scientific reports

Check for updates

OPEN

Prevalence of dry eye disease symptoms, associated factors and impact on quality of life among medical students during the pandemic

Attapinya Kunboon[1], Napaporn Tananuvat[1]✉, Phit Upaphong[1], Nahathai Wongpakaran[2] & Tinakon Wongpakaran[2]

This cross-sectional study aimed to evaluate the prevalence of dry eye disease (DED) symptoms, their associated factors, and the impact on quality of life (QOL) and mental health among medical students during the COVID-19 pandemic using online surveys. Participants completed questionnaires covering demography, medical history, and personal data. The Thai version of the Dry Eye-related Quality-of-Life Score (DEQS-Th) was used for DED screening. The QOL and mental health challenges (support, coping, stress, and depression) were evaluated by the EuroQoL-5 dimensions-5 levels (EQ-5D-5L) and Thymometer questionnaires. A total of 449 participants were analyzed, with a mean age of 21.8 years and 61.5% female. The prevalence of DED symptoms was 60.4% (95%CI 55.7–64.8). The DEQS-Th score, the EQ-5D-5L score, and all aspects of mental health challenges were significantly worse in DED participants compared to non-DED participants. Associated factors for DED symptoms included preexisting DED ($p = 0.001$), refractive errors ($p = 0.007$), allergic conjunctivitis ($p = 0.001$), artificial tears use ($p < 0.001$), and decreased EQ-5D-5L score ($p < 0.001$). This study highlighted the high prevalence of DED symptoms among medical students during the pandemic and its negative impact on QoL and mental health. Notably, female gender, contact lens wear, screen time, and mask-wearing duration were not associated with DED symptoms.

Keywords Dry eye disease, Quality of life, Mental health, COVID-19

Abbreviations

CL	Contact lens
COVID-19	Coronavirus disease 2019
DED	Dry eye disease
DEQS-Th	Thai version of the Dry Eye-related Quality-of-Life Score
DES	Digital eye strain
EQ-5D-5L	EuroQoL-5 dimensions-5 levels
MADE	Mask-associated dry eye
QOL	Quality of life
VDT	Visual display terminal

Dry eye disease (DED) is a multifactorial disease involving tear film and the ocular surface, resulting in ocular discomfort and visual disturbance. Two major subtypes of DED are aqueous deficiency and increased tear evaporation, which contribute to tear film instability, hyper-osmolarity, inflammation, and ocular surface damage[1]. The ocular symptoms of DED include dryness, discomfort, irritation, fatigue, increase in sensitivity to light, and fluctuating visual disturbances.

Due to its chronic nature, ocular symptoms and visual impairment have been shown to have a multifaceted impact on an individual with DED[2]. These adverse effects on visual and physical functions lead to a decreased ability to perform everyday tasks such as reading, driving, and working[2]. Previous studies demonstrated that

[1]Department of Ophthalmology, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand. [2]Department of Psychiatry, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand. ✉email: ntananuvat@gmail.com

patients with symptomatic DED encountered greater challenges with mobility and work-related functions, as well as an increased likelihood of psychological disorders such as anxiety or depression[3–5]. Moreover, DED has a substantial economic burden resulting from direct medical costs and indirect costs including loss of productivity and impaired quality of life (QOL)[5–7].

According to the 2017 International Dry Eye Workshop, the global prevalence of DED varied between 5 and 50%[8]. While the definition of the disease varied across studies, its prevalence tended to rise with age, with females being more frequently affected than males[8]. Consistent and non-modifiable risk factors for DED include aging, female, Asian race, meibomian gland dysfunction, connective tissue diseases, and Sjogren syndrome. While computer use, contact lens wear, androgen deficiency, hormone replacement therapy, hematopoietic stem cell transplantation, environment, and medications are modifiable risk factors for DED[8]. Interestingly, there appears to be a high reported prevalence of DED (60.5-90%) among young populations and school children[9–11]. Potential risk factors in youth may be associated with screen usage, contact lenses, inadequate refractive correction, topical medication, and poor sleep quality[9–14]. DED has a strong association with children who use smartphones[12]. In addition, other co-existing ocular conditions (such as ocular allergy, meibomian gland dysfunction, Stevens-Johnson syndrome, and vitamin A deficiency) also pose a risk for DED in the pediatric population[10,15].

During the global Coronavirus Disease 2019 (COVID-19) pandemic, many countries implemented lockdowns or other restrictions to prevent the spread of the virus. As a result, solutions such as online studying or remote work were adopted to maintain productivity in schools and workplaces. However, the increased use of visual display terminal (VDT) associated with these activities may have adverse effects on the QOL related to vision, particularly in DED patients[16]. A study conducted among university students in Chile during the COVID-19 pandemic revealed that 77.5% of students experienced dry eye symptoms, with the duration of VDT use increasing to 15.9 h during online classes, compared to 9.8 h before the pandemic[17]. Lifestyle changes such as increased screen device usage, air conditioning, and adherence to social distancing measures can trigger or worsen dry eye symptoms. An online survey conducted among DED patients during the initial wave of COVID-19 indicated that exacerbation of dry eye symptoms had a detrimental effect on QOL, especially among individuals reporting increased screen time (59%), elevated stress levels (50%), and sleep deprivation (43%)[18].

Given that DED is primarily a symptomatic disease, chronic dry eye symptoms can lead to complications including impaired QOL and a deterioration in mental health[19,20]. Fortunately, there are several questionnaires with sufficient psychometric properties for assessing dry eye symptoms, and their impact on an individual's QOL as well as the patient-reported outcome after treatment[20]. These assessment tools can be valuable for studying DED prevalence, especially during a pandemic when performing ocular examinations may be challenging.

This study aimed to evaluate the prevalence of DED symptoms among medical students in Thailand, identify associated factors, and examine its impact on QOL and mental health during the COVID-19 pandemic. We hope the findings of this study can help increase awareness among medical students and other young individuals about the risks associated with DED and could also assist in implementing appropriate management strategies to alleviate its consequences.

Methods

This study was a cross-sectional study using an internet-based survey conducted between February to April 2022. The study protocol was approved by the Research and Ethics Committee, Faculty of Medicine, Chiang Mai University (Study code: OPT-2546-08534) and adhered to the Declaration of Helsinki. The survey was launched online using the REDCap (Research Electronic Data Capture; Vanderbilt University, Tennessee) platform version 7.6.5.

Participants

The inclusion criteria specified medical students from Chiang Mai University's Faculty of Medicine, aged 18 years or older. Exclusion criteria included other chronic ocular diseases (such as glaucoma, uveitis); ocular infection and inflammation within 3 months; previous ocular or refractive surgery within 6 months; and systemic disease or disabilities that affect daily life activities and psychological disorders. Patients who agreed to participate had given written informed consent online before answering the questionnaires.

Measurement tools

The questionnaire and measurements used in the online survey include:

(1) *Self-developed Questionnaire* This part was to gather general information and details associated with physical health such as demography (as gender, and age); refractive error and methods of correction (glasses, contact lenses, or refractive surgery); previous diagnosis of ocular disease and treatment; other underlying systemic diseases; current medication; exercise frequency; VDT use (time and type of screen); sleep duration (hours/day); mask use (duration, hours/day; and type); and frequency of artificial tears used.

(2) *Thai version of the Dry Eye-related Quality-of-Life Score (DEQS-Th)* This questionnaire was developed from the English version[21]. It contains 15 questions addressing two subscales: "Bothersome Ocular Symptoms" (6 items) and "Impact on Daily Life" (9 items). Each question was evaluated for frequency and severity, based on a 5-point scale, ranging from "none of the time" (0) to "all of the time" (4) for the frequency, and a 4-point scale, ranging from "no affect" (1) to "high affect" (4) for the severity. The DEQS score is calculated using the following formula: (sum of the severity scores of all questions answered) x 25/ (total number of questions answered). The higher scores indicated more severe symptoms and poorer QOL. The Thai version of the DEQS (DEQS-Th) has been validated for its psychometric properties in normal and DED participants. The cut-off DEQS-Th score of 18 or more is the criterion for a diagnosis of DED[22].

(3) *EuroQoL-5 dimensions-5 levels (EQ-5D-5L)* This self-assessment questionnaire evaluated health-related QOL across 5 dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/ depression[23]. Each dimension was rated on a 5-level scale: no problems (Level 1), slight, moderate, severe, and extreme problems (Level 5). The EQ-5D has two parts, (1) a descriptive system that calculates a five-digit code specifying a specific health state to the index score. The score ranges from 0 (death) to 1(complete health), and negative values indicate a health state considered worse than death (total utility score = 1 - proportion in each dimension). (2) a visual analog scale, ranging from 0 (worst imaginable health state) to 100 (best imaginable health state). In this study, we utilized the Thai version of the EQ-5D-5L and its corresponding index score[24].

(4) *Thymometer* This single rating scale, assessing depression, perceived stress, perceived social support, and coping, was used to evaluate mental health status. For stress and depression, the score ranges from 1 (no stress/depression) to 10 (stressful), whereas in the case of support and coping, the score ranges from 1 (nothing) to 10 (helpful/good support)[25]. The final scores of perceived social support and coping were calculated from the inversion of the raw scores. Hence, in all four dimensions, the higher the score the worse the mental health.

Statistical analysis

The data extracted from the online platform were analyzed using SPSS program version 25 (IBM Corp., Armonk, NY, USA). Continuous data were presented as mean (standard deviation, SD) or median (interquartile range, IQR) depending on the distribution of the data. Categorial data were analyzed and presented as a proportion. To compare participant characteristics, the QOL scores, and mental health issues between participants with DED and non-DED, Chi-square, Fisher's exact, Mann Whitney-U, and t-test were used, depending on the types of variables and the distribution of the data. Pearson's correlation was used to determine any correlations between DED and health-related QOL, and DED and mental health challenges. A p-value under 0.05 was considered statistically significant. The variables selected for the multivariable regression model were those that showed significant differences between DED and non-DED participants, and important variables identified in previous literature. The sample size was calculated to be 269, based on a 77.5% prevalence of DED as reported in a previous study[17], and the precision of the estimate set at 0.05.

