• Investigation •

Sleep and mental status as key factors to asthenopia in Chinese adults

Na Lin, Xin Chen, Xiao–Tian Wu, Fu–Yue Tian, Mao–Yuan Yang, Yong–Shun Liu, Fan Lyu, Ru–Zhi Deng

National Clinical Research Center for Ocular Diseases, Eye Hospital, Wenzhou Medical University, Wenzhou 325027, Zhejiang Province, China

Co-first authors: Na Lin and Xin Chen

Correspondence to: Ru-Zhi Deng. National Clinical Research Center for Ocular Diseases, Eye Hospital, Wenzhou Medical University, Wenzhou 325027, Zhejiang Province, China. drz@eye.ac.cn

Received: 2024-01-23 Accepted: 2024-10-09

Absrtact

● **AIM:** To investigate the occurrence of eye asthenopia in Chinese adults and pinpoint the factors contributing to it using a 17-item Asthenopia Survey Questionnaire (ASQ-17).

● **METHODS:** A total of 2509 Chinese adults aged 18 and above from 30 regions in China participated in a cross-sectional online survey in February 2020. The survey utilized the ASQ-17, which had been proven reliable and validated for assessing asthenopia-related symptoms experienced in the past two weeks among the Chinese population. Data on demographics and living conditions, including age, gender, humidity, air quality in their residential areas, frequency of heightened anxiety or depression, daily duration of near vision activity, sleep duration, sleep quality, and history of eye surgery, were collected. Principal component analysis and multivariