a cross-sectional study.[16]

Sampling and Recruitment

Four investigators visited a central mosque and mall on weekends and a university on weekdays to recruit participants. The stratification of sample was done by population of four cities. However, the response in different cities was variable with a high number of participants recruited from Abha city. Therefore, age-sex adjusted rates were calculated for better representation. The information on the survey for the adult population was distributed through mosque announcements, social media, and emails. For university students E-mails and whatsApp groups were used to inform about survey and request for participation.

Survey Tools and Validity

We used a validated Dry Eye Syndrome Questionnaire.[2,17] The questions were translated into Arabic. Reverse translation was carried out to ensure the quality of the questions. The steps of quality assurance for using Arabic OSDI questionnaire were like those used by Bakker et al and Aljarousha et al.[18,19] The questionnaire and responses were tested for reliability. The Cronbach's Alpha of the Ocular Surface Disease Index (OSDI) of 12 questions was 0.923.

Data Management

The demographic information included age group, gender, education, city of residence, and occupation. Participants replied to principal comorbidity and known risk factors from offered options. Subgroup 1 of the OSDI questionnaire had five questions. Subgroup 2 had four questions and Subgroup 3 had three questions. The frequency of symptoms was given a score from 0 to 4. 0 = not at all, 1 = some of the time, 2 = half of the time, 3 = most of the time, and 4 = all the time in the last week of the survey. To account for partial responses to the questions the following formula was used to calculate the OSDI score:

$$\text{OSDI©} = \frac{(\text{sum of scores}) \text{ x } 25}{(\# \text{ of questions answered})}$$

The DED was graded as "Absent" if the score was "0 to 12", mild if the score is "13 to 22" moderate DED if the score is "23 to 32" and severe DED if the score is 33 and more. To calculate the age-sex-adjusted prevalence of DED, we used a population, examined sample, persons with different grades of DED subgroup of gender, age group, and city of residence. We projected the number of persons with DED in the smallest subgroup and then estimated adjusted prevalence using the total population as the denominator (Supplementary Tables 1–5).

Statistical Analysis

The data was entered into a spreadsheet of Microsoft XL®. After consistency check, the data was transferred into a spreadsheet of Statistical Package for Social Studies (SPSS 25) (IBM, NY, USA). The qualitative variables were presented as numbers and percentage proportions. The quantitative variables were presented as median and interquartile range. To compare the OSDI score (outcome variable) in two subgroups, we used the Mann–Whitney *U*-test to estimate Z and two-sided P values. For more than 2 subgroup comparisons, we used the Kruskal–Wallis *H*-test to estimate the chi-square value and two-sided p-value. A P value of <0.05 was considered statistically significant. The independent variables that were significantly associated with the OSDI score were included in the regression model to study predictors and estimate adjusted Odds ratio with a 95% confidence interval and P value.

Results

We enrolled 401 participants. Of them, 388 completed more than one question so their responses were included in the analysis.

We compared the study population of males and females in age groups. Table 1. Fifty years and older males were overrepresented in our study, while "18 to 25" and "38 to 50" years old females were overrepresented in the examined sample compared to their population proportion. Therefore, the prevalence of DED was age-sex-adjusted.

Table 1 Comparison of Adult Population and Study Participants of Four Cities of Southwest Saudi Arabia

Male				Age-Group	Female			
Population		Study Participants			Population		Study Participants	
Number	%	Number	%		Number	%	Number	%
108,220	14.5	14	8.1	**18 to 25**	104,654	18.4	54	25.1
238,958	32.0	38	22.1	**26 to 37**	194,729	34.2	61	28.4
241,265	32.3	49	28.5	**38 to 50**	150,553	26.4	69	32.1
168,500	22.6	71	41.3	**50 & +**	119,722	21.0	31	14.4
756,944	100	172	100	**Total**	569,659	100	215	100

The age-sex-adjusted prevalence of mild, moderate, and severe DED was 21.7% (95% CI 21.6; 21.8), 13.1% (95% CI 13.0; 13.2), and 32% (95% CI 31.9; 32.1), respectively. Of the 1.3 M adult population in the study area, 0.88 M (66.6%) are projected to have DED. Of them, 0.42M with severe DED. The prevalence of DED by subgroup is given in Table 2.

