



RESEARCH

Association Between Dry Eye and Sleep Quality in an Elderly Chinese Population in Taiwan: The Shihpai Eye Study

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Abstract

Introduction: Dry eye symptoms often do not align with test results, and discrepancies between symptoms and clinical signs are common. Interestingly, dry eye symptoms correlate more with non-ocular conditions than clinical signs. **Purpose:** Our study explored the link between dry eye symptoms, signs, and sleep quality among the elderly. **Methods:** This community-based cross-sectional survey targeted vision and eye diseases in non-institutionalized individuals aged 65 and older. It began with a structured questionnaire on dry eye symptoms and the Pittsburgh Sleep Quality Index (PSQI), followed by a standardized ophthalmic examination, including slit lamp and dry eye tests. **Results:** Frequent dry eye symptoms were significantly associated with poor sleep quality (OR: 1.92; 95% CI: 1.36-2.70). Positive dry eye symptoms with tear break-up time ≤ 10 sec (OR: 1.78; 95% CI: 1.25-2.52) and a Schirmer test ≤ 5 mm (OR: 1.61; 95% CI: 1.10-2.34) were linked to poor sleep quality, as was having meibomian gland disease (OR: 1.60; 95% CI: 1.09-2.32). Dry eye symptoms were also associated with the use of sleeping medication (OR: 1.41; 95% CI: 1.01-1.95). Subjects with dry eye symptoms and tear break-up time ≤ 10 sec (OR: 1.59; 95% CI: 1.13-2.22) or a Schirmer test score ≤ 5 mm (OR: 1.46; 95% CI: 1.01-2.08) were more likely to use sleeping medication. **Conclusions:** Our study showed dry eye, especially dry eye symptoms, significantly impacts subjective sleep quality and the use of sleeping medication in the elderly. The causal relationship between sleep quality and dry eye requires further investigation.

Keywords: dry eye symptoms; sleep quality; use of sleeping medication; the elderly population

Introduction

Sleep disorders have become a significant public health concern in recent years, known to impact both physical and psychological well-being.^[1] Poor sleep is associated with an increased risk of conditions like diabetes, hypertension, and depression.^{[2],[3],[4]} Dry eye is a common condition in ophthalmology characterized by tear film and ocular surface abnormalities, leading to discomfort and potential visual disturbances. It can also contribute to anxiety, depression, and a reduced quality of life.^{[5],[6],[7],[8]} The association between sleep quality and dry eye has caused attention lately. Among different ocular surface diseases, Ayaki et al.^{[9],[10]} noted that patients with dry eye experienced worse sleep quality than allergic conjunctivitis and chronic conjunctivitis. It is recognized that dry eye symptoms frequently correlate poorly with the outcomes of dry eye tests.^{[11],[12]} Discrepancies between the ocular symptoms and signs of dry eye are common despite the availability of various clinical examinations. Interestingly, dry eye symptoms are more highly correlated with non-ocular conditions than dry eye signs.^[13] A cross-sectional investigation conducted in Singapore found that both inadequate sleep duration and low sleep quality exhibited significant associations with dry eye symptoms among individuals of Malay and Indian ethnicity.^[14] However, no dry eye examination was performed. In contrast, Wu et al.^[15] noted that patients with poor sleep quality had more severe dry eye signs, notably shorter tear break-up time and lower Schirmer test scores, but not dry

eye symptoms. Meta-analyses have further suggested an association between sleep quality and dry eye disease.^{[16],[17]} One meta-analysis that included seventeen articles reported that participants with dry eye had poorer sleep quality, more daytime sleep, shorter total sleep duration, and a higher prevalence, incidence, and severity of sleep disorders than those without dry eye.^[16] Another literature review and meta-analysis that included 21 articles found that individuals with dry eye had worse sleep quality than the healthy population, including poorer subjective sleep quality, longer sleep latency, and a higher risk of unhealthy sleep durations, such as insufficient or excessive sleepiness.^[17] However, small sample sizes and inaccurate selection criteria for dry eye subjects are limited in current studies.

