

# Prevalence and Risk Factors of Dry Eye Disease among Adults in Saudi Arabia

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## Abstract

**Background:** Environmental and epidemiological factors increase the risk of dry eye in Saudi Arabia, but most studies have limited generalizability.

**Objective:** To determine the prevalence of dry eye disease (DED) among adults across Saudi Arabia and the associated risk factors. The secondary objective was to estimate the economic burden of DED by calculating lubricant usage and its annual costs.

**Methods:** This cross-sectional study invited adults from across Saudi Arabia to complete a questionnaire that collected data regarding demographics, symptoms related to DED, previous diagnosis of DED, use of contact lenses, and use of eye lubricants.

**Results:** A total of 2042 responses were received, of which 784 (38.4%) respondents had previously been diagnosed with DED and 752 (36.8%) were symptomatic but undiagnosed. Between the DED diagnosed and symptomatic-undiagnosed groups, a significant difference was found in terms of age ( $P < 0.001$ ), gender ( $P = 0.002$ ), presence of diabetes mellitus ( $P = 0.004$ ), smoking status ( $P = 0.007$ ), duration of electronic screen use ( $P = 0.05$ ), number of ocular complaints ( $P < 0.001$ ), and frequency of lubricants use ( $P < 0.001$ ). Between the DED-diagnosed and non-DED groups, significant differences were found in terms of age ( $P < 0.001$ ), gender ( $P < 0.001$ ), presence of diabetes mellitus ( $P = 0.001$ ), allergy ( $P = 0.001$ ), autoimmune disease ( $P = 0.005$ ), smoking status ( $P < 0.001$ ), and history of refractive surgery ( $P < 0.001$ ). The mean estimated annual cost of using lubricating agents was SAR  $328.2 \pm 210.3$  (USD  $87.5 \pm 56.1$ ), and this was significantly higher in the diagnosed group ( $P = 0.01$ ) than the symptomatic-undiagnosed group.

**Conclusions:** The prevalence of DED is high among adults in Saudi Arabia. High-risk population include elderly, female, and using electronic screens for  $>2$  hours/day.

**Keywords:** Dry eye disease, economic burden, epidemiology, ocular surface disease, risk factors, Saudi Arabia

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## INTRODUCTION

The definition of dry eye disease (DED) has continually changed since it was first defined as a disease >30 years ago. According to the 2017 Tear Film and Ocular Surface Society Dry Eye Workshop II (TFOS DEWS II), DED is defined as a “multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film, and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles.”<sup>[1]</sup>

Risk factors for DED include increasing age, female gender, comorbidities such as hypertension and diabetes mellitus, and the use of medications such as antidepressants.<sup>[2,3]</sup> The prevalence of DED has varied in epidemiological studies conducted in the United States, Australia, and Asia, ranging from 5% to 50%.<sup>[4,5]</sup> However, the differences in prevalence are also attributable to the different definitions of DED across studies.

In Saudi Arabia, where environmental and epidemiological factors increase the risk of dry eye, the prevalence of DED has been found to range from 32.1% to 75.9%.<sup>[6,7]</sup> However, most studies were limited to single cities, and thus had limited generalizability. Accordingly, the current study was conducted with the primary aim of determining the prevalence of physician-diagnosed DED among adults across Saudi Arabia and to evaluate the associated risk factors. The secondary objective of the study was to estimate the economic burden of DED by calculating lubricant usage and its annual costs.

## MATERIALS AND METHODS

### Study design, setting, and participants

This cross-sectional, questionnaire-based study included adults from across Saudi Arabia and was conducted between August 31, 2018, to September 26, 2018. The study was approved by the Institutional Review Board of Imam Abdulrahman Bin Faisal University, Dammam.

The study used snowball sampling, wherein initial invitations to this open survey were sent/posted through popular social media/messaging platforms used by adults in Saudi Arabia, namely, WhatsApp and Twitter.

The first page of the questionnaire informed all respondents that participation in this survey was voluntary, and no incentives were offered. In addition, participants were assured of anonymity, with no identifying data being collected, and informed that their responses would only

be used for the purposes of this study. All respondents provided electronic informed consent before participating in the study.

### Sample size calculation

Sample size was calculated using the Raosoft software (<http://www.raosoft.com/samplesize.html>), with a 95% confidence level, 3% margin of error, and 50% response distribution, and the population size of all adults in Saudi Arabia. Accordingly, 1067 responses were deemed as the minimum recommended sample size for this survey.

### Study tool and data collection

The 21-item questionnaire used in this study was first developed in English considering similar questionnaires in the literature and variables determined to be necessary for meeting the study's objective [Supplementary File]. The questions elicited data regarding demographics, DED symptoms, an ophthalmologist-confirmed DED diagnosis, vocation type (office or field-based), digital device use, frequency of eye lubricant use, types of lubricants used, frequency of contact lens (CLs) usage, and history of refractive surgery. Randomization of items was not done while developing the questionnaire.

The questionnaire was translated into Arabic by one of the authors and then back translated by another. Both authors had advanced language skills in both Arabic and English. A third author, who was an expert and also has advanced language skills in both languages, cross-checked the original and back-translated English versions as well as verified the translated Arabic version, and resolved all discrepancies. This author also verified the face validity of the questionnaire. Further, to determine clarity, a pilot study was conducted, wherein the questionnaire was administered to 10 participants, and based on their responses, identified ambiguities were resolved.

The Arabic version of the questionnaire was hosted on Google Forms and the usability and technical functionality of the questionnaire was tested before distribution. The questionnaire was adaptive, and participants could review their responses before submitting. Answering all questions was mandatory for submitting the response.

### Definitions

The following definitions were used to describe the three groups used to categorize the participants in this study. DED-diagnosed is the participants previously diagnosed by an ophthalmologist to have a DED. Symptomatic-undiagnosed are the participants who believe they have DED; have symptoms of DED such as redness,

tearing, or foreign body sensations; and were not diagnosed to have DED. Finally, non-DED are not symptomatic participants, have not been diagnosed with DED, or do not think they have DED.

### Eye lubricant use calculations

In general, the formula for calculating the number of bottles or minims is number of drops  $\times$  number of eyes  $\times$  dosing frequency  $\times$  days. This will provide an estimate of the total drops needed for the treatment course. The total drops are divided by the volume of the bottle which gives the total number of bottles or minims needed for the treatment course. Finally, the number of bottles or minims can be multiplied by the unit cost of the eye lubricant to determine the total cost. Another point to note is that eye drops in multiple-application containers should be used within 4 weeks of opening, unless stated otherwise by the manufacturer, and thus a bottle cannot be used for  $>1$  month.<sup>[8]</sup>

While estimating the cost and amount of eye lubricant units; knowing the volume of a single eye drop is pivotal. Literature demonstrates that the volume of an eyedrop in an ophthalmic solution may vary from 25 to 70  $\mu\text{L}$ . The number of drops per milliliter has been estimated with a range from 20.9 drops/mL to 40.8 drops/mL. It has been suggested that for calculating the amount of eye drops, a rough figure of 0.05 mL per eyedrop or 20 drops per mL is applicable.<sup>[9]</sup> For this study, “some days of the week” was defined as using eyedrops three times/week in both eyes. In addition, usage was considered as 1–2 drops per application.

### Statistical data analysis

All statistical analyses were conducted using STATA (ver. 16). The collected data were analyzed using descriptive statistics, such as frequency and percentage for qualitative variables. Quantitative data were presented as mean and standard deviation. In addition, the Chi-square test and student *t*-test were used to compare proportions and means between DED diagnosed vs. DED symptomatic undiagnosed and as well with non-DED groups as appropriate. *P* value  $< 0.05$  was considered statistically significant.

