

Association between Nighttime Sleep Duration and Tear Film Parameters in Young Adults

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Abstract

Background: The aim of this study was to investigate the relationship between nighttime sleep duration and tear film parameters and dry eye symptoms.

Design: This is a cross-sectional observational study conducted among students.

Methods: 648 (241 female) students with a mean age of 22.06 ± 3.96 years were examined. Each participant completed the Ocular Surface Disease Index (OSDI) and Pittsburgh Sleep Quality Index (PSQI) questionnaire, and then the values of Schirmer tests, corneal staining, tear meniscus assessment and tear break-up time (TBUT) were recorded.

Results: We divided the subjects into 3 groups based on sleep duration: sleep-deprived (< 5 hours), normal sleep (between 5-9 hours), or long sleep (9 < hours). Based on the results of ANOVA analysis, OSDI values ($P=0.01$), TBUT ($P=0.04$), Schirmer test results ($P=0.03$), and tear meniscus height ($P=0.01$) were significantly worse in short sleepers.

The results of the multivariate logistic regression model showed that nighttime sleep duration had an independent and significant effect on the presence of dry eye syndrome (DED) ($OR=1.20$; $P=0.05$) and that reduced sleep hours were significantly associated with an impaired (TBUT) and corneal staining ($OR=1.21$; $P=0.01$).

Conclusions: People with shorter sleep duration had severe symptoms and poorer tear film parameters than others. These results indicate that sleep pattern can be a modifiable factor associated with ocular surface status. Therefore, attention to sleep hygiene and appropriate regulation of sleep duration can be considered as part of non-pharmacological strategies in the management and prevention of dry eye.

Introduction

Dry eye disease (DED) is one of the most common ophthalmological disorders, which is defined by the International Dry Eye Workshop (DEWS) as follows: "Dry eye is a multifactorial disease of the ocular surface in which tear film homeostasis is impaired, ultimately leading to ocular discomfort, foreign body sensation, and blurred vision. Tear instability, hyperosmolarity, inflammation, and ocular surface injury, as well as neurosensory abnormalities, play a major role in the etiology of this disease" ⁽¹⁾. Worldwide, between 5% and 50% of people suffer from dry eye. Dry eye disease, due to widespread eye problems, ultimately negatively affects the quality of life of individuals. Recently, several studies have shown an association between dry eye and poor sleep quality, including higher PSQI scores and a higher prevalence of sleep disorders, but the specific role of nightly sleep duration on tear film stability and DED has been less well studied ⁽²⁻⁴⁾. A recent meta-analysis found that people with dry eye had poorer sleep quality and were more likely to be either sleep deprived or overslept, but no consistent and clear differences in total sleep duration were observed between groups, indicating uncertainty about the direct relationship between sleep duration and ocular surface status(5). However, most studies have focused

on sleep quality as a composite score, and the independent effect of nightly sleep duration on objective tear film parameters remains unclear. Experimental evidence suggests that sleep deprivation can impair lacrimal gland function and tear secretion, which reinforces the possible physiological pathways between reduced sleep duration and tear film instability. Therefore, examining the precise effect of nighttime sleep duration on tear quantity and quality and dry eye symptoms in young people fills an important gap in existing knowledge and could introduce sleep duration as a modifiable factor in the prevention and management of dry eye. The aim of this article is to investigate the relationship between nighttime sleep hours on tear film quality and quantity and dry eye symptoms.

Subjects and Methods

This cross-sectional study was conducted on all students enrolled in the Faculty of Rehabilitation Sciences during 2016–17, with a mean age of 22.06 ± 3.96 years (range 18–40). The Ethics Committee of the University of Medical Sciences approved the study protocol, and all procedures adhered to the ethical principles of the Declaration of Helsinki. Before the examinations, the study objectives and procedures were explained to each participant, and written informed consent was obtained.

Demographic information was recorded for all participants, and a detailed ocular history was taken. Inclusion criteria were enrollment in the Faculty of Rehabilitation Sciences in 2016–17 and absence of ocular or systemic diseases affecting dry eyes. Exclusion criteria included unwillingness to participate, eyelid margin disorders, lacrimal duct obstruction, history of antihistamine or antidepressant use, ocular surgery, and contact lens use.

Participants first completed the standard Ocular Surface Disease Index (OSDI) questionnaire(6) and Pittsburgh Sleep Quality Index (PSQI)(7). Nighttime sleep duration was obtained from items 1–3 of the PSQI, with the primary measure derived from the sleep duration component reflecting the average number of hours slept per night during the previous month. Sleep duration categories were defined according to commonly used epidemiological classifications (5). Participants were categorized into three groups based on sleep duration: sleep-deprived (< 5 hours), normal sleep (5–9 hours), and long sleep (> 9 hours).