Dry eye disease is more prevalent in Asian populations compared to Caucasian populations,^[8] and its prevalence in the latter is expected to rise with an aging population.^[18] Despite the significant impact of dry eye on affected individuals, there is a lack of population-based studies investigating the relationship between sleep quality and dry eye symptoms and signs in older Asian populations.^[19] This study aimed to explore this connection among an urban elderly Asian population.

Methods

Selection of subjects

The Shihpai Eye Study^[12] constituted a community-based, cross-sectional analysis focusing on vision and eye disorders among individuals aged 65 and older in Shihpai, Taipei, Taiwan, who were not residing in institutions. The Shihpai community is located in the Peitou district of Taipei. The Peitou district has a population of approximately 247,100 and a land area of approximately 56.8 square kilometers, making it the second-largest district in Taipei City. The Shihpai community is the Peitou district's prosperous commercial hub. The study was conducted at Taipei Veterans General Hospital, one of the largest medical centers in Taiwan. The hospital has complete equipment and provides referral medical services. Shihpai was chosen as the study community after considering the population stability, metropolitan area, and local support. We enlisted a random sample of approximately 2,000 residents aged 65 or above, possessing comprehensive baseline information identified from the official household registration system. This system includes official personal details records such as birthdate, gender, home address, and family affiliations. According to the 1999 registration data, the total count of residents aged 65 and above in Shihpai was 4,750.

After applying the inclusion and exclusion criteria, the sample was defined as inclusion criteria: residents aged 65 years or older, permanent residents of the Shihpai community, and individuals with complete baseline information in the household registration system.

Exclusion criteria: vacant households (658 individuals), residents who had passed away before contact (48 individuals), and individuals with inpatient status, paralysis, or disabilities that prevented participation (298 individuals).

After exclusions, 3,746 eligible participants remained, and 2,045 were randomly selected to participate in the study. The sample was chosen using a random sampling method from the household registration system, which involved consecutive sampling of eligible individuals over a specified period. Specifically, eligible participants were identified from the system, and those who met the inclusion criteria were invited to participate consecutively based on their availability and willingness until the target sample size was reached. This selection process ensured a representative sample of the target population while maintaining practical feasibility in recruitment. The baseline examination was conducted at Taipei Veterans General Hospital from July 1, 1999, to December 31, 2000, providing a robust setting with state-of-the-art facilities and referral services.

A survey instrument was utilized to collect data encompassing demographics (age, gender, marital status, and educational background) and data on dry eye symptoms and depressive tendencies. A checklist was employed to assess participants' personal medical histories. Each participant was inquired about whether a physician had diagnosed them with chronic ailments, including diabetes (yes/no), hypertension (yes/no), cardiovascular disease (yes/no), or stroke (yes/no). Individuals who underwent interviews were cordially invited to partake in an exhaustive ophthalmic examination conducted at Taipei Veterans General Hospital. These examinations were overseen by ophthalmologists, following a standardized protocol. After receiving a comprehensive explanation of the study's purpose and procedures, each participant was offered written informed consent to join the study. The survey adhered to the principles outlined in the Declaration of Helsinki. The Institutional Review Board of Taipei Veterans General Hospital approved this study (VGHIRB 89-11-01A).

Dry-eye questionnaire

The dry-eye symptom questionnaire included eight symptoms: 1) Do your eyes ever feel dry?; 2) Do you ever feel a gritty or sandy sensation in your eyes?; 3) Do your eyes ever have a burning sensation?; 4) Do your eyes ever feel sticky?; 5) Do your eyes ever feel watery or tearing?; 6) Are your eyes ever red?; 7) Do you notice much crusting or discharge on your lashes?; Furthermore 8) Do your eyes ever get stuck shut in the morning? Six of the items were the same as those used by Schein et al.^[20] We added two more symptoms: stickiness (question 4) and tearing (question 5) because these are widespread

complaints of dry-eye patients and have also been included in the questionnaires of other dry-eye studies. When a respondent indicated the presence of a symptom, he or she was asked to indicate whether the symptom was experienced rarely, sometimes, often, or all of the time.

