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# Prevalence and Behavioral-Based Risk Factors (Eye Cosmetic and Tobacco Use) of Symptomatic Dry Eye Disease in Four Middle Eastern Countries: Lebanon, Syria, Jordan, and Palestine

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**Purpose:** To estimate the prevalence of symptomatic dry eye disease (DED) in four Middle Eastern Countries and investigate the association between behavioral-based risk factors and severity of DED.

**Patients and Methods:** Population-based cross-sectional study of 1463 participants from 4 Mediterranean countries (Lebanon, Syria, Jordan, and Palestine). The Arabic version of the Ocular Surface Disease Index (ARB-OSDI) questionnaire was used to estimate the prevalence and severity of symptomatic DED using an online format survey. The survey also included demographic questions and possible behavioral risk factors (tobacco and cosmetic use). One-Way ANOVA and multivariate regression analyses were used to investigate the association between OSDI mean scores and behavioral-based risk factors.

**Results:** The prevalence of symptomatic DED (OSDI score  $\geq 13$ ) among the overall population (332 males and 1132 females) reached 70.2%. Tobacco and cosmetic users reported a higher significant prevalence and severity of symptomatic DED than non-users ( $p < 0.0001$ ). Smoking habits (eg, smoking cigarettes or Ajami, smoking in closed areas, and daily smoking) were more likely to report symptomatic DED. Bad hygiene process during the use of any cosmetic product was behind the high prevalence and severity of symptomatic DED among the females of the study population.

**Conclusion:** Symptomatic DED is substantial in Middle Eastern countries. It is statistically associated with cosmetic and tobacco use.

**Keywords:** eye dryness, Ocular Surface Disease Index, smoking, cosmetic use, middle east

## Introduction

The Tear Film and Ocular Surface Society-Dry Eye Workshop II (TFOS DEWS II) defines dry eye disease (DED) 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>

Several eye epidemiological studies revealed that the prevalence of DED is increasing globally whereas Asian and Arab countries registered the highest estimation.<sup>2-4</sup> Among the Middle Eastern countries, West Bank- Palestine (69%), the Eastern Province of Saudi Arabia (62.4%) and Jordan (59%) showed the highest estimation of symptomatic DED.<sup>5-7</sup> These epidemiological studies were alarming enough to highlight the possible relation between DED prevalence and the

geographical area where the climate conditions and behavioral habits (eg, Tobacco and cosmetic use) are approximately similar.

Focusing on tobacco use, direct contact with the irritative smoke may lead to defects in ocular surface defense and retinal nerve fiber layer.<sup>8,9</sup> Exposure to smoke toxicants may also affect the tear film secretion and stability as well as reduce blood flow or increase the formation of clots within ocular capillaries, which could limit the delivery of vital nutrients for eye health.<sup>10</sup> Even though smokers are highly exposed to smoke irritants, a contradictory relationship between DED and smoking was concluded in 25 countries including Lebanon, Jordan, and Palestine.<sup>5,6,11,12</sup> Additionally, limited studies had investigated the relationship of DED prevalence with the types of smoked tobacco (eg, cigarette, waterpipe).<sup>11,13</sup>

Additionally, the exposure to irritating toxicants in behavioral habits is not limited to smoking. As known, females predominantly use eye cosmetics to enhance their attractiveness and to improve self-confidence by intensifying the beauty of their eyes.<sup>14</sup> According to the epidemiological review, females record consistently higher DED percentages than males.<sup>1</sup> Even though the literature reported that toxicants in eye cosmetics may lead to discomfort, inflammation, oxidative stress, and tear film change,<sup>15–17</sup> limited studies investigated the association between eye cosmetics and the perception of ocular discomfort and the reduction in the tear film lipid layer thickness.<sup>18,19</sup> Additionally, no study has investigated the association between the prevalence of DED and cosmetic use among Arabic females who are well-known for their excessive use of eye cosmetics (eg, Kohl).<sup>20</sup>

An association study between the prevalence of symptomatic DED and behavioral habits (eye cosmetics and tobacco use) in Lebanon, Syria, Jordan, and Palestine is necessary to foster awareness about symptomatic DED and its associated risk factors. In the current study, an Arabic version of the OSDI (ARB-OSDI) questionnaire was utilized to assess quantitatively the prevalence of symptomatic DED and investigate behavioral-based risk factors (Eye cosmetics and Tobacco Use) in the four neighboring Middle Eastern countries.