## RESULTS

A total of 2042 responses were received, of which the majority were aged  $\geq 45$  years (39.4%) and 30–44 years (39.0%). Further, most respondents were female (71.5%), had a bachelor's degree (61.8%), were from the Eastern Province of Saudi Arabia (44.2%), and worked indoors (85.5%) [Table 1]. In terms of chronic diseases,

**Table 1: Demographic characteristics of the participants**

Characteristics	<i>n</i> (%)
Age (years)	
18–29	441 (21.6)
30–44	797 (39.0)
$\geq 45$	804 (39.4)
Gender	
Female	1461 (71.5)
Male	581 (28.5)
Education	
Primary school	31 (1.5)
Middle school	71 (3.8)
High school	409 (20.0)
Bachelor's degree	262 (61.8)
Master's degree and above	269 (13.2)
Residential region	
Riyadh Province	458 (22.4)
Eastern Province	903 (44.2)
Western Province	568 (27.8)
Northern and Southern Provinces	113 (5.5)
Work environment ( <i>n</i> =1916)	
Indoor	1638 (85.5)
Outdoor	278 (14.5)

the most frequently reported conditions were allergic disorder (12.2%) and diabetes mellitus (10.7%). In addition, 141 (6.9%) reported having autoimmune diseases, and 264 (12.9%) were current smokers. In terms of duration of electronic screen use per day, most participants used it for 4–8 hours (34.6%), followed by 2–4 hours (28.5%),  $>8$  hours (18.7%), and  $<2$  hours (18.2%). In terms of CL use, 1495 (73.2%) participants did not wear CL, 467 (22.9%) wore it occasionally, and 80 (3.9%) wore it daily.

### Prevalence and characteristics of dry eye disease

The prevalence of diagnosed DED among the sampled population was 38.4% (*n* = 784). In addition, 36.8% (*n* = 752) of the participants were symptomatic but undiagnosed. About three-fourths of the diagnosed participants had received their diagnosis in the past 2 years (*n* = 390; 50.3%) or 2–5 years (*n* = 206; 26.7%).

Following are the frequencies of all eye complaints: on/off blurry vision (*n* = 738, 20%), foreign body sensation (*n* = 546; 14.8%), tearing (*n* = 496; 13.4%), photophobia (*n* = 482; 13%), burning sensation (*n* = 434; 11.8%), eye redness (*n* = 432; 11.7%), CL intolerance (*n* = 262; 7.1%), mucus discharge (*n* = 187; 5.1%), and difficulty in driving at night (*n* = 118; 3.2%). Of the diagnosed and symptomatic-undiagnosed participants (*n* = 1536), most believed that their symptoms worsen during summer (*n* = 1050; 68.4%), followed by winter (*n* = 248; 16.1%), autumn (*n* = 148; 9.6%), and spring (*n* = 90; 5.9%).

Of the total participants, 286 (14%) had a history of refractive surgery. In addition, 133 (6.5%) participants reported that their eyes are slightly open during sleep,

while 83 (4.1%) were unsure but believe they might have lagophthalmos or incomplete closure of lids during sleep.

#### Eye lubricant use and its associated costs

A total of 1138 (55.7%) participants used eye lubricants, with 779 (68.5%) using it occasionally (some days in a week), while 313 (27.5%) used it four or fewer times daily and 46 (4%) used it more than four times daily. Bottled lubricant drops with preservatives were most commonly used ( $n = 856$ ; 66.3%), followed by preservative-free lubricants ( $n = 272$ ; 21.1%), lubricants gel ( $n = 105$ ; 8.1%), and lubricants ointment ( $n = 59$ ; 4.6%).

The mean estimated annual cost of the usage of lubricating agents was Saudi Riyals (SAR)  $328.2 \pm 210.3$  (range: SAR 144.6–1351.8). After conversion to the United States Dollar (USD), the mean estimated annual cost of the usage of lubricating agents in USD was  $87.5 \pm 56.1$  (range: USD 38.7–360.5).

#### Comparisons between diagnosed and symptomatic-undiagnosed groups

Between the DED diagnosed and symptomatic-undiagnosed groups, a significant difference was found in terms of age ( $P < 0.001$ ), gender ( $P = 0.002$ ), presence of diabetes mellitus ( $P = 0.004$ ), smoking status ( $P = 0.007$ ), duration of electronic screen use ( $P = 0.05$ ), number of ocular complaints ( $P < 0.001$ ), frequency of lubricants use ( $P < 0.001$ ), and the subsequent annual estimated cost of the used lubricants ( $P = 0.01$ ) [Table 2]. In summary, symptomatic-undiagnosed participants were significantly younger, less likely to be diabetic, had a higher proportion of current smokers, spent more time using electronic screens, had fewer ocular symptoms, had lower use of eye lubricants, and consequently lower estimated cost of lubricants. Although females comprised most of the participants in both groups, there was a significantly higher proportion of males in the symptomatic-undiagnosed group than the diagnosed group (28.2% vs. 21.3%, respectively).