Dry eye examination

The dry eye examination techniques were conducted systematically. The tear film's break-up time was tested as the initial assessment before any anesthetic application or lid manipulation. Participants were asked to look upward as a dry fluorescein strip lightly touched the conjunctiva of the lower eyelid. After blinking several times, they kept their eyes open, and the time until the tear film broke was recorded using a slit-lamp with a cobalt-blue filter. This procedure was repeated three times per eye, with the average time noted. A comprehensive slit-lamp examination assessed the eyelid margin, conjunctiva, cornea, and anterior segment. Fluorescein staining of the cornea was graded on a scale from 0 to 3. The condition of the meibomian glands was evaluated, noting lid margin telangiectasia and grading meibomian gland obstruction on a scale from 0 to 3. The final assessment was the Schirmer test to measure tear production. After administering 0.5% proparacaine and gently drying any visible fluid, precalibrated filter strips were placed temporally in the lower fornix of each eye for five minutes. The amount of strip wetting was recorded in millimeters after this period. These tests provided a comprehensive evaluation of dry eye symptoms and tear function.

Definition

Dry eye was defined as the presence of one or more symptoms often or all the time. Positive signs were defined as one or both eyes with a tear-film break-up time of ≤ 10 s, a Schirmer test score of ≤ 5 mm, a fluorescein score of ≥ 1 , or the existence of meibomian gland disease. Meibomian gland disease was defined as telangiectasia at the lid margin or plugging of the gland orifices (grade ≥ 1). A cutoff of 10 s was chosen for the tear-film break-up time, and a cutoff of 5 mm was selected for the Schirmer score because these two values were used in previous studies and are commonly adopted in clinical practice.

The Chinese Version of the Pittsburgh Sleep Quality Index questionnaire (PSQI)

The Chinese Pittsburgh Sleep Quality Index (PSQI) was a questionnaire to assess subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction in the preceding month of the participants. This questionnaire is effective and is widely used in epidemiological studies.^[21] The score for each subitem ranged from 0 to 3. The global score for the PSQI is the sum of the scores of the seven sub-items. This study

analyzed two items: subjective sleep quality and the use of sleep medication. The reliability of the questionnaire was assessed among 30 participants (pilot analysis). The reliability was confirmed (Cronbach alpha = 0.812).

Statistical analysis

We employed chi-square analysis to assess potential correlations between demographic factors, self-reported medical history, dry eye symptoms, subjective sleep quality, and the utilization of sleeping medication. Statistical significance was determined with a threshold p-value of less than 0.05. Fairly bad or very bad subjective sleep quality collapsed into bad, and fairly good or very good subjective sleep quality collapsed into good subjective sleep quality, respectively. Logistic regression analysis was used to evaluate whether subjective sleep quality and use of sleeping medication were independently related to symptoms and different signs of dry eye. Subsequently, a multivariate logistic regression analysis was conducted, with subjective sleep quality and the utilization of sleeping medication as the dependent variables and dry eye symptoms and signs as the independent variables. Each regression was adjusted for factors such as sex, education level, diabetes mellitus, and stroke. The statistical analysis was executed using Statistical Analysis System (SAS 6.12; SAS Institute, Cary, NC) software.

Results

Of 2,045 initially recruited subjects, an impressive 99.7% (2,038 individuals) actively participated in the household interview and completed the questionnaire, demonstrating high cooperation. Subsequently, 66.6% (1,361 subjects) completed the comprehensive eye examinations, while 33.1% (677 subjects) did not. A comparison between the two groups revealed significant differences. The participants who completed the study were younger and more likely to be male with higher levels of education. However, variables such as marital status,

Table 1. Subjective sleep quality and use of sleeping medicine of study subjects among residents 65 years of age and older in Shihpai, Taipei, Taiwan (N= 1,354)*

Variable	N	Percentage (%)
Subjective sleep quality: during the past month, how would you rate your sleep quality overall?		
Very good	569	42.0
Fairly good	626	46.3
Fairly bad	131	9.7
Very bad	28	2.0
Use of sleeping medication: during the past month, did you usually take medicine (prescribed or "over the counter") to help you sleep?		
Yes	186	13.7
No	1,168	86.3

*The calculation excluded seven missing data.