Conference presentation

This study was presented in part as a poster at the 8th Asia Cornea Society Biennial Scientific Meeting, 23–25 November 2022, Bangkok, Thailand.

Results

Demographic data of the participants

The response rate of this online survey was 50.6% (648 respondents from a total of 1,281 medical students). However, 197 responses were incomplete or duplicated, and 1 participant was subsequently excluded due to previous glaucoma treatment. The characteristics of the remaining 449 eligible participants are summarized in Table 1.

Among the participants, 271 were diagnosed as DED based on the DEQS-Th criteria, thus the prevalence of DED symptoms was 60.4%, (95% CI 55.7–64.8). The mean age of all participants was 21.8 ± 1.8 years, with females being predominant (61.5%). There was no significant difference in characteristics between DED and non-DED participants including satisfaction with income, and underlying conditions (such as hypertension, diabetes mellitus, systemic allergic diseases, and cerebrovascular diseases). In addition, there was no significant difference in the time spent on visual-related activities (overall mean ± SD) between DED and non-DED groups such as total study time (29.8 ± 18.3 h/week), total screen time (10.8 ± 4.3 h/day), and screen time for study (6.8 ± 2.9 h/day) or mean sleep hours (6.5 ± 1.0 h/day). Regarding ocular history, DED participants had a higher prevalence of pre-existing dry eye and allergic conjunctivitis compared to non-DED participants (19.2% vs. 3.9%, $p < 0.001$, and 6.3% vs. 1.7%, $p = 0.021$, respectively). In the DED group, the proportion of participants with refractive errors who used corrective spectacles was higher than in the non-DED group (80.8% vs. 70.8%, $p = 0.014$) whereas correction with contact lenses and refractive surgery were comparable between groups. In addition, those in the DED group used artificial tears more frequently than the non-DED group (46.5% vs. 23.5%, $p < 0.001$). Surgical mask was the most common mask type (overall 84.9%) and there was no difference in mask-wearing hours among students with DED and non-DED (8.4 ± 3.2 vs. 8.2 ± 3.1 h/day, $p = 0.215$) (Table 1).

Association of DED, QOL, and mental health

In Table 2, the QOL and mental health status of DED and non-DED participants were compared using the DEQS-Th, EQ-5D-5L, and Thymometer criteria. DED participants had significantly higher DEQS-Th scores compared to non-DED participants (total score of 32.12 ± 12.73 vs. 9.11 ± 4.67, $p < 0.001$). The QOL determined by the EQ-5D-5L was significantly lower in DED compared to non-DED participants (0.97 ± 0.07 vs. 0.99 ± 0.03, $p < 0.001$). Coping (with inversion score), stress, and depression scores in the Thymometer were significantly higher in DED participants compared to those in the non-DED group (all $p < 0.01$).

Table 3 shows the correlations between the ocular symptoms and the impact on daily life subscale scores of DEQS-Th and the EQ-5D-5L, as well as the Thymometer. EQ-5D-5L score had a negative correlation with DEQS-Th in both subscale scores and total scores (r -0.324 to -0.337, all $p < 0.001$). Additionally, almost all aspects of the Thymometer (with the conversion of support and coping) were statistically significantly positively correlated with both subscale scores and total score of the DEQS-Th ($r = 0.094$ to 0.210, all $p < 0.05$), except for the support part and the symptom subscale of the DEQS-Th ($r = 0.005$, $p = 0.245$).

Variables	Overall ($n=449$)	DED ($n=271$)	Non-DED ($n=178$)	*P* values
Age (years, mean ± SD)	21.8 ± 1.8	21.7 ± 1.8	21.9 ± 1.7	0.169
Gender (%)				
Male	173 (38.5)	95 (35.1)	78 (43.8)	
Female	276 (61.5)	176 (64.9)	100 (56.2)	0.062
Activities (hours, mean ± SD)				
Total study time/week	29.8 ± 18.3	28.8 ± 19.4	31.3 ± 16.5	0.152
Total screen time/day	10.8 ± 4.3	11 ± 4.9	10.5 ± 3.3	0.180
Screen time for study/day	6.8 ± 2.9	6.9 ± 3.0	6.6 ± 2.9	0.380
Sleep hours/day	6.5 ± 1.0	6.5 ± 0.9	6.4 ± 1.0	0.555
Mask-wearing time	8.4 ± 3.2	8.2 ± 3.1	8.6 ± 3.2	0.215
Primary device usage for study (n, %)				
Computer	146 (32.5)	87 (32.1)	59 (33.2)	0.965*
Tablet	289 (64.4)	175 (64.6)	114 (64.0)	
Smartphone	14 (3.1)	9 (3.3)	5 (2.8)	
Medical history (n, %)				
Systemic allergic diseases	131 (29.2)	88 (32.5)	43 (24.2)	0.058
Pre-existing dry eye	59 (13.1)	52 (19.2)	7 (3.9)	< 0.001
Allergic conjunctivitis	20 (4.5)	17 (6.3)	3 (1.7)	0.021*
Refractive error and correction ($n=378$%)				
Glasses	345 (76.8)	219 (80.8)	126 (70.8)	0.014
Contact lens	67 (14.9)	45 (16.6)	22 (12.4)	0.217
Refractive surgery	7 (1.6)	5 (1.8)	2 (1.1)	0.546*
Mask types				
Surgical mask	381 (84.9)	226 (83.4)	155 (87.1)	0.366*
Fabric mask	12 (2.7)	10 (3.7)	2 (1.1)	
N95 mask	21 (4.7)	14 (5.2)	7 (3.9)	
≥ 2 layers of mask	35 (7.8)	21 (7.7)	7 (3.9)	
Artificial tear use				
Never	286 (63.7%)	148 (54.6%)	138 (77.5%)	< 0.001*
Occasional (not every day)	129 (28.7%)	95 (35.1%)	34 (19.1%)	
1–2 times/day	19 (4.2%)	17 (6.3%)	2 (1.1%)	
3 or more times/day	15 (3.3%)	11 (4.1%)	4 (2.3%)	