All participants were examined by a single investigator under standardized conditions for the following parameters: tear meniscus height, Schirmer test (without anesthesia), tear break-up time (TBUT), and corneal fluorescein staining using a slit lamp (Haag-Streit, Koeniz, Switzerland). A washout period was observed between tests to minimize interference.

Clinical Examinations

Tear meniscus height was assessed using a 0.2 mm linear light (yellow parallelepiped, 45° angle) under slit lamp illumination, and a height < 0.2 mm was considered pathological. For the Schirmer test, a 35 × 5 mm paper strip was placed in the lateral third of the lower conjunctival sac with the eyes closed for 5 minutes, and wetting ≤ 5 mm was considered abnormal.

After a 30-minute washout period, TBUT was measured. A fluorescein strip dipped in normal saline was applied to the inferior bulbar conjunctiva. Participants were instructed to close their eyes, then open them and refrain from blinking until instructed. TBUT was timed from eye opening to the first appearance of a dark spot on the fluorescein-stained tear film using cobalt blue slit-lamp illumination. The test was repeated three times, and the mean value was recorded.

Corneal fluorescein staining was subsequently assessed under cobalt blue illumination using the Oxford grading scale. In the OSDI questionnaire, a score ≥ 23 and presence of at least one symptom at all times were considered abnormal. For clinical tests, TBUT ≤ 10 s, Schirmer ≤ 5 mm, and corneal staining ≥ 1 were considered abnormal. Participants with a positive OSDI and at least one abnormal clinical test (TBUT ≤ 10 s or corneal staining ≥ 1) were classified as having dry eye syndrome (DED).

To avoid inter-eye correlation bias, only right-eye data were included in the statistical analyses for TBUT, Schirmer test, and tear meniscus height. Statistical significance was defined as $P < 0.05$. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs).

Statistical Analysis

Sample size was calculated to achieve a statistical power greater than 0.85, assuming a medium effect size (0.25) and a type I error rate of 5%. Data were entered into Microsoft Excel 2007 and analyzed using SPSS version 22 (IBM Corp., Armonk, NY, USA).

Sleep duration was analyzed as a categorical variable (sleep-deprived, normal sleep, and long sleep). One-way analysis of variance (ANOVA) was used to compare continuous variables among the three sleep-duration groups. When overall differences were significant, Scheffé post hoc tests were applied. Effect sizes were calculated using partial eta squared (η^2). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test.

For multivariable analysis, binary logistic regression models were constructed to evaluate the independent association between sleep duration and dry eye disease (DED) and related ocular surface parameters. DED, abnormal TBUT, abnormal Schirmer test, high OSDI score, increased corneal staining, and reduced tear meniscus height were entered as dichotomous dependent variables. Sleep duration was entered into the regression model as a categorical variable, with normal sleep (5–9 hours) specified as the reference category. All models were adjusted for age, sex, digital screen time, and outdoor activity.

To avoid inter-eye correlation bias, only right-eye data were included in the statistical analyses for TBUT, Schirmer test, and tear meniscus height. Statistical significance was defined as $P < 0.05$. Results of logistic regression analyses were reported as odds ratios (OR) with 95% confidence intervals (CI).

Results

Data from 648 individuals (241 females) with a mean age of 22.06 ± 3.96 years were statistically analyzed. Based on the number of hours of sleep per night, they were divided into three groups: Sleep-

deprived(< 5 hours), normal (between 5 and 9 hours), or long sleep (< 9 hours). The main indicators are described in Table 1:

Table 1
Demographic and lifestyle characteristics of the study population (N = 648)

Variable		sleep-deprived	Normal sleep	Long sleep	total
Age (years), mean $\pm$ SD		21.38 $\pm$ 1.71	22.11 $\pm$ 3.96	21.31 $\pm$ 5.66	22.08 $\pm$ 3.96
gender	Male (%)	53.8	62.4	72.20	62.80
	Female (%)	46.2	37.6	27.80	37.20
Digital screen time(h/day), mean $\pm$ SD		3.38 $\pm$ 1.39	3.18 $\pm$ 1.48	3.46 $\pm$ 1.81	3.23 $\pm$ 1.54
Outdoor activity (h/day), mean $\pm$ SD		2.42 $\pm$ 1.04	2.08 $\pm$ 1.28	2.89 $\pm$ 0.86	2.13 $\pm$ 1.30

Based on the results of the ANOVA and Scheffé post hoc test, sleep duration had a significant effect on OSDI severity ($P = 0.01$). OSDI scores were significantly higher in sleep-deprived individuals compared to normal sleepers ($P = 0.03$). The mean TBUT was significantly lower in sleep-deprived individuals than in normal sleepers ($P = 0.04$). The Schirmer test results indicated that long sleepers had significantly greater tear secretion compared to sleep-deprived individuals ($P = 0.03$). Tear meniscus height was significantly lower in sleep-deprived individuals compared to both normal sleepers ($P = 0.01$) and long sleepers ($P = 0.01$), More comprehensive information is provided in Table 2.