#### Comparisons between participants with and without dry eye disease

Between the DED-diagnosed and non-DED groups, significant differences were found in terms of age ( $P < 0.001$ ), gender ( $P < 0.001$ ), presence of diabetes mellitus ( $P = 0.001$ ), allergy ( $P = 0.001$ ), autoimmune disease ( $P = 0.005$ ), smoking status ( $P < 0.001$ ), and history of refractive surgery ( $P < 0.001$ ) [Table 3]. In summary, the DED-diagnosed group had a significantly higher frequency of participants with allergies, diabetes mellitus, autoimmune disorders, and history of refractive surgery,

while the non-DED group had higher frequency of males and current smokers.

## DISCUSSION

This study, which included participants from across Saudi Arabia, estimated the prevalence of diagnosed DED to be 38.4%, while another 36.4% were found to experience the symptoms of DED but without a clinical diagnosis. In studies from single cities in Saudi Arabia, the estimated prevalence of DED was between 32.1% and 75.9%.<sup>[6,7,10]</sup> These significant variations are likely due to differences in methods and questionnaires. In the United States, the estimated prevalence of diagnosed-DED among adults was 6.8%, while 2.5% were symptomatic-undiagnosed.<sup>[11]</sup> This significant difference in the prevalence estimates between the two countries might be related to environmental factors, such as the weather, genetic backgrounds, and lifestyle. Nonetheless, a number of risk factors for DED were similar in both studies, such as the female gender and increasing age.<sup>[11]</sup> In addition, the current study found that among those diagnosed with DED, significantly higher proportions had diabetes mellitus, autoimmune diseases, previous refractive surgery, and allergy. This may also be because these patients are likely to receive referrals to ophthalmologists during other clinical visits.

In this study, smoking was less prevalent in the diagnosed-DED group, which is in contrast to the findings of studies from Saudi Arabia. That is most likely because of the higher percentage of male participants in the non-DED group, as smoking is known to be highly prevalent among Saudi males compared with Saudi females.<sup>[12]</sup>

Longer duration of daily electronic screen usage was found to be associated with higher prevalence of DED. These findings are similar to previously published studies, which demonstrated that severe DED symptoms were more prevalent among those using digital screens for  $>4$  h/day.<sup>[13]</sup> Another study from South Korea among a group of children found that smartphone use was more prevalent among those with DED.<sup>[14]</sup> When those children with DED stopped smartphone use for 4 weeks, improvement in DED was noted, as measured by superficial punctate erosions, tear breakup time, and ocular surface disease index score, suggesting lifestyle modifications can help improve DED. It has been widely hypothesized that digital screen use influences blinking dynamics by decreasing blink rate and blink completeness, contributing to increased ocular surface dryness. Although reading on a digital screen has been noted to decrease blink rates, reading from a book also decreases the blink rate, suggesting that electronic screen usage is not