## Materials and Methods

The population was recruited from Lebanon, Syria, Jordan, and Palestine between March 2021 and December 2021 using the convenience sampling. A total of 1463 participants (aged  $\geq 18$ ) were asked to participate in this non-clinical cross-sectional study using an online version of the questionnaire distributed throughout several online platforms. Participants with eye surgeries, active ocular diseases, and ocular or systemic medications that are known to interfere with tear film production or ocular surface integrity were excluded from the study.<sup>6,11</sup>

## Study Tool

The ARB-OSDI utilized in the current study is a validated Arabic version of the OSDI questionnaire on dry eye symptoms induced by environmental factors over the preceding week.<sup>21</sup> The OSDI questionnaire was originally developed by the Outcomes Research Group at Allergan Inc. (Irvine, California) and was designed to provide a rapid assessment of symptoms related to ocular irritation and dry eye disease.<sup>22</sup> The 12-item OSDI questionnaire is three sections: 5 questions related to the ocular symptoms, 4 questions related to vision-related function, and 3 questions related to the environmental triggers. Each item was graded on a scale of 0 to 4 ranging from none of the time to all of the time. The OSDI score was then calculated according to the following formula:

$$OSDI\ Score = \frac{Sum\ of\ scores\ for\ all\ questions\ answered \times 100}{Total\ number\ of\ questions\ answered \times 4}$$

In the current study, the OSDI status was classified with a cut-off value of OSDI score  $\geq 13$  between normal status and DED status (mild, moderate, and severe).<sup>23,24</sup> The measurement scale of the OSDI status was divided into three intervals: the interval of normal cases [0, 12], the interval of mild-to-moderate cases [13, 32], and the interval of severe cases [33, 100].<sup>23,24</sup>

The risk factor of tobacco exposure was assessed through questions related to the types of tobacco used eg, regular cigarette, electronic cigarette, Mouassal waterpipe (an Arabic translation for “honeyed” which contains 30% tobacco and around 70% honey/sugarcane as well as glycerol and flavor) and Tumbak or Ajami (an Arabic translation for “non-honeyed”

pure dark paste of tobacco),<sup>25</sup> indoor-outdoor smoking areas, rate of smoking (daily, weekly, and monthly), quantification of cigarettes or waterpipes per week along with the smoking duration (in years).

The risk factor of cosmetic exposure was assessed through questions related to the type of eye makeup (mascara, eyeliner, eyeshadow, eyelashes, and anti-aging cream), rate of makeup use (daily, weekly, and monthly) along with application hours per day, and cleaning methods (water, soapy water, cleansing products) along with the rate of night cleansing (never, sometimes, always). The overall study tool is provided in the [Supplementary Information](#).

## Data Analysis

The data were analyzed using the Statistical Package for the Social Sciences, version 21 (SPSS, International Business Machine Corp. IBM, Chicago, IL, USA). The prevalence of symptomatic DED in the participants was determined by the percentage of the population with OSDI score  $\geq 13$  (mild, moderate, and severe OSDI status). The significant differences between variables were evaluated using the multivariate regression analysis and the One-way ANOVA tests.

## Ethical Considerations

The Institutional Review Board (IRB) at the Modern University for Business and Science (MUBS) has reviewed and approved the protocol of the study (MU - 20210323-22E). The study was conducted according to the principles contained in the Declaration of Helsinki. Informed consent was obtained from all the participants prior to their participation in the study. Confidentiality and absence of potential risk were controlled during data collection and analysis.