Table 2
One-way ANOVA Results Comparing Sleep Duration Groups

Variable	F (2. 645)	P value	Partial η^2	Effect Size Interpretation
Corneal Staining	16.20	< 0.001	0.048	Small–Moderate
OSDI	3.52	0.011	0.011	small
TBUT	3.33	0.040	0.010	small
Schirmer test	3.60	0.030	0.011	small
Tear Meniscus Height	4.90	0.008	0.015	small

In the multivariable logistic regression analysis, participants with sleep deprivation (< 5 hours per night) had significantly higher odds of DED compared with those reporting normal sleep duration (5–9 hours) (OR = 6.60; 95% CI: 2.01–21.67 $P = 0.002$).

Reduced sleep duration was also significantly associated with abnormal TBUT, such that individuals with short sleep duration had approximately 2.35 times higher odds of TBUT disorder compared with others (OR = 2.35; 95% CI: 2.01–2.73; P = 0.001).

There was no significant association between sleep duration and Schirmer test results (OR = 0.98; 95% CI: 0.95–1.02; P = 0.09). However, corneal staining was significantly higher in individuals with Sleep-deprived (OR = 1.21; 95% CI: 1.05–1.41; P = 0.01). Female sex showed consistently higher odds across all models. So that women were more likely than men to have DED (OR = 1.76; 95% CI: 1.20–2.72; P = 0.01), higher OSDI score (OR = 1.89; 95% CI: 1.33–2.68; P < 0.001), lower TBUT (OR = 1.55; 95% CI: 1.08–2.23; P = 0.018), lower Schirmer test values (OR = 2.17; 95% CI: 1.07–4.95; P < 0.001), and higher staining (OR = 1.73; 95% CI: 1.23–2.44; P = 0.002). Digital screen time and outdoor activity were not significantly associated with DED in the adjusted models.

Discussion

Due to the importance and high prevalence of dry eye, several studies have examined possible risk factors, including sleep. However, authors who have studied sleep have mostly examined sleep quality (8) and sleep quantity has been less studied. Studies show that sleep time is decreasing in developed societies and sleep disorders are also increasing in these societies (9). In this article, nighttime sleep hours were examined as a possible risk factor, which significantly was associated with a higher prevalence of DED, decreased TBUT, decreased Schirmer test and tear meniscus height, increased corneal staining, and increased OSDI score. In this study, in subgroup analysis, tear film breakup time in Sleep-deprived individuals was significantly shorter than in normal individuals, which has also been reported in the study of Makateb and Torabi Fard (10), the study of Lee et al (3), and the study of Ahmadi et al (11). This may be due to increased stress hormones such as norepinephrine and cortisol and increased tumor necrosis factor alpha (TNF- α) in sleep-deprived individuals (12), which can increase tear film instability and damage the mucin layer (13). Also, sleep deprivation can cause the ocular surface to be more open during the day and increase evaporation from the ocular surface (14). In the study of the tear meniscus height, which evaluates basal tear secretion, a significant relationship was found with sleep deprivation, which could be due to an imbalance of the hormones serotonin and dopamine (15). Of course, lack of sleep can cause parasympathetic system hypo function (12), and as a result, tear flow is impaired (16, 17). In Schirmer test, there was a difference between the results of the ANOVA and regression tests, indicating that there was a crude difference between the groups, but this effect lost its statistical significance after controlling for other factors such as age and gender. This suggests that the effect of sleep hours on tear secretion is likely to occur indirectly and through other factors.