Table 2. Demographics characteristics and dry eye questionnaire of study subjects by subjective sleep quality and use of sleeping medicine in Shihpai, Taipei, Taiwan

Variable	Total (%)	Subjective sleep quality (%)			Use of sleeping medication (%)		
		Bad	Good	P-value	Yes	No	P-value
		(fairly bad or very bad)	(very good or fairly good)				
Age							
75 years	28.5	29.6	28.4	0.7666	33.9	27.7	0.0843
65-74 years	71.5	70.4	71.6		66.1	72.3	
Gender							
Male	60.3	48.4	62.0	0.0011	47.9	62.4	0.0002
Female	39.7	51.6	38.0		52.1	37.6	
Education							
Primary school and illiterate	47.4	59.1	45.7	0.0015	41.9	48.2	0.1142
Has current smoking habit	17.8	15.1	17.9	0.3836	16.1	17.8	0.5796
Has hypertension	45.0	45.9	44.7	0.7635	55.9	43.0	0.0010
Has diabetes mellitus	25.2	30.2	24.4	0.1146	41.9	22.4	<0.0001
Has stroke	4.8	5.7	4.7	0.5877	7.0	4.5	0.1320
Dry-eye questionnaire (response one or more symptoms often or all of the time)							
Do your eyes ever feel dry? (yes)	16.5	24.5	15.4	0.0035	24.7	15.1	0.0011
Do you ever feel a gritty or sandy sensation in your eyes? (yes)	7.4	7.6	7.4	0.9620	11.3	6.8	0.0320
Do your eyes ever have a burning sensation? (yes)	1.9	1.8	1.9	0.6355	3.2	1.7	0.9455 ^a
Do your eyes ever feel sticky? (yes)	12.3	17.6	11.7	0.0338	14.0	12.1	0.4815
Do your eyes ever feel watery or tearing? (yes)	16.5	26.4	15.2	0.0004	18.8	16.2	0.3662
Are your eyes ever red? (yes)	3.2	3.1	3.2	0.9824	3.8	3.1	0.6212
Do you notice much crusting or discharge on your lashes? (yes)	3.4	4.4	3.3	0.4552	3.2	3.4	0.8910
Do your eyes ever get stuck shut in the morning? (yes)	1.0	1.9	0.9	0.207	0.5	1.1	0.7069 ^a

^a P-value for Fisher's exact test

diabetes, and hypertension history showed no significant differences. The average age of participants was 72.2 years, with 60.4% being male. Further details on the participants can be found in a previously published paper.^[12]

Of the 1,361 participants who underwent ophthalmic examinations in this study, seven had partial missing data. After excluding these seven participants, the analysis for this study will be conducted on the remaining 1,354 participants. Of the 1,354 participants, 9.7% reported fairly bad sleep quality, and 2.0% experienced very bad sleep quality in the past month. Additionally, 13.7% reported using sleeping medication during this period (Table 1).

The associations between gender, education level, medical history, dry eye symptoms, sleep quality, and the use of sleeping medication are summarized in Table 2. Notably, female participants reported poor sleep quality and higher use of sleeping medication more frequently than males. Lower education levels were associated with poor sleep quality, while a history of hypertension and diabetes mellitus was linked to increased medication use. For dry eye symptoms, participants experiencing frequent dryness, stickiness, or tearing were likelier to report poor sleep quality, while those reporting gritty or sandy sensations were likelier to use sleeping medication.

Table 3 summarized the associations between dry eye symptoms, tear film break-up time, Schirmer test, meibomian gland disease, sleep quality, and the use of sleeping medication. Multivariate logistic regression analysis revealed that frequent dry eye symptoms were significantly associated with poor subjective sleep quality (odds ratio (OR): 1.92; $p = 0.0002$). Additionally, dry eye symptoms combined with tear break-up time ≤ 10 sec, Schirmer test ≤ 5 mm and meibomian gland disease were significantly correlated with bad sleep quality. Dry eye symptoms alone were also significantly associated with sleeping medication, particularly when accompanied by abnormal tear break-up time or Schirmer test results.