## Results

In this study, a total of 1463 persons participated from four Middle Eastern countries. The highest participation rate was from Palestine (576 respondents: 39.4%) and Jordan (508 respondents: 34.7%) while the Syrian and Lebanese people showed the lowest rate (115 respondents: 7.9%; 264 respondents: 18%, respectively) ([Table 1](#)). The majority of the respondents were

**Table 1** OSDI Status, Mean Scores (Standard Deviation), One-Way ANOVA, and Distribution of Responses (Frequency and Relative Percentages) per Country with Respect to Gender, Age Group, Tobacco, and Makeup Use

Variable		Lebanon	Syria	Palestine	Jordan
		Frequency (Percentages)			
Gender	Male	64 (24.2%)	45 (39.1%)	116 (20.1%)	106 (20.9%)
	Female	200 (75.8%)	70 (60.9%)	460 (79.9%)	402 (79.1%)
Age Interval	18–24	131 (49.6%)	15 (13%)	483 (83.9%)	185 (36.4%)
	25–44	106 (40.2%)	62 (53.9%)	74 (12.8%)	238 (46.8%)
	$\geq 45$	27 (1.8%)	38 (33%)	19 (3.3%)	85 (16.7%)
Smoking Status	Smoker	166 (62.9%)	65 (56.5%)	374 (64.9%)	355 (69.9%)
	Non-smoker	98 (37.1%)	50 (43.5%)	202 (35.1%)	153 (30.1%)
Makeup Users	Yes	181 (68.6%)	62 (53.9%)	379 (65.8%)	345 (67.9%)
	No	83 (31.4%)	53 (46.1%)	197 (34.2%)	163 (32.1%)
OSDI Status	Normal	99 (37.5%)	40 (34.8%)	157 (27.3%)	135 (26.6%)
	Mild-to-Moderate	88 (33.3%)	34 (29.5%)	213 (36.9%)	150 (29.5%)
	Severe	77 (29.2%)	41 (35.7%)	206 (35.8%)	223 (43.9%)
OSDI Mean score (SD)		24.1 (23.1)	24.8 (21.4)	27.6 (22.4)	31.5 (23.6)
One-Way ANOVA		F-value = 7.641, p-value < 0.0001			

**Abbreviations:** OSDI, Ocular Surface Disease Index; SD, Standard Deviation.

females from all the participating countries (1132 females; 77.4%). Except for Syria, almost half of the study population (814 respondents; 55.6%) belonged to the young age group (18–24 years old). Looking at the participants' habits, the prevalence of smoking and makeup use habits was high in the study population (65.6% and 66.1%, respectively) with comparable results among the four study countries.

## DED Comparison Among the Four Countries

According to Table 1, the prevalence of symptomatic DED in the studied countries was relatively high where 70.5% of the studied population showed symptoms of mild-to-severe DED (OSDI score was  $\geq 13$ ). Among the four countries, the highest prevalence of symptomatic DED (OSDI score  $\geq 13$ ) and DED severity (represented by mean OSDI scores) was distinguished in the Jordanian respondents (73.4%; mean score =31.5). The F-value is 7.64 (p-value < 0.0001), which indicates a statistically significant difference between the mean OSDI scores of the four countries as demonstrated by the One-Way ANOVA test. Additionally, the Tukey Post Hoc test showed that Jordan has an OSDI mean score higher than each of the other three countries (p-value < 0.001).

## DED and Tobacco Use

In the current study, smoking factors such as rate, duration (in years), types, and areas of smoking were investigated as shown in Table 2. Of the study population, smokers demonstrated a 3 times higher prevalence of symptomatic DED (OSDI score  $\geq 13$ ) and 4.75 times higher DED severity (represented by mean OSDI scores) than the non-smokers. The highest prevalence of symptomatic DED (OSDI scores  $\geq 13$ ) was recorded among the smokers of Ajami tobacco compared to those who smoked other types. On the other hand, the highest DED severity (represented by mean OSDI scores) was recorded among mixed tobacco smokers.

**Table 2** OSDI Status, Mean Scores (Standard Deviation), One-Way ANOVA, and Distribution of Responses (Relative Percentages) with Respect to Smoking Types, Rates, and Areas