**Table 2: Characteristics of dry eye disease: diagnosed versus symptomatic-undiagnosed**

Characteristics	Diagnosed DED (n=784), n (%)	Symptomatic-undiagnosed DED (n=752), n (%)	P
Age (years)			
18–29	121 (15.4)	182 (24.2)	<0.001
30–44	302 (38.5)	307 (40.8)	
≥45	361 (46.1)	263 (35)	
Gender			
Female	617 (78.7)	540 (71.8)	0.002
Male	167 (21.3)	212 (28.2)	
Allergic disorder			
Yes	113 (14.4)	96 (12.8)	0.3
Diabetes mellitus			
Yes	109 (13.9)	69 (9.2)	0.004
Autoimmune disorders			
Yes	64 (8.2)	56 (7.5)	0.6
Smoking			
Yes	74 (9.4)	104 (13.8)	0.007
Education			
Primary school	12 (1.5)	11 (1.4)	0.6
Middle school	30 (3.8)	29 (3.9)	
High school	163 (20.8)	157 (20.9)	
Bachelor's degree	466 (59.5)	468 (62.2)	
Master's degree and above	113 (14.4)	87 (11.6)	
Residential region			
Riyadh Province	166 (21.2)	190 (25.3)	0.1
Eastern Province	363 (46.3)	307 (40.8)	
Western Province	216 (27.5)	210 (27.9)	
Northern and Southern Provinces	39 (5)	45 (6)	
Work environment	n=745	n=709	
Indoor	630 (84.6)	613 (86.5)	0.3
Outdoor	115 (15.4)	96 (13.5)	
Duration of electronic screen use per day (h)			
<2	151 (19.3)	115 (15.3)	0.05
2–4	239 (30.4)	208 (27.7)	
4–8	256 (32.7)	272 (36.2)	
>8	138 (17.6)	157 (20.8)	
DED worsening season			
Autumn	74 (9.4)	74 (9.8)	0.6
Winter	118 (15.1)	130 (17.3)	
Spring	49 (6.3)	41 (5.5)	
Summer	543 (69.2)	507 (67.4)	
Number of ocular symptoms	n=763	n=751	
One	248 (32.5)	325 (43.3)	<0.001
Two	160 (21.0)	181 (24.1)	
Three or more	355 (46.5)	245 (32.6)	
Lubricant's usage	n=697	n=434	
Occasional*	403 (57.8)	370 (85.3)	<0.001
1–4 times daily	252 (36.2)	60 (13.8)	
>4 times per day	42 (6)	4 (0.9)	
Estimated annual costs of lubricants <sup>†</sup>	341.4±221.6 SAR (91.0±59.1 USD)	309.2±190.3 SAR (82.5±50.7 USD)	0.01
Previous refractive surgery			
Yes	163 (20.8)	88 (11.7)	<0.001
Contact lens use			
Sometimes	173 (22.1)	182 (24.2)	0.4
Daily	32 (4.1)	36 (4.8)	

\*3 days/week; <sup>†</sup>Assuming one bottle/month. DED – Dry eye disease

the only risk factor.<sup>[13]</sup> Other studies have suggested that the engagement in an active versus passive computer task further reduced the blink rate.<sup>[13]</sup> Our study design did not allow objective assessment of the effects of electronic screen use on DED, including the blink rate and blink completeness.

A study done in Japan found that being female is a persistent risk factor for both symptomatic-undiagnosed DED and

diagnosed-DED. It also found that younger age is a risk factor for symptomatic-undiagnosed-DED.<sup>[15]</sup> Similarly, in our study, younger age group comprised the largest age group of the symptomatic-undiagnosed DED. This could be explained by the limited time and money available with the younger group. Also, older people are usually more frequent visitors to hospitals due to other health conditions such as diabetes and hypertension that prompt referral to

**Table 3: Summary of the characteristics of dry eye disease diagnosed versus the non-dry eye disease participants**

Characteristics	Diagnosed DED (n=784), n (%)	Non-DED (n=506), n (%)	P
Age			
18–29	121 (15.4)	138 (27.3)	<0.001
30–44	302 (38.5)	188 (37.2)	
45 and more	361 (46.1)	180 (35.5)	
Gender			
Female	617 (78.7)	304 (60.1)	<0.001
Male	167 (21.3)	202 (39.9)	
Allergic disorder			
Yes	113 (14.4)	41 (8.1)	0.001
Diabetes mellitus			
Yes	109 (13.9)	40 (7.9)	0.001
Autoimmune disorders			
Yes	64 (8.2)	21 (4.2)	0.005
Smoking			
Yes	74 (9.4)	86 (17)	<0.001
Education			
Primary school	12 (1.5)	8 (1.6)	0.3
Middle school	30 (3.8)	12 (2.4)	
High school	163 (20.8)	89 (17.6)	
Bachelor's degree	466 (59.4)	328 (64.8)	
Master's degree and above	113 (14.4)	69 (13.6)	
Residential region			
Riyadh Province	166 (21.2)	102 (20.2)	0.5
Eastern Province	363 (46.3)	233 (46.1)	
Western Province	216 (27.5)	142 (28.1)	
Northern and Southern Provinces	39 (5)	29 (5.7)	
Work environment	n=745	n=462	
Indoor	630 (84.6)	395 (85.5)	0.7
Outdoor	115 (15.4)	67 (14.5)	
Duration of electronic screen use per day (h)			
<2	151 (19.3)	105 (20.8)	0.5
2–4	239 (30.4)	135 (26.7)	
4–8	256 (32.7)	179 (35.4)	
>8	138 (17.6)	87 (17.2)	
Previous refractive surgery			
Yes	163 (20.8)	35 (6.9)	<0.001
Contact lens use			
Sometimes	173 (22.1)	112 (22.1)	0.3
Daily	32 (4.1)	12 (2.4)	