Table 1. Participants characteristics. Continuous variables with normal distribution are presented as mean ± SD and are compared between DED and non-DED participants by Student's t-test. *DED* dry eye disease, *N95* N95 respirators mask, *SD* standard deviations. Categorical variables are presented as numbers with percent and are compared by the chi-square test or Fisher's Exact test*.

Questionnaires	DED ($n=271$) (mean ± SD)	Non-DED ($n=178$) (mean ± SD)	*P* value*
DEQS-Th			
Total score	32.18 ± 12.73	9.11 ± 4.67	< 0.001
Ocular symptoms score	13.13 ± 5.82	4.65 ± 2.79	< 0.001
Impact on daily life score	19.05 ± 8.81	4.46 ± 3.55	< 0.001
EQ-5D-5L	0.97 ± 0.07	0.99 ± 0.03	< 0.001
Thymometer			
Support	3.22 ± 1.63	2.99 ± 1.59	0.152
Coping	3.78 ± 1.56	3.40 ± 1.49	0.01
Stress	5.12 ± 2.07	4.37 ± 2.22	< 0.001
Depression	3.44 ± 2.10	2.72 ± 1.84	< 0.001

Table 2. Mental health-associated scores in DED vs. non-DED participants. *DED* dry eye disease, *non-DED* non-dry eye disease, *DEQS-TH* Thai-version of dry eye-related quality of life score, *EQ-5D-5L* EuroQoL-5D-5L. *The comparison was conducted by Wilcoxon's Rank-sum test.

	Symptoms		Impact on daily life		Total score	
	R	*P* value	*R*	*P* value	*R*	*P* value
EQ-5D-5L	− 0.329	< 0.001	− 0.337	< 0.001	− 0.324	< 0.001
Thymometer						
Support	0.055	0.245	0.094	0.045	0.094	0.045
Coping	0.111	0.018	0.135	0.004	0.135	0.004
Stress	0.180	< 0.001	0.200	< 0.001	0.200	< 0.001
Depression	0.191	< 0.001	0.210	< 0.001	0.210	< 0.001

Table 3. Correlation between the DEQS-Th and the EQ-5D-5L questionnaires, and the DEQS-Th and the thymometer questionnaires. By Pearson correlation. *DEQS-Th* Thai version of the dry eye-related quality of life score, *EQ-5D-5L* EuroQoL-5dimensions-5levels.

Variables	Coefficient	95% CI	*P* values
Gender	− 0.27	− 2.89 to 2.35	0.842
Age	− 0.19	− 0.98 to 0.61	0.644
Preexisting dry eye	9.33	5.43 to 13.23	< 0.001
Allergic conjunctivitis	9.80	3.78 to 15.81	0.001
Contact lens use	0.74	− 2.78 to 4.26	0.681
Refractive error	5.29	1.85 to 8.72	0.003
Total study time	− 0.04	− 0.11 to 0.03	0.247
Total screen time	0.16	− 0.18 to 0.50	0.355
Type of device usage	1.23	− 1.15 to 3.62	0.311
Sleep duration	− 0.66	− 2.00 to 0.68	0.336
Mask-wearing time	− 0.05	− 0.49 to 0.38	0.82
Frequency of artificial tears	2.79	1.48 to 4.09	< 0.001
Thymometer			
Support	− 0.21	− 1.15 to 0.74	0.667
Coping	0.03	− 0.99 to 1.06	0.950
Stress	0.51	− 0.23 to 1.24	0.181
Depression	0.58	− 0.22 to 1.38	0.157
EQ-5D-5L	− 40.14	− 51.05 to − 29.24	< 0.001

Table 4. Factors associated with dry eye disease symptoms determined by multivariable logistic regression. *CI* confidence interval, *EQ-5D-5L* EuroQoL-5dimensions-5levels.