Variable		Normal	Mild-to-Moderate DED	Severe DED	Mean OSDI Score (SD)
Smoking Types	Cigarette	8.4%	30.7%	60.9%	41.8 (23.6)
	Electronic cigarette	10%	81.6%	8.3%	22.7 (15.4)
	Waterpipe (Mouassal)	15%	44.3%	40.7%	30.6 (19.1)
	Waterpipe (Ajami)	1.7%	37.3%	61%	36.9 (14)
	Mixed	3.4%	20.7%	75.9%	48.2 (21.3)
	Non-smoker	69.4%	29%	1.6%	8 (8.5)
	One-Way ANOVA: F=11.41, P value < 0.0001				
Smoking Rate	Daily	4.8%	34.8%	60.5%	41 (21.3)
	Weekly	25.8%	42.5%	31.7%	26.3 (21.4)
	Monthly	21.8%	30.7%	47.3%	35.2 (25.3)
	Non-smoker	69.4%	29%	1.6%	8 (8.5)
	One-Way ANOVA: F=39.35, P value < 0.0001				
Smoking Areas	Indoor	5.5%	28.3%	66.2%	43.3 (22)
	Outdoor	14.6%	50%	35.4%	29.6 (19.3)
	Non-Smoker	69.4%	29%	1.6%	8 (8.5)
One-Way ANOVA: F=34.81, P value < 0.0001					

Smoking rate (daily, weekly, monthly) did not show a perfect harmonic relation with the symptomatic DED (prevalence and severity). Except for respondents who smoked weekly, all the other groups were consistent with the expectation that the prevalence of symptomatic DED (OSDI scores  $\geq 13$ ) increases with the regular consumption of tobacco (Daily = 95.2% > Monthly = 78.2% > No smoking = 30.6%). Expectedly, the highest DED severity (represented by mean OSDI scores) was recorded among the daily smokers (OSDI mean score = 41).

Smoking areas (indoor or outdoor) revealed a better harmonic relation with the symptomatic DED (prevalence and severity). Expectedly, the highest prevalence of symptomatic DED (94.5% of the participants recorded OSDI scores  $\geq 13$ ) and DED severity (mean OSDI score = 43.3) was recorded among indoor smokers (where bad ventilation areas are expected) compared to outdoor smokers and non-smokers.

The One-Way ANOVA test showed a considerable statistical significance among DED severity (represented by OSDI mean scores) and all the studied factors of tobacco use ( $p < 0.001$ ) as represented in Table 2. Additionally, Spearman correlation tests showed a strong negative correlation between the DED severity, smoking rate ( $\rho = -0.670$ , P-value < 0.0001) and smoking areas ( $\rho = -0.673$ , P-value < 0.0001).

To investigate the relationship between smoking and the OSDI score, a multiple regression analysis was carried out to test whether there is a linear relationship between the dependent variable, the OSDI score (Y), and the independent variables, the number of smoking years ( $X_1$ ), the number of cigarettes smoked ( $X_2$ ), and the number of water pipes smoked ( $X_3$ ) on weekly basis (Table 3). According to the multiple regression test, 43.7% of the DED variance was linked to independent variables ( $X_1$ ), ( $X_2$ ), and ( $X_3$ ) which confirms the association hypothesis of DED prevalence with smoking, specifically the duration, and frequency of smoking (cigarette or waterpipe). Also, the coefficient of the regression model (OSDI Score (Y) =  $13.33 + 1.138X_1 + 0.143X_2 + 1.665X_3$ ) indicated that smoking water pipe has

**Table 3** Multivariate Regression Results Analysis for OSDI Scores on the Basis of the Number of Smoking Years, Smoked Cigarettes, and Waterpipes per Week

Model Summary						
R-value	0.661	R <sup>2</sup> -value	0.437	Durbin-Watson (DW)	1.955	
ANOVA						
F-statistics	378.107		p-value	< 0.0001		
Regression Coefficients						
Unstandardized Coefficients B		Standardized Coefficients	t-value	p-value	95% Confidence Interval Estimate for B	
Constant	13.33	–	20.44	0.000	12.050	14.609
Nb. of smoking yrs	1.138	0.242	9.984	0.000	0.914	1.361
Cigarette	0.143	0.381	16.521	0.000	0.126	0.16
Waterpipe	1.665	0.324	15.22	0.000	1.45	1.879
Multicollinearity Tests						
Eigen Values (EV)	Condition Index (CI)		Tolerance (TOL)		Variance Inflation Factor (VIF)	
2.573	1.000		–		–	
0.781	1.816		0.654		1.530	
0.391	2.566		0.726		1.378	
0.255	3.175		0.850		1.177	
Regression Equation:						
OSDI Score (Y) = 13.33 + 1.138X <sub>1</sub> + 0.143X <sub>2</sub> + 1.665X <sub>3</sub>						