The median OSDI of 388 adult participants was 22.9 (IQR 10.4; 47.9) (Minimum; Maximum 0.0; 100). The OSDI of the examined sample was compared in subgroups. Table 3. The score was significantly higher in females (Mann–Whitney *U*-test P = 0.038), residents of Taif city (KW P = 0.05), those with primary/middle school education (Kruskal–Wallis P = 0.004), comorbidities like hypertension, asthma and other (KW P < 0.001) risk-like past refractive surgeries, arthritis and other (KW P = 0.013).

Linear regression analysis suggested that Education status (P <0.001) [B = −9.0 95%] and presence of comorbidity (P = 0.022), [B = −0.823] were significant predictors of DED. Of the 41 contact lens users, DED was present in 14 participants. While among 276 participants who were not using contact lenses, 27 had DED. The risk of DED among CL users was not significant (P = 0.43). Of the 26 participants with a history of refractive surgery in the past, DED was present in 19 persons. While among 276 persons without refractive surgery DED was present in 183 persons. The risk of DED among persons with a history of refractive surgery was not significant (P = 0.23).

We compared the DED rates noted in the present study to other studies of Saudi Arabia and other using OSDI questionnaire in Arabic language from the literature. Table 4.

Discussion

The prevalence of DED was high and one-third of them had a severe grade of DED. Females, less educated, residents of Taif city, history of refractive surgeries, hypertension, dyslipidemia, and asthma were significantly associated with higher OSDI scores. Two-thirds of the adult population was projected to suffer from DED. Of them, one-third with a severe grade of DED would need further evaluation and prompt treatment. There is a strong need for DED preventive measures and counseling for adopting eye health measures among the adult population.

Table 2 Prevalence of Symptom-Based Dry Eye Disease (DED) in Adult Population of Four Cities of Southwest Saudi Arabia

		Mild DED		Moderate DED		Severe DED	
		Adjusted Rate*	**95% CI**	**Adjusted Rate**	**95% CI**	**Adjusted Rate**	**95% CI**
Total		21.7	21.6; 21.8	13.1	13.0; 13.2	32.0	31.9; 32.1
Gender	Male	22.5	22.4; 22.6	18.9	18.8; 19.0	28.1	28.0; 28.2
	Female	20.6	20.5; 20.7	5.4	5.3; 5.5	37.1	37.0; 37.2
Age group (Years)	18 to 25	22.0	21.8; 22.2	19.8	19.6; 19.9	27.0	26.8; 27.2
	26 to 37	31.2	31.1; 31.3	11.8	11.7; 11.9	35.0	34.8; 35.1
	38 to 50	15.3	15.2; 15.4	8.6	8.5; 8.7	35.4	35.3; 35.6
	50 +	15.8	15.7; 16.0	16.2	16.0; 16.3	26.4	26.3; 26.6
City	Abha	29.5	29.3; 29.7	7.5	7.4; 7.6	31.5	31.3; 31.7
	Taif	11.2	11.1; 11.3	16.3	16.2; 16.4	46.5	46.4; 46.6
	Al-Baha	37.9	37.7; 38.1	15.9	15.8; 16.0	18.5	18.4; 18.6
	Khamis Mushait	13.8	13.7	6.9	6.8; 7.0	23.6	23.4; 23.8

Notes: *The prevalence rates were adjusted for age, gender and city for the adult population in study area (Census 2021). For example, when the prevalence of mild dry eye disease for male is calculated, it is adjusted for age groups and four cities.

Table 3 Ocular Surface Disease Index (OSDI) Score in Adult Population of Four Cities of Southwest Saudi Arabia