Discussion

Dry eye considerably impacts visual function, emotional well-being, workplace productivity, physical functioning, and quality of life.^{[5],[6],[7],[8],[22]} Several studies have reported an association between sleep quality and dry eye.^{[9],[10],[14],[15],[23]} However, most of these studies were oriented on hospital-based middle-aged adults or the diagnosis of dry eye was based on a few questions about symptoms, and examinations on ocular surface parameters were rarely performed. Our results revealed

Table 3. Univariate and multivariate analyses of the relation between symptoms and signs of dry eye and subjective sleep quality and use of sleeping medication among residents 65 years of age and older in Shihpai, Taipei, Taiwan

Variable	Subjective sleep quality (bad vs good)					Use of sleeping medication (yes vs no)				
	Univariate (χ^2 test)		Multivariate ^d (logistic regressions)		P	Univariate (χ^2 test)		Multivariate ^d (logistic regressions)		P
	OR	95% CI	OR	95% CI		OR	95% CI	OR	95% CI	
Symptoms and signs of dry eye										
Frequent symptoms ^a	2.01	1.44-2.80	1.92	1.36-2.70	0.0002	1.62	1.18-2.22	1.41	1.01-1.95	0.0418
BUT ≤ 10 sec	1.03	0.69-1.57	1.02	0.68-1.57	0.9165	1.09	0.74-1.62	1.10	0.74-1.66	0.6474
F/S ≥ 1 ^b	0.87	0.61-1.25	0.83	0.57-1.18	0.3076	0.91	0.66-1.27	0.87	0.61-1.22	0.4221
Schirmer test ≤ 5 mm	0.92	0.66-1.28	0.98	0.63-1.23	0.4484	1.18	0.86-1.62	1.05	0.76-1.46	0.7622
MGD ^c	1.07	0.76-1.51	1.09	0.77-1.55	0.6273	0.89	0.66-1.23	0.83	0.60-1.16	0.2708
Both reporting one or more symptoms often or all time and having positive signs										
BUT ≤ 10 sec	1.85	1.32-2.63	1.78	1.25-2.52	0.0014	1.77	1.28-2.45	1.59	1.13-2.22	0.0073
F/S ≥ 1 ^b	1.37	0.85-2.21	1.25	0.75-1.99	0.3746	1.25	0.79-1.98	1.08	0.66-1.71	0.7603
Schirmer test ≤ 5 mm	1.08	1.06-2.43	1.61	1.10-2.34	0.0134	1.76	1.25-2.48	1.46	1.01-2.08	0.0388
MGD ^c	1.66	1.14-2.40	1.60	1.09-2.32	0.0148	1.39	0.97-1.99	1.19	0.82-1.72	0.3528

^a Defined as reporting one or more symptoms often or all of the time.

^b 0, none; 1, mild; 2, moderate; 3, severe.

^c Positive anatomic abnormalities of the meibomian gland, such as plugging and lid margin telangiectasia.

BUT= tear break-up time; OR= odds ratio; CI= confidence interval; F/S= fluorescein stain score of the cornea; MGD= meibomian gland disease.

^d Multivariate logistic regressions adjusting for gender, education level, hypertension, diabetes mellitus, stroke, and smoking habit.

that after adjustment for demographic and comorbid conditions, dry eye symptoms were more significantly correlated to subjective sleep quality and use of sleeping medication than dry eye signs in elderly Asians. This finding is in concert with Galor et al.^[13], who state that dry eye symptoms are more highly correlated with non-ocular conditions than dry eye signs. This also agrees with the Lim et al.^[14] study, which demonstrated that short sleep duration and poor sleep quality are significantly correlated to dry eye symptoms. However, this was in stark contrast with the study of Wu et al.^[15], which revealed that sleep quality in middle-aged adults was correlated only to tear break-up time and Schirmer test results but not to dry eye symptoms. The discordance in findings may be due to different age groups and the hospital-based design of their study.