more contribution to the OSDI score ( $X_3$  by a factor of 1.665) than smoking cigarettes ( $X_2$  by a factor of 0.143) during the long-term smoking ( $X_1$  by a factor of 1.138). On the other hand, the standardized coefficients indicated that cigarette smoking has a considerable impact on DED where its standardized coefficient (0.381) recorded the highest value among the other two independent variables. The impact of waterpipe smoking came in the second place with a standardized coefficient value of (0.324), whereas, the effect of smoking years on DED came in the third place with a standardized coefficient of (0.242). As a result, both regression and correlation tests confirmed that the higher the rate of smoking tobacco, the higher the prevalence of symptomatic DED (OSDI scores  $\geq 13$ ).

## DED and Eye Cosmetics Use

Eye cosmetics usage is a common tradition and whilst some products are utilized in proximity to the ocular surface, the current study also aimed to investigate the use of eye cosmetics among 1132 females (males were excluded in this section) and identify any association between symptomatic DED (prevalence and severity) and cosmetic usage (eg the factors of rate; duration in hours); type; cleaning techniques and rates). The results are summarized in Table 4.

Regardless of the groups of cosmetics, cosmetics users demonstrated a higher prevalence of symptomatic DED (OSDI score  $\geq 13$ ), in which these percentages ranged between 77.5-and 85.1% than the non-cosmetics users (69.3% of the participants recorded OSDI scores  $\geq 13$ ). Expectedly, all the users of cosmetics recorded higher DED severity (represented by mean OSDI scores) than non-users. The highest prevalence of symptomatic DED (OSDI scores  $\geq 13$ ) and DED severity (represented by mean OSDI scores) was recorded among the users of eyeliner internally (84.4%; mean score = 38.4) and mascara (85.1%; mean score = 38.1) compared to those who utilized other types of eye cosmetics.

As opposed to the factors of cosmetic usage rate (daily, weekly, monthly) and duration of cosmetic wear ( $D < 6$  hours,  $6 < D < 12$  hours,  $D > 12$  hours), the cosmetics cleaning protocol (material and rate) revealed a better harmonic relation with the symptomatic DED (prevalence and severity) as represented in Table 4. Expectedly, the lowest prevalence of symptomatic DED (OSDI scores  $\geq 13$ ) and OSDI severity (represented by mean OSDI scores) was recorded among the makeup users who remove regularly their eye makeup before sleep (74.9%; mean score = 30.3) and who use cleansing creams for makeup removal (72.6%; mean score = 28.8) compared to those who did not remove their eye makeup regularly or who cleaned their eye makeup with either water or soapy water.

Finally, the One-Way ANOVA test showed a considerable statistical significance among DED severity (represented by OSDI mean scores) and all the studied factors of cosmetic use ( $p < 0.001$ ) as represented in Table 4.

**Table 4** OSDI Status, Mean Scores (Standard Deviation), One-Way ANOVA, and Distribution of Responses (Relative Percentages) with Respect to Cosmetics Types, Rates, Applying Durations and Conditions in Addition to Cleaning Techniques and Rates

Variable		Normal	Mild-to-Moderate DED	Severe DED	Mean OSDI Score (SD)
Type of Cosmetics (Significant effect)	Mascara	14.9%	28.9%	56.2%	38.1 (38.1)
	Internal Eye Liner	15.6%	26.2%	58.2%	38.4 (25.3)
	External Eye Liner	16.3%	39.5%	44.2%	36.4 (27.1)
	Eye Shadow	22.7%	31.8%	45.5%	34.5 (27.1)
	Anti-aging cream	18.2%	30.3%	51.5%	34.2 (23)
	Eye Lashes Glue	17.8%	27.8%	54.4%	36 (23.9)
	Do not use	30.7%	34.6%	34.6%	26.79 (22.75)
One-Way ANOVA: $F=2.32$ , $P\text{-value} < 0.0001$					

(Continued)