Associated factors for DED symptoms

The results from the multivariable logistic regression analysis are shown in Table 4. Factors that were significantly associated with an increase in DED symptoms determined by the DEQS-Th scores included preexisting dry eye (coefficient = 9.33, 95%CI = 5.43 to 13.23, $P < 0.001$), allergic conjunctivitis (coefficient = 9.80, 95%CI = 3.78 to 15.81, $P = 0.001$), the presence of refractive errors (coefficient = 5.29, 95%CI = 1.85 to 8.72, $P = 0.003$), and frequency of artificial tears use (coefficient = 2.79, 95%CI = 1.48 to 4.09, P = < 0.001). Conversely, a decrease in the EQ-5D-5L score was significantly associated with an increase in the DEQS-Th score (coefficient =-40.14, 95% CI= -51.05 to -29.24, $P < 0.001$). Notably, female gender, contact lens wear, screen time, and mask-wearing duration as well as all mental health issues did not show a significant association with DED symptoms.

Discussions

During the COVID-19 pandemic, university students, including medical students, had to shift most study programs to online platforms. This study ascertained the prevalence of DED symptoms in young people and its associated factors, along with its impact on QoL during the pandemic. This online survey, conducted during the third wave of the COVID-19 pandemic in Thailand in 2022, revealed the prevalence of DED symptoms among medical students of 60.4%, determined by the DEQS-Th questionnaire. This number was comparatively lower than those reported in previous studies conducted among high school and university students during the early onset of the pandemic, where prevalence ranged from 70.5 to 77.5%[17,26,27]. These variations may partly differ due to the diagnostic criteria for DED across studies, as well as the timing of the research. However, it is noteworthy that the prevalence of DED among this specific young population remains high across all studies compared to the pre-COVID-19 era (8.2–26.6%)[13,14,28].

This study identified several factors significantly associated with DED symptoms, including preexisting dry eye, refractive error, allergic conjunctivitis, the frequency of artificial tear use, and impaired QOL as measured by the EQ-5D-5L scores. Interestingly, factors such as female gender, contact lens wear, screen time, and mask-wearing were not found to have a significant association with DED symptoms, which contradicts previous literature.

The use of digital devices for education such as laptops, tablets, mobile phones, e-readers, as well as video conference platforms has increased since the pandemic. Previous studies found an association between VDT use and DED among young adults and children, including primary school students[10–12]. In addition, VDT use increased significantly in comparison to before the pandemic[17]. Although the average screen time in this study was high (> 10 h/day), there was no significant difference between DED and non-DED participants. This might be because digital devices have been increasingly used in the past decade and have become a norm in people's lifestyles. Excessive exposure to VDT can lead to the deterioration of dry eye symptoms[29]. While using digital screens, or when paying attention to something, the blink rate usually decreases, or incomplete blinking occurs which leads to an increase in tear evaporation and tear film instability[12,30]. In addition, prolonged use of digital devices or exposure to screen illumination (> 4 h) may contribute to ocular surface-related symptoms such as burning sensation, grittiness, watering, itching, dryness, and eye fatigue known as "digital eye strain (DES)", which may overlap with dry eye symptoms[31]. DES symptoms can be accommodation-related such as difficulty refocusing from one distance to another, or can be extraocular symptoms such as headache, neck or shoulder, and back pain[31]. Moreover, myopic progression has been linked to DES in the pediatric population[32]. Both DES and DED are associated with prolonged screen exposure and may co-occur. Uwimana et al. found a concurrent rise of DES and DED symptoms with a strong and significant positive correlation between both conditions ($r = 0.695$, $p < 0.001$) among university students during the COVID-19 pandemic[33].

Other known associated risk factors for DED include female gender, contact lens (CL) use, and allergic diseases[8,34]. Although we found that female students were predominant in the DED group, the difference was not statistically significant. In general, females tend to exhibit a higher prevalence of DED with advancing age compared to males, although there is considerable variability. It appears that the differences between the sexes become more pronounced after the age of 50[8]. This could be related to the decline in sex hormones post-menopause, which contributes to aqueous tear deficiency in females. Since the study population consisted of young adults, the impact of gender may not be as significant. Nevertheless, age and sex stratification should be important considerations in future studies.

This study found that refractive error was significantly associated with DED symptoms similar to previous studies[12,14,17]. Among the students with refractive error, particularly individuals with improper correction, using accommodation may lead to ocular symptoms (i.e. eye pain, strain, and discomfort), which overlap with dry eye symptoms[14].

CL wear is associated with an increased prevalence of symptomatic DED as it can disrupt normal ocular surface homeostasis. This impact may vary depending on the type of CLs used and the wearing schedule. Our findings are contrary to previous evidence that CL use is a consistent risk factor for DED in students[9,10,13]. This may be partly due to medical students' understanding of proper CL usage, recognizing CL wear as a modifiable risk factor for DED. Furthermore, previous research indicated that the average daily wearing hours of CLs decreased during the pandemic compared to pre-pandemic levels[35,36]. The main reason for this decrease was attributed to the reduction in social and outdoor activities. Additionally, fear of infection with SARS-CoV-2 led some individuals to discontinue CL wear[35,36].