DED – Dry eye disease

ophthalmology for checkup and screening for these disease complications.

Another risk factor for DED among the diagnosed group in the Japanese study was the use of CLs.<sup>[15]</sup> In our study, CL was not a significant risk factor for DED, probably because DED is actually more prevalent in our region due to other factors, which render the statistics for CL insignificant. Primary eye-care service and optometry practice in other parts of the world that provide eye checkup besides glasses and CL prescription might have increased the chance of having more diagnosed-DED, thereby increasing the prevalence of diagnosed-DED in those studies. A more detailed questionnaire and objective tests are needed to determine whether CL wear can increase the severity of DED.

The estimated annual cost of lubricating eye drops per patient if one bottle is used per month, in our study, was

higher in the diagnosed-DED group compared to the symptomatic-undiagnosed DED group. Higher expense in the diagnosed-DED group may be related to the severity of the disease. However, it could also be due to the fact that the medication expenses for those with a diagnosis are covered by governmental hospitals or insurance, whereas the symptomatic-undiagnosed DED group bought the medications at their own expense, and thus may have been conservative in usage. The cost was calculated based on the participants' responses, indicating the type and number of lubricants used and estimated from the local market prices. The cost estimate may not be very accurate, as our questionnaire did not ask specifically about the brand (s) of lubricant (s) used, frequency, and the number of bottles participants use in a month.

In comparison to our annual cost estimation, which was USD 87.5 ± 56.1 (range: USD 38.7–360.5) per subject, Yu *et al.*, estimated that the average annual direct cost for

subjects who were self-medicating with ocular lubricant treatment or nutritional supplements was USD 126 per subject. Further, they estimated the average annual direct medical cost per patient for those with mild, moderate, and severe DED symptoms to be USD 678, USD 771, and USD 1267, respectively. It should be noted that the direct cost included the cost for plugs, cyclosporine, ocular lubricant treatment, office visits, and nutritional supplements.<sup>[16]</sup>

Further to cost estimation, there could be an association with the size and volume of an eye drop. Gaynes *et al.*, in their study that evaluated 45° versus 90° administration of artificial tear bottles, found that with a 45° angle of administration, smaller drop volumes were observed, resulting in significantly greater number of drops per bottle and savings of USD 1.93 per bottle.<sup>[17]</sup> According to Jünemann *et al.*, the volume of eye drop depends on the physicochemical properties of a drug and its applicator. These factors may include fluid viscosity, surface tension, temperature, and adhesion to the dropper tip aperture. The volume of a droplet can be reduced by surface active substances (surfactants), which are added to eye drop formulations as preservatives and penetration enhancers. Adding 0.01% of benzalkonium chloride to phosphate buffer solution reduces the droplet size from 43.7 µL to 31.5 µL. When dispensing the smaller drops of the surface-active solutions, less force is needed to be exerted on the bottle and a lower dispensing time is noted, which can increase patient adherence.<sup>[18]</sup>

Another major factor is the cost of single dose minims, which is much higher than a multidose bottle with preservatives. As per the Saudi Food and Drug Authority data, the price of a 15 ml multidose bottle and one box of 30 minims of polyethylene glycol 400 + propylene glycol lubricant is SAR 31.05 and SAR 47.8, respectively. The bottle of 15 ml can have up to 300 doses, whereas one box of 30 minims will only have 30 doses. Rahemtulla *et al.* explained the cost difference in a hospital after switching most of their dilating eye drop practice from multidose eye drop bottles to single-use minims, resulting in the cumulative cost increment from USD 4960 to USD 30,367.<sup>[19]</sup>