**Table 4** (Continued).

Variable		Normal	Mild-to-Moderate DED	Severe DED	Mean OSDI Score (SD)
Rate of Cosmetics Use	Daily	23.9%	34.2%	41.9%	31.1 (23.8)
	Weekly	26.2%	28%	45.8%	31.7 (23.8)
	Occasionally	23.4%	35.6%	41%	30.2 (23.6)
	One-Way ANOVA: F=2.35, P-value < 0.0001				
Duration of Cosmetics Use (per Day)	D < 6 hours	23.8%	33.9%	42.3%	30.5 (23.5)
	6 < D < 12 hour	24.1%	32.7%	43.2%	31.3 (23.3)
	D > 12 hours	30.2%	29.2%	40.6%	31.5 (27.1)
	One-Way ANOVA: F=1.71, P-value = 0.002				
Cleaning materials of Cosmetics	Water only	17.6%	33.6%	48.9%	33 (23.2)
	Soap and water	22.3%	30.8%	46.9%	33.3 (24.4)
	Cleansing cream	27.4%	34.4%	38.1%	28.8 (23.5)
	One-Way ANOVA: F=2.14, P-value = 0.0001				
Cleaning Rate of Cosmetics (before sleeping)	Always	25.1%	33.8%	41.1%	30.3 (23.6)
	Sometimes	24.3%	31.5%	44.2%	31.7 (24.3)
	Never	22.9%	25.7%	51.4%	33 (24.4)
	One-Way ANOVA: F=1.7 – P value = 0.002				

## Discussion

In agreement with the literature on DED prevalence among the Arab population, the average estimation of DED prevalence is relatively high (70.2%) with high ranging percentages (65.2–73.4%) among the studied countries.<sup>4,26</sup> The high prevalence in the Arab countries could be associated with the high prevalence of rheumatoid arthritis, diabetes mellitus, and the heavy use of age-related systemic and topical medications in elderly people.<sup>4</sup> Additionally, the population of the Middle Eastern countries is identified with poor education concerning DED, irregular follow-up, high proportions of contact lens use along with some environmental factors (eg, heavy use of air conditions, hot weather, excessive use of electronic devices, fine particulate pollution, and corrosive air salts due to proximity of countries to the sea).<sup>26</sup> As being Middle Eastern countries (also Arab) with similar climate features, Lebanon, Syria, Jordan, and Palestine were chosen for this study to minimize the interference of environmental risk factors in the study findings.<sup>27</sup>

## Evolution of DED Among the Studied Countries

The comparison of the current finding with the previous DED studies showed an increase in the prevalence of symptomatic DED in Lebanon (from 36.4% to 62.5%), Jordan (from 59% to 73.4%), and Palestine (from 69% to 72.7%).<sup>5,6,11</sup> On the other hand, this study showed the first estimation of DED prevalence in Syria (65.2%). This increase in DED estimation could be explained by the shifting of people's behavior towards heavy use of digital devices for remote learning/working and/or the continuous wearing of masks during the spread of the COVID-19 pandemic.<sup>28,29</sup> To neutralize the variation of COVID interference among the four countries and to enlarge the sample population in the next section of the discussion, the respondents from the four countries were merged into one study population from the Middle East.



## Symptomatic DED and Smoking

Lebanon, Syria, Jordan, and Palestine recorded high rates of smoking (53.9%, 34.8%, 38.1%, and 39.7%, respectively) in the MENA region.<sup>30,31</sup> For that, several types of tobacco such as Mouassal waterpipe, Ajami waterpipe, regular cigarette, and e-cigarette were investigated in the current association study with DED. According to the literature about tobacco, water pipes may have higher amounts of irritants (ie, Nicotine, Heavy metals, Carbon monoxide (CO), Polycyclic aromatic hydrocarbons (PAHs)) and generate more aerosols (puff smoke) than cigarettes.<sup>32–34</sup> However, the moisturized puffs in the waterpipe could be less irritating particularly upon dilution with water.<sup>35</sup> The latter would explain why cigarette smokers had more DED severity (higher OSDI mean score) than waterpipe smokers. On the other hand, the low DED severity among e-cigarette smokers confirmed the hypothesis that e-cigarettes contain fewer toxicants than other types of tobacco.<sup>36</sup> Among waterpipes, the low DED severity among Mouassal tobacco users could be explained by the features of tobacco in producing 30–40% less CO when mixed with molasses.<sup>37</sup>