During the pandemic, a face mask became the most common personal prevention equipment to protect against viral infection. Various studies found evidence to show an increase in dry eye symptoms and ocular discomfort related to face mask users. The incidence of mask-associated dry eye (MADE) varied from 7.9 to 18.3%[37,38]. The possible pathophysiological mechanisms associated with MADE may be related to an unnatural upward airflow towards the ocular surface during expiration leading to increased tear evaporation and inducing stress which may increase in improperly fitted face masks[38,39].

This study found that the surgical mask was the most common type of mask used (85%) in all students and there was no significant difference in mean mask-wearing time among the DED and non-DED students with overall mask-wearing time was more than 8 h/day. This may be because medical students might have been trained in proper mask-wearing as they needed to wear masks for their work.

Evidence showed that DED symptoms can significantly impair visual function, limit activities, and reduce work productivity[2,4,5,7]. Our previous study demonstrated a significant association between perceived stress, neuroticism, and QOL in DED patients[40]. In addition, the personality of the patients may influence the symptoms and QOL in DED patients[40]. During the pandemic, stress levels and sleep disturbance have been identified as factors exacerbating dry eye symptoms, along with a decrease in pain threshold and inflammation[18]. Lin et al. studied high school students in China and found that apart from prolonged VDT use and female gender, stress and poor sleep quality were factors significantly associated with DED during the COVID-19 outbreak[27]. Increased online studying and a decrease in normal learning activities may heighten stress levels beyond typical circumstances, potentially leading to increased stress and depression among medical students. In this study, DED symptoms exhibited a significant negative correlation with QOL and mental health, particularly regarding perceived stress and depression. While the observed difference was statistically significant, its clinical significance remained uncertain. Future research, including studies that measure changes in EQ-5D-5L and mental health scores over time, will be necessary to understand the clinical implications fully. Nevertheless, our findings underscore that DED is among the ocular disorders that significantly affect the QOL and mental well-being of an individual. Meanwhile, impaired QOL determined by the EQ-5D-5L score was significantly associated with DED symptoms. In a younger population, chronic dry eye symptoms and impaired mental

health may potentially affect the learning ability of individuals as well as their personalities. However, further studies are needed to explore these relationships.

The main strength of this study lies in the use of validated questionnaires with adequate psychometric properties to assess DED symptoms, in addition to QOL and mental health. Participants voluntarily and anonymously completed the survey. The results of this study will enable clinicians and carers to become aware of this ocular problem, which can significantly impact the QOL of students. However, this study also has some limitations. Firstly, it was conducted during the pandemic using an online platform, lacking clinical evaluations for DED such as tear film break-up time, ocular surface staining, or the Schirmer test. Thus, asymptomatic DED participants may have been overlooked. Secondly, relying on self-conducted questionnaire surveys might introduce recall bias. In addition, the lower response rate of this survey could induce selective bias. This study is cross-sectional, further investigations are required to determine the causal relationship between individual risk factors and DED.

In conclusion, the prevalence of DED symptoms among medical students was notably high during the COVID-19 pandemic. Significant associated factors for DED symptoms in this young population included preexisting DED, refractive errors, allergic conjunctivitis, frequency of artificial tears use, and impaired QOL. Meanwhile, dry eye symptoms also had negative impact on both quality of life and mental health. However, we did not establish an association with certain known risk factors, such as female gender, contact lens use, duration of mask-wearing, or screen time. This divergence in our results compared to earlier studies suggests that DED in younger populations may be influenced by other factors or lifestyle changes, potentially exacerbated by the effects of the pandemic. Nevertheless, our findings may contribute to the development of preventive and management strategies to identify students at risk who may require further investigation and treatment for DED, ultimately mitigating the consequences of chronic DED.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Received: 29 July 2024; Accepted: 4 October 2024
Published online: 14 October 2024