		Examined	Ocular Surface Disease Index		Validation
			Median	**Interquartile Range**	
Gender	Male	176	18.7	9.9; 41.7	MW P = 0.038
	Female	212	25.0	12.5; 50.0	
Age group	18 to 25	68	20.8	8.5; 39.6	KW P = 0.173
	26 to 37	99	18.7	10.4; 44.2	
	38 to 50	117	25.0	8.3; 46.7	
	More than 50 years	104	29.5	14.6; 55.7	
Resident of	Abha	200	20.8	8.3; 47.9	KW P = 0.052
	Taif	111	33.3	14.6; 54.2	
	Al-Baha	34	20.8	14.1; 33.3	
	Khamis Mushait	43	18.8	8.3; 43.8	
Social status	Single	107	20.8	12.5; 45.5	KW P = 0.609
	Married	258	24.0	10.4; 47.9	
	Divorced	18	20.8	12.5; 51.0	
	Widow	5	60.4	14.4; 65.2	
Education	Primary school	12	71.9	29.7; 89.6	KW P = 0.004
	Middle school	6	39.1	5.6; 58.3	
	Secondary school	76	27.1	12.5; 53.1	
	College and higher	294	20.8	10.4; 41.7	
Occupation	Working	209	20.8	8.3; 43.8	MW P = 0.124
	Not working	179	25.0	12.5; 50.0	
Participant reported comorbidities	None	95	18.7	10.4; 39.6	KW P < 0.001
	Allergic rhinitis	58	26.0	14.6; 48.4	
	Diabetes	53	25.0	10.4; 55.2	
	Hypertension	35	41.7	18.8; 68.8	
	Asthma	16	39.6	20.8; 75.8	
	Other	22	39.6	14.6; 61.4	
	Missing	109	16.7	6.3; 39.3	
Participant reported known risk factors	Smoking	48	22.9	14.6; 44.9	KW P = 0.013
	Caffeine intake	45	18.7	11.5; 50.0	
	Vitamin deficiency	40	20.8	13.0; 38.0	
	Using eyedrops	36	26.0	13.9; 51.6	
	Using contact lens	41	25.0	7.9; 50.0	
	H/o refractive surgery	26	33.3	13.3; 41.7	
	Dyslipidemia	22	33.7	13.5; 54.5	
	Arthritis	22	37.9	15.1; 65.6	
	Other	33	36.4	20.8; 61.5	
	None	75	12.5	4.2; 29.5	

Abbreviations: MW, Maan–Whitney; KW, Kruskal–Wallis.

This is perhaps the first study showing the influence of high altitude on DED among adult urban residents of rapidly evolving countries like Saudi Arabia. The validity of the questionnaire used in present study was like that found in Arabic OSDI questionnaire used in Jordan and Palestine.[18,19] Reasonably large sample and age sex adjustment of OSDI score-based prevalence of DED enabled to provide of more accurate rates and projections to undertake public health measures to address this fast-developing eye health issue.

Table 4 Comparison of Rate, Grades and Risk Factors of Dye Eye Disease in Adult Population of Different Studies

S No	Author	Year	Country	Sample Size	Score/Grade	Reference
1	Present study	2022	South KSA	388	Median ODSI score 22.9; Normal (29.4%), Mild (25.5%) Moderate (13.1%), Severe DED (32%)	–
2	Alkhaldi et al	2023	Five regions of KSA	2016	DED prevalence 49.5%	[10]
3	Dossari et al	2022	KSA	1381	DED prevalence 17.5%	[11]
4	Alshamrani et al	2016	Al Hassa, KSA	1858	DED prevalence 32.1%	[12]
5	Yasir et al	2013–17	Riyadh	890	Age-sex adjusted 45.1% in 40 plus population. Female higher risk	[13]
6	Vidal-Rohr et al	2023	UK	282 volunteers	DED prevalence 32.1% by (TFOS DEWS II) criteria	[20]
7	Wu et al	2020	Northern China	1287	DED 34.5% in 40 plus population (OSDI + physical assessment)	[21]
8	Tandon et al		India	9735	DED 26%, Plains 41.3% and 24% in hilly area (OSDI + physical assessment)	[22]
9	Tellefsen et al	2012–18	Norway	1823	42.4% of patient in dry eye clinic (ODSI + assessment)	[23]
10	Bakkar et al	2016	Jordan	1039	59% with OSDI score >20	[24]
11	Betiku et al	2022	South west Nigeria	415	28.2% (ODSI + assessment)	[25]
12	Caffery et al	2017	Ontario, Canada	5163	21.3% (DEQ-5 + assessment)	[26]

In the present study, the prevalence of severe DED was 32%. While 66% had some grade of DED. Aldossari et al used a similar OSDI score to define and grade DED and noted 17% DED prevalence in the adult Saudi population.[11] Yasir et al used McCarty Symptom Questionnaire and noted a 45% age-sex-adjusted prevalence of DED among 40 years and older population of Riyadh governorate.[13] The age-adjusted prevalence of DED in the adult population of Al Hassa province was assessed using six symptoms-based questionnaires and it was 32%.[12] By using Tear Film Ocular Surface Dry Eye Workshop II (TFOS DEWS II) criteria, the researchers noted a 32% prevalence of DED in UK.[20] Literature shows a wide variation of DED assessment both using objective and questionnaire methods and noted a high prevalence of DED globally.[1,21–26] The variations in magnitude and severity of DES in different studies could be due to differential behavior of using digital devices, humidity, temperatures of the study area and comorbidities.