Our results were also consistent with Kawashima's survey^[23], which noted that poor sleep quality is associated with dry eye disease, especially dry eye symptoms in a group of Japanese workers who were often exposed to visual display technology. The only dry eye sign their study revealed to be associated with poor sleep quality was the Schirmer test. Besides the Schirmer test, we further demonstrated that dry eye symptoms, short tear film break-up time, and meibomian gland disease were associated with poor sleep quality.

Poor sleep quality may reduce parasympathetic tone, which results in the reduction of tear secretion.^[24] Sleep deprivation may also affect other hormonal levels like androgen and cortisol. For example, the androgen level is known to affect the structure and function of the lacrimal gland^{[25],[26]}, and the level is reduced with a shorter

period of sleep duration. In fact, androgen deficiency is associated with aqueous-deficient and evaporative dry eye.^[26] Moreover, patients who take antiandrogen medication exhibit dry eye symptoms.^[27]

On the other hand, sleep medications, which mainly include benzodiazepines, benzodiazepine receptor agonists, and antidepressants, have anticholinergic effects, which suppress the cholinergic innervation in the lacrimal and meibomian glands. Other sleeping medications, like selective serotonin reuptake inhibitors, are thought to suppress tear production through other unknown mechanisms despite not having anticholinergic properties.^[28] The pharmacologic relationships between diverse types of sleep medication and dry eye require further studies.

It is also possible that dry eye contributes to poor sleep quality. The discomfort caused by dry eye usually aggravates in the evening and may lead to insomnia and, hence, the use of sleeping medication. This concurs with the findings of Stapleton et al.^[8], which state that the pain associated with dry eye disease may be comparable with moderate-to-severe angina in severe dry eye cases. A preliminary report also confirms that sleep quality improved in patients with dry eye disease after topical dry eye treatment.^[29] Dry eye symptoms may cause anxiety^{[6],[15]}, which increases norepinephrine levels^[30] and affects sleep quality^[31]. Although the causal relationship between sleep quality and dry eye deserves further investigation, clinicians should be aware that one condition may aggravate the other, and this may constitute a vicious cycle. Diagnosis and proper treatment of dry eye disease and referral to psychiatry for management may

alleviate both disease statuses. Our study also reinforces that ophthalmologists should not rely only on objective clinical measures to evaluate dry eye disease. Combining subjective symptoms with clinical signs may be the best way to determine the impact of dry eye in the elderly.^[32]

Conclusions

Our study has some limitations to consider. Firstly, it excludes individuals in institutional settings, potentially introducing a bias as inpatients and those with disabilities might have poorer overall health. Therefore, the association between sleep quality and dry eye could be more significant than our results suggest. Additionally, our participants had specific demographic characteristics, being younger, more educated, and predominantly male. Notably, females with lower education levels were more likely to use sleep medication. This implies that the link between dry eye and sleep quality may be stronger. Our study did not differentiate other ocular diseases, such as blepharitis and conjunctivitis, that might affect dry eye symptoms. As a result, we did not control for or adjust the potential impact of these conditions, which could introduce bias. The presence of other ocular diseases may alter the severity or presentation of dry eye symptoms, so this limitation should be considered when interpreting the results. Future studies could provide a more accurate understanding of dry eye by excluding or controlling for these factors.

Additionally, using medications for unrelated conditions and detailed sleep quality could further impact the results. We suggest that future research explore these variables to provide a more comprehensive understanding of the relationship between dry eye and other health conditions. Finally, since the study sample is limited to the Shihpai community, generalizing the results to the broader Asian population requires careful consideration. While the Shihpai Eye Study occurred almost two decades ago, we acknowledge that lifestyles and habits have changed. However, our study remains one of the rare community-based investigations exploring the relationship between dry eye and sleep, particularly in older Asian individuals. We utilized a comprehensive dry eye questionnaire and diagnostic tests to improve the depth and reliability of our findings, and this study can still benefit elderly Asian individuals. In conclusion, our study showed that dry eye, especially dry eye symptoms, is significantly related to subjective sleep quality and the use of sleeping medication in the elderly.

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