References

1. Craig, J. P. et al. TFOS DEWS II definition and classification report. *Ocul. Surf.* **15**, 276–283. https://doi.org/10.1016/j.jtos.2017.05.008 (2017).
2. Miljanović, B., Dana, R., Sullivan, D. A. & Schaumberg, D. A. Impact of dry eye syndrome on vision-related quality of life. *Am. J. Ophthalmol.* **143**, 409–415. https://doi.org/10.1016/j.ajo.2006.11.060 (2007).
3. Uchino, M. & Schaumberg, D. A. Dry eye disease: impact on quality of life and vision. *Curr. Ophthalmol. Rep.* **1**, 51–57. https://doi.org/10.1007/s40135-013-0009-1 (2013).
4. Dana, R., Meunier, J., Markowitz, J. T., Joseph, C. & Siffel, C. Patient-reported burden of dry eye disease in the United States: results of an online cross-sectional survey. *Am. J. Ophthalmol.* **216**, 7–17. https://doi.org/10.1016/j.ajo.2020.03.044 (2020).
5. Hossain, P. et al. Patient-reported burden of dry eye disease in the UK: a cross-sectional web-based survey. *BMJ Open* **11**, e039209. https://doi.org/10.1136/bmjopen-2020-039209 (2021).
6. Yu, J., Asche, C. V. & Fairchild, C. J. The economic burden of dry eye disease in the United States: a decision tree analysis. *Cornea* **30**, 379–387. https://doi.org/10.1097/ICO.0b013e3181f7f363 (2011).
7. Uchino, M. et al. Dry eye disease and work productivity loss in visual display users: the Osaka study. *Am. J. Ophthalmol.* **157**, 294–300. https://doi.org/10.1016/j.ajo.2013.10.014 (2014).
8. Stapleton, F. et al. TFOS DEWS II epidemiology report. *Ocul. Surf.* **15**, 334–365. https://doi.org/10.1016/j.jtos.2017.05.003 (2017).
9. Garza-León, M., López-Chavez, E. & De La Parra-Colín, P. Prevalence of ocular surface disease symptoms in High School students in Monterrey, Mexico. *J. Pediatr. Ophthalmol. Strabismus* **58**, 287–291. https://doi.org/10.3928/01913913-20210308-01 (2021).
10. Aćimović, L., Stanojlović, S., Kalezić, T. & Dačić Krnjaja, B. Evaluation of dry eye symptoms and risk factors among medical students in Serbia. *PLoS ONE* **17**, e0275624. https://doi.org/10.1371/journal.pone.0275624 (2022).
11. Muntz, A. et al. Extended screen time and dry eye in youth. *Cont. Lens Anterior Eye* **45**, 101541. https://doi.org/10.1016/j.clae.2021.101541 (2022).
12. Moon, J. H., Kim, K. W. & Moon, N. J. Smartphone use is a risk factor for pediatric dry eye disease according to region and age: a case control study. *BMC Ophthalmol.* **16**, 188. https://doi.org/10.1186/s12886-016-0364-4 (2016).
13. Uchino, M. et al. Japan Ministry of Health study on prevalence of dry eye disease among Japanese high school students. *Am. J. Ophthalmol.* **146**, 925–929. https://doi.org/10.1016/j.ajo.2008.06.030 (2008).
14. Zhang, Y., Chen, H. & Wu, X. Prevalence and risk factors associated with dry eye syndrome among senior high school students in a county of Shandong Province, China. *Ophthal. Epidemiol.* **19**, 226–230. https://doi.org/10.3109/09286586.2012.670742 (2012).
15. Donthineni, P. R., Das, A. V. & Basu, S. Dry eye disease in children and adolescents in India. *Ocul. Surf.* **18**, 777–782. https://doi.org/10.1016/j.jtos.2020.07.019 (2020).
16. Saldanha, I. J., Petris, R., Makara, M., Channa, P. & Akpek, E. K. Impact of the COVID-19 pandemic on eye strain and dry eye symptoms. *Ocul. Surf.* **22**, 38–46. https://doi.org/10.1016/j.jtos.2021.06.004 (2021).
17. Cartes, C. et al. Dry eye and visual display terminal-related symptoms among University students during the coronavirus disease pandemic. *Ophthal. Epidemiol.* **29**, 245–251. https://doi.org/10.1080/09286586.2021.1943457 (2022).
18. Barabino, S. A. Narrative review of current understanding and classification of dry eye disease with new insights on the impact of dry eye during the COVID-19 pandemic. *Ophthalmol. Ther.* **10**, 495–507. https://doi.org/10.1007/s40123-021-00373-y (2021).
19. Sayegh, R. R. et al. Ocular discomfort and quality of life among patients in the dry eye assessment and management study. *Cornea* **40**, 869–876. https://doi.org/10.1097/ico.0000000000002580 (2021).
20. Okumura, Y. et al. A review of dry eye questionnaires: measuring patient-reported outcomes and health-related quality of life. *Diagnostics (Basel)* 10559. https://doi.org/10.3390/diagnostics10080559 (2020).
21. Sakane, Y. et al. Development and validation of the dry eye-related quality-of-life score questionnaire. *JAMA Ophthalmol.* **131**, 1331–1338. https://doi.org/10.1001/jamaophthalmol.2013.4503 (2013).
22. Tananuvat, N., Tansanguan, S., Wongpakaran, N. & Wongpakaran, T. Reliability, validity, and responsiveness of the Thai version of the dry eye-related quality-of-life score questionnaire. *PLoS ONE* **17**, e0271228. https://doi.org/10.1371/journal.pone.0271228 (2022).