Increasing age is a known risk factor for DED. In our study, the prevalence of DED was not significantly different in age groups. But mild DED was more in the younger population and severe DED was more in the older population. The ODSI score was less than 20 in 18 to 38 years of age, while the score was >20 in the adult population of more than 38 years of age. Elderly people have a 75% higher risk of DED compared to young adults.[1,27] The presence of age-related comorbidities like diabetes, exposure to a dry environment, more screen time, and hormonal changes could be responsible for this observed increased risk of DED by age.

Females had a significantly higher prevalence and severity of DED in our study. Among Asian adult females, the DED rate was higher than males (21.7% vs 16.4%).[28] Higher incidence of refractive error, less outdoor activities and more time spent in front of visual display gadgets, higher risk of dyslipidemia and differential hormonal profile could be responsible for this higher risk of DED.[1,29]

All four cities in our study were at high altitudes (more than 6000 feet above sea level). Our study had high DED prevalence and symptoms of severe grade DED. In contrast, Tandon et al noted that in hilly areas DED prevalence was 24% compared to

41.3% in plains and only 9.9% at places on the seashore.[22] Environmental factors like temperatures, humidity, air pollution, and pollens are associated with ocular surface changes including DED.[30] These factors are likely to be different at the present study site compared to the places mentioned in other studies from Saudi Arabia.[10–13] Higher rate in the present study compared to rates found in the hilly area of India is difficult to explain. Each environmental factor should be associated with DED using a more appropriate study design.

In our study, the OSDI score was 22 among smokers and it was not a significant risk factor for DED. This was also noted in a meta-analysis by Tariq et al.[31] However, information on smoking collected in our study was not of desired details. Therefore, further studies with current vs past, extent, and type of nicotine abuse need to be associated with DED before concluding it as a risk factor.

In our study, DED was not associated with contact lens use or a history of refractive surgery. This contrasted with the findings of Li et al.[32] Selecting persons without DED for contact lens fitting or performing refractive surgeries in eyes could result in differential DED rate. In our study, subjective definition was used for DED, while objective methods are usually used for selecting patients for CL or surgery.

OSDI score among diabetics was higher but not significantly different from non-diabetic persons in our study. The risk of DED and meibomian gland dysfunction was significantly associated with type 2 diabetes and poor glycemic control.[33] An objective assessment of DED is recommended before concluding the association of diabetes with DED.

Among four cities in southwest Saudi Arabia, two-third of the adult population (0.8 Million) are projected to have symptoms of DED. Of them, 0.42 million could be with a severe grade of DED. Therefore, there is an urgent need for a public health approach to address DED. Identified cases with symptoms may be further assessed using objective methods to confirm DED and then offer management to reduce symptoms and visual disabilities.[27,34,35] The population at large should be educated to adopt ways to reduce the risk of DED through mass media and social media. Ministry of Health is aware of the negative impact of exposure to devices with visual display terminals especially in reducing screen time in children.[36]

There were a few limitations in our study. This being the cross-sectional nature of the study, a causal association of the determinants and comorbidities to DED should be done with caution as spatial relationships cannot be established. The DED was entirely symptom-based and needed to be confirmed by objective assessments. Therefore, present study outcomes should be compared with the studies done by a subjective and objective assessment of DED with caution. The sample size calculation was based on 50% prevalence, but our study noted as high as 66%. This could have resulted in calculation error but the sample of 401 instead of 330 could to some extent minimize this error. The examined sample was not recruited by random sampling and stratification. However, age-sex-city adjusted DED rates were carried out to give more reliable projections of DED for the study population.

Conclusions

In the present study adult population of urban areas of high altitude in Saudi Arabia showed a high prevalence of DED. Although the OSDI score is an accepted and widely used method to estimate the magnitude of ocular surface dysfunction, it should be complemented with objective assessments to confirm the presence and severity of DED. Prompt action is needed in the study area to address the DED to reduce its impact on vision-related quality of life. Identified risk factors like female gender and less educated persons should be noted while preparing health education material and selecting the mode of propagating these DED prevention messages to the target population. Primary eye care professionals and family physicians should be periodically trained to diagnose, and suspect DED in patients of systemic comorbidities known to cause DED and provide management to the identified persons at risk.

Acknowledgments

We thank the people of four cities to cooperate and participate in this survey.

Disclosure

The authors report no conflicts of interest in this work.

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