In the subgroup analysis, the corneal staining value was significantly higher in sleep-deprived individuals, which could indicate a shortened tear break-up time or reduced tear secretion, which was observed in the previous two subgroups in this study and could be related to the neurological and hormonal causes of sleep disturbance (12). The results of this study demonstrated that short sleep duration (< 5 hours per

night) was significantly associated with higher OSDI scores, consistent with previous studies^(2, 8, 14, 15, 18). This could be due to lower tear secretion, higher tear evaporation, and damage to the corneal epithelium, which also occurred significantly in sleep-deprived individuals in our study. According to the results of this study, sleep-deprivation (< 5 hours per night) was significantly associated with a higher prevalence of dry eye. Although it is currently unclear how sleep disorders cause dry eye, several mechanisms have been proposed. One possible mechanism is the effect of various hormones on dry eye. sleep deprivation causes decreased androgen levels, disruption of circadian rhythms, and high levels of stress hormones, which can possibly reduce tear secretion⁽¹²⁾. Androgens have been hypothesized to facilitate meibomian function, and low androgen levels are thought to increase tear evaporation⁽¹⁹⁾. Sleep deprivation increases tumor growth factor alpha, which is hypothesized to increase inflammation and epithelial layer destruction and tear stability⁽¹³⁾. The hormones of the renin-angiotensin-aldosterone system change significantly with the circadian rhythm^(20, 21). These changes in renin-angiotensin-aldosterone hormone levels can cause a state of dehydration in the body, which can also affect tear secretion and increase tear osmolarity^(22, 23). This increase in osmolarity can contribute to corneal epithelial layer destruction⁽²⁴⁾. It has also been shown that tear secretion follows a circadian rhythm, and sleep disturbances may also disrupt its regulation⁽²⁵⁾. Poor sleep quality can also cause mood disorders⁽²⁶⁾, which are closely associated with dry eye, such as depression⁽²⁷⁾. Circadian rhythm and mood disorders can cause hormonal changes, such as imbalances in serotonin, norepinephrine, and dopamine, and disruption of the hypothalamic-pituitary-adrenal axis, leading to dry eye symptoms⁽¹⁵⁾. Another possible mechanism is autonomic nervous system dysfunction secondary to poor sleep. sleep deprivation has been shown to reduce parasympathetic activity⁽²⁸⁾, and loss of parasympathetic nerve function can lead to decreased tear production⁽¹⁶⁾. In this study, as in most previous studies⁽²⁹⁾, the prevalence of dry eye was significantly higher in women than in men, which has also been reported in previous studies and is due to hormonal changes, especially estrogen changes in women. One of the strengths of the present study is the comprehensive evaluation of dry eye disease using both subjective symptom assessment and multiple objective tear film parameters, including quantitative and qualitative tests.

Several limitations should be considered when interpreting the findings. The cross-sectional design limits the ability to establish temporal relationships. Sleep duration was assessed through a self-reported questionnaire, which may introduce recall bias. Moreover, the study population consisted exclusively of university students within a relatively narrow age range, thereby restricting the generalizability of the results to the broader population. Sleep quality was not examined as an independent variable, and residual confounding from unmeasured factors such as stress levels, caffeine consumption, or systemic inflammatory status cannot be entirely excluded.

Further longitudinal and interventional studies incorporating objective sleep measurements and detailed assessments of sleep quality are needed to better elucidate the relationship between sleep patterns and dry eye disease. Nevertheless, the present findings indicate that shorter sleep duration is associated

with unfavorable ocular surface parameters. Considering the substantial impact of dry eye on quality of life, attention to sleep hygiene may be incorporated into comprehensive, non-pharmacological management strategies. Discussing sleep behaviors during patient counseling may help improve symptom control and overall well-being.

Conclusions

The findings of this study showed that nighttime sleep duration was significantly associated with objective and subjective indices of dry eye. People with shorter sleep had more severe symptoms and poorer tear film parameters than others. These results indicate that sleep pattern can be one of the modifiable factors affecting the ocular surface condition. Therefore, attention to sleep hygiene and appropriate regulation of sleep duration can be considered as part of non-pharmacological strategies in the management and prevention of dry eye. Prospective and interventional studies are required to determine whether modifying sleep duration influences ocular surface parameters.

Abbreviations

DED: Dry Eye Disease, OSDI: Ocular Surface Disease Index, PSQI: Pittsburgh Sleep Quality Index, TBUT: Tear Break-Up Time, CI: Confidence Interval, OR: Odds Ratio

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran. All procedures were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Written informed consent was obtained from all participants prior to enrollment.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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The authors received no specific funding for this work.

Authors' contributions

SSS designed the study, collected data, performed statistical analysis, and drafted the manuscript.

AD, MK, and AF contributed to study design and critically revised the manuscript.

MK (Mohammad Kamali) contributed to statistical consultation and data interpretation.

SR and MGB supervised the research process and revised the manuscript critically for important intellectual content.

All authors read and approved the final manuscript.

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Conflict of interest:

The authors have no financial or personal conflicts of interest with other institutions.

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