The current study focused on the ocular exposure to the irritative aerosols of tobacco based on the assumption that the ocular surface may be exposed to over  $10^{14}$  short-lived radicals through the gas-tar phases of the puff smoke. The radicals in the puff smoke may increase the risk of lipid peroxidation of the outer layer of the pre-corneal tear film and eventually dry eye symptoms.<sup>38</sup> The complexity (over 7000 chemicals), formulations (tobacco brands) and the variability of waterpipe use (size of waterpipe, level of water, amount of tobacco in the waterpipe head, and the type of coal) are limiting factors for finding justification.<sup>10,13,37,39</sup> Regardless of the types of tobacco, indoor and frequent smoking could lead to a high risk of DED where smokers will be exposed to cumulative levels of aerosol irritants in the absence of an effective ventilation system.<sup>40</sup> When people smoke every day, they are continuously exposed to the irritants of tobacco which in turn could increase the risk of diagnosis with DED.

## Symptomatic DED and Cosmetic Use

Contrary to smoking, all types of cosmetic types recorded a comparable relationship with DED prevalence whereas Eyeliner (internally) and mascara users recorded the highest DED prevalence and severity. Here, their proximity and migration across the eyelid margin may increase the risk of their accidental exposure and thereby could explain the finding with either tear-film instability and/or corneal epithelium inflammation.<sup>17</sup> During frequent use of eye makeup, the lipophilic constituents of the formulations may also diffuse through the surface lipid layer and accumulate at the lipid-aqueous interface to reduce the stability of the overlying tear film layer.<sup>41</sup> Besides, the water-based formulations (eg, eyeliner and mascara products) provide a high risk of ocular irritation caused by Demodex mites which survive in cosmetic products or applicators and have a high affinity toward oil-rich environments (tear lipid film).<sup>16</sup>

As known, eye hygiene is necessary to reduce the risk of chemical overexposure and microbial contamination during the continuous use of cosmetics. Due to the lipophilicity of the formulations, water (lipophobic) alone will not effectively remove the eye makeup.<sup>16</sup> This would explain why worse DED prevalence and severity were recorded among respondents who used water alone or with soap as alternatives to surfactant-containing cleaners. Regardless of the possible association of these cleansing products with tear film instability, makeup removal products (slightly basic PH value  $\approx 7.3$ – $7.4$ ) provide a better cleansing effect (eg, waterproof products) with less risk of eye irritation than regular soaps (more basic PH values  $> 9$ ).<sup>17,42</sup>

## Strength and Limitations

The current study has investigated the first association data of symptomatic DED with tobacco and cosmetic use among four Middle Eastern countries (Lebanon, Syria, Jordan, and Palestine). The outcome of this study could provide their Ministries of Public Health and the medical research institutions with evidence regarding behavioral-based risk factors of DED to be a guiding platform for further investigations into DED. In addition, public health specialists, ophthalmologists, and optometrists could utilize these data to implement SDG3-based programs to spread awareness of DED and its associated factors among these populations. However, some limitations in the design of this study should be noted. The study findings relied only on an online self-responding questionnaire where some responding bias or social desirability could affect these findings. Also, the findings depended solely on the subjective analysis which could be consistent or not

with the clinical signs.<sup>43</sup> Thus, additional studies are recommended to assess clinically the occurrence of DED signs among these populations and investigate its association with tobacco and cosmetic use.

## Conclusion

Almost three-quarters of the studied population had been diagnosed with symptomatic DED assessed with the validated ARB-OSDI survey. Jordan and Palestine had recorded the highest prevalence of symptomatic DED compared to Lebanon and Syria. This paper has clearly shown that cosmetic usage and tobacco smoking are significantly associated with the prevalence and severity of symptomatic DED ( $P < 0.05$ ). In tobacco use; cigarettes, Ajami, indoor and daily smokers were more likely to report the symptomatic DED. Regardless of cosmetic types and frequency, users were more likely to report the symptomatic DED when eye hygiene was not effectively considered. The study provides a valuable platform for prospective studies on the evolution of DED in Middle Eastern countries.

## Abbreviations

DED, dry eye disease; OSDI, Ocular Surface Disease Index; MENA, the Middle East and North Africa.

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## Disclosure

The authors report no conflicts of interest in this work.

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