In contrast to the formula used in the current study for calculating the cost and amount of eye lubricants units, Yu *et al.* used another formula, which also takes into consideration the compliance rate. The formula for calculating the annual cost of ocular lubricant treatment for patients who sought professional treatment was as follows: the mean price of each drop of ocular lubricant treatment × the recommended number of daily drops × compliance rate × 365 days. For those patients

who did not seek professional treatment, the formula for calculating the yearly cost of ocular lubricants was as follows: the mean price of each drop of ocular lubricant treatment × the average number of daily drops for a dry eye population × 365 days.<sup>[16]</sup>

The rate of work/education absenteeism due to DED was not assessed. Inclusion of this in the questionnaire would have provided a better estimate of the economic burden of DED, both at the governmental and individual levels. As the prevalence of DED is higher in Asian countries, addressing the possible causes for DED in our particular region can be helpful to reduce the incidence, expenses, and consequences of such disease.<sup>[4]</sup>

Hot weather leads to frequent use and reliance on air conditioners in most of the Saudi regions, this might be a contributing factor towards the higher prevalence of DED. Introducing environmental modifications, such as air humidifiers and treating any co-existing ocular diseases, such as allergy or meibomian gland dysfunction, might decrease the incidence and severity of DED, or even contribute to resolution of the disease.

### Limitations

This study is not without limitations. Self-selection bias is one limitation in this study, as older people are not familiar with smartphones or those who did not have access to the questionnaire, regardless of the cause, could not contribute to the study. Therefore, conducting a dry eye screening campaign where all people can access it will decrease the possibility of selection bias. In addition, the lack of objective methods for diagnosing DED is another limiting factor in this cross-sectional study. Moreover, addressing the frequency of absence from work/school as a consequence of DED or the reduced efficiency might also reflect another aspect of the true economic burden of this condition.

### CONCLUSION

The prevalence of DED is high among adults in Saudi Arabia, which is likely related to environmental factors such as very dry and hot weather. Future research should concentrate on the solutions to reduce the prevalence, and thus the economic burden of this disease. Older age, female gender, and usage of screen time >2 hours/day are risk factors associated with DED.

### Ethical considerations

The study was conducted after obtaining ethical approval from the Institutional Review Board of Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia (Ref. no.:

IRB-2020-01-168). Electronic informed consent was obtained from all participants before participation. The study adhered to the principles of the Declaration of Helsinki, as revised in 2013.

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Peer review

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### Author Contributions

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There are no conflicts of interest.

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### Questionnaire: Prevalence of Dry Eye Disease Among Adults in Saudi Arabia

Item No.	Question	Answer
1	Do you agree to participate in this research?	Yes/No
2	Do you suffer from any of the following symptoms? (More than one option can be selected)	Eye redness/foreign body sensation in the eye/sensation of heat or itching/mucus around your eyes/sensitivity to light/difficulty in wearing contact lenses/difficulty driving at night/eye tears (reaction due to dehydration)/blurred vision or eye fatigue/not applicable
3	Do you think you have dry eye disease?	Yes/No/Maybe
4	Have you been previously diagnosed with dry eye disease?	Yes/No
5	If your previous answer is yes, when did you diagnose with dry eye disease?	Less than two years ago/two years to 5 years/more than 5 years ago
6	Age	Less than 18/18-29/45 and more
7	Gender	Male/Female
8	Nationality	Saudi/Non-Saudi
9	Have you diagnosed with any of the following chronic diseases? (More than one option can be selected)	Systemic Lupus Erythematosus (SLE)/(SJOJREN'S syndrome)/Crohn's Disease/Ulcerative colitis/Rheumatoid Arthritis/Other/Not applicable
10	Are you a smoker?	Yes/No
11	Education level	Primary/Intermediate/Secondary/University/Postgraduate
12	Region of residence in the Kingdom	North/Central/Eastern/Western/Southern
13	Work field	Field outside a building/Inside a building (office)/not applicable
14	How much time do you spend on a smartphone/ computer/tablet?	Less than two hours per day/4-2 hours per day/8-4 hours per day/more than 8 hours per day
15	In which season of the year does your dry eye problem get worse?	Summer/Spring/Winter/Fall/Not applicable
16	How often do you use eye lubricants?	Rarely/4-1 times daily/more than 4 times daily/I don't use
17	What kind of eye lubricants do you use? (More than one option can be selected)	Eye drops/eye drops without preservatives/gel/ointment/I don't use
18	Do you use any other medications to treat dry eye problem? (More than one option can be selected)	(Omega-3) without a prescription/(oral antibiotic to treat blepharitis) doxycycline/(prescription by an ophthalmologist) cyclosporine/I don't use
19	Did you undergo any ophthalmic procedure to correct refractive defects or corneal transplantation?	Yes/No
20	Do you use contact lenses?	No/sometimes/daily
21	Did any of your family member tell you that your eyes were open during your sleep?	Yes/No/Maybe

استبيان: انتشار مرض جفاف العين بين البالغين في المملكة العربية السعودية

رقم	سؤال	إجابة
1	هل توافق على المشاركة في البحث؟	نعم/لا
2	هل تعاني من الاعراض التالية؟ (يمكن اختيار أكثر من إجابة)	احمرار العين /الإحساس بجسم غريب في العين /احساس حرارة أو خدش في عينيك /مخاط خفيف حول عينيك/حساسية للضوء / صعوبة في ارتداء العدسات اللاصقة/ صعوبة في القيادة ليلا / دموع في العين (ردة فعل بسبب الجفاف)/ عدم وضوح الرؤية أو إرهاق العين/ لا ينطبق
3	هل تم تشخيصك سابقا بمرض جفاف العين؟	نعم/لا
4	هل تعتقد بأنك مصاب بجفاف العين؟	نعم/لا/ربما
5	هل تم تشخيصك سابقا بمرض جفاف العين؟	نعم/لا
6	العمر؟	أقل 18 بين 18-29 45 عاما وأكثر
7	الجنس	ذكر/أنثى
8	الجنسية؟	سعودي/غير سعودي
9	هل لديك مرض مزمن؟	حدد كل الإجابات الملائمة مرض الذئبة الحمراء/ التهاب القولون التقرحي /التهاب المفاصل (الروماتويد)/ أخرى /لا ينطبق
10	هل أنت مدخن؟	نعم/لا
11	مستوى التعليم	ابتدائي/ متوسط/ثانوي/ جامعي/ دراسات عليا
12	من أي منطقة بالمملكة؟	الشمالية /الوسطى/ الشرقية /الغربية/ الجنوبية
13	مجال العمل	مكتبي (داخل مبنى/ لا ينطبق) ميداني (خارج مبنى /)
14	كم من الوقت تقضيه على الهاتف الذكي، الحاسوب , التابلت؟	أقل من ساعتين يوميا /ساعات يوميا 2-4/ساعات يوميا 4-8/أكثر من 8 ساعات يوميا
15	في أي فصل من فصول السنة تزداد مشكلتك سوءا؟	الصيف /الربيع /الشتاء /الخريف/ لا ينطبق
16	كم مره تستخدم مرطبات العين؟	نادرا /مرات يوميا 1-4 /أكثر من 4 مرات يوميا
17	ماهو نوع مرطبات العين الذي تستخدمه؟	(يمكن اختيار أكثر من إجابة) قطرات العين /قطرات العين بدون مواد حافظة/جل/ مرهم/ لا أستخدام
18	هل هناك أدوية و فيتامينات أخرى تستخدمها لعلاج مشكلة جفاف العين؟	(يمكن اختيار أكثر من إجابة) (أوميغا 3) بدون وصفة/ مضاد حيوي عن طريق الفم لعلاج التهاب الجفن ( doxycycline ) دوكسيسيكليين /وصفة عن طريق طبيب العيون)
19	هل خضعت لأي عملية لتصحيح العيوب الانكسارية أو زراعة قرنية ؟	نعم/لا
20	هل تستخدم عدسات لاصقة؟	لا / أحيانا /يومية
21	هل أخبرك أحد من أفراد عائلتك بأن عينك مفتوحتان خلال نومك ؟	نعم/لا/ربما