23. EuroQol—a new facility for the measurement of health-related quality of life. *Health Policy* **16**, 199–208. https://doi.org/10.1016/0168-8510(90)90421-9 (1990).
24. Tongsiri, S. & Cairns, J. Estimating population-based values for EQ-5D health states in Thailand. *Value Health* **14**, 1142–1145. https://doi.org/10.1016/j.jval.2011.06.005 (2011).
25. Lohanan, T. et al. Development and validation of a screening instrument for borderline personality disorder (SI-Bord) for use among university students. *BMC Psychiatry* **20**, 479. https://doi.org/10.1186/s12888-020-02807-6 (2020).
26. Tangmonkongvoragul, C. et al. Prevalence of symptomatic dry eye disease with associated risk factors among medical students at Chiang Mai University due to increased screen time and stress during COVID-19 pandemic. *PLoS ONE* **17**, e0265733. https://doi.org/10.1371/journal.pone.0265733 (2022).
27. Lin, F. et al. Prevalence of dry eye disease among Chinese high school students during the COVID-19 outbreak. *BMC Ophthalmol.* **22**, 190. https://doi.org/10.1186/s12886-022-02408-9 (2022).
28. Supiyaphun, C., Jongkhajornpong, P., Rattanasiri, S. & Lekhanont, K. Prevalence and risk factors of dry eye disease among University students in Bangkok, Thailand. *PLoS ONE* **16**, e0258217. https://doi.org/10.1371/journal.pone.0258217 (2021).
29. Neti, N., Prabhasawat, P., Chirapapaisan, C. & Ngowyutagon, P. Provocation of dry eye disease symptoms during COVID-19 lockdown. *Sci. Rep.* **11**, 24434. https://doi.org/10.1038/s41598-021-03887-4 (2021).
30. Courtin, R. et al. Prevalence of dry eye disease in visual display terminal workers: a systematic review and meta-analysis. *BMJ Open* **6**, e009675. https://doi.org/10.1136/bmjopen-2015-009675 (2016).
31. Kaur, K. et al. Digital eye strain—A comprehensive review. *Ophthalmol. Ther.* **11**, 1655–1680. https://doi.org/10.1007/s40123-022-00540-9 (2022).
32. Mohan, A., Sen, P., Peeush, P., Shah, C. & Jain, E. Impact of online classes and home confinement on myopia progression in children during COVID-19 pandemic: Digital eye strain among kids (DESK) study 4. *Indian J. Ophthalmol.* **70**, 241–245. https://doi.org/10.4103/ijo.IJO_1721_21 (2022).
33. Uwimana, A., Ma, C. & Ma, X. Concurrent rising of dry eye and eye strain symptoms among University Students during the COVID-19 pandemic era: a cross-sectional study. *Risk Manag. Health Policy* **15**, 2311–2322. https://doi.org/10.2147/rmhp.S388331 (2022).
34. Vehof, J., Kozareva, D., Hysi, P. G. & Hammond, C. J. Prevalence and risk factors of dry eye disease in a British female cohort. *Br. J. Ophthalmol.* **98**, 1712–1717. https://doi.org/10.1136/bjophthalmol-2014-305201 (2014).
35. Morgan, P. B. Contact lens wear during the COVID-19 pandemic. *Cont. Lens Anterior Eye* **43**, 213. https://doi.org/10.1016/j.clae.2020.04.005 (2020).
36. Bakkar, M. M. & Alzghoul, E. A. Assessment of contact lens wearers' attitude toward contact lens wear and care during Coronavirus Disease 2019 (COVID-19) pandemic: a cross-sectional online survey. *Cont. Lens Anterior Eye* **44**, 101410. https://doi.org/10.1016/j.clae.2021.01.005 (2021).
37. Fan, Q. et al. Wearing face masks and possibility for dry eye during the COVID-19 pandemic. *Sci. Rep.* **12**, 6214. https://doi.org/10.1038/s41598-022-07724-0 (2022).
38. Boccardo, L. Self-reported symptoms of mask-associated dry eye: a survey study of 3,605 people. *Cont. Lens Anterior Eye* **45**, 101408. https://doi.org/10.1016/j.clae.2021.01.003 (2022).
39. Burgos-Blasco, B. et al. Face mask use and effects on the ocular surface health: a comprehensive review. *Ocul. Surf.* **27**, 56–66. https://doi.org/10.1016/j.jtos.2022.12.006 (2023).
40. Tananuvat, N., Tansanguan, S., Wongpakaran, N. & Wongpakaran, T. Role of neuroticism and perceived stress on quality of life among patients with dry eye disease. *Sci. Rep.* **12**, 7079. https://doi.org/10.1038/s41598-022-11271-z (2022).

Acknowledgements
The authors wish to express our gratitude to all students who participated in this study by responding to the online survey.

Author contributions
Study concept and design: A.K., N.T., P.U., N.W., and T.W. Acquisition of data: A.K., N.T., and P.U. Analysis and interpretation of data: A.K., N.T., P.U., N.W., and T.W. Drafting of the manuscript: A.K. and N.T.Statistical analysis: A.K., and P.U. Critical revision of the manuscript: N.T., P.U., N.W., and T.W.All authors read and approved the final manuscript.

Funding
This work was granted by the Faculty of Medicine Endowment Fund, Faculty of Medicine, Chiang Mai University (Grant Number: 089/2565). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to N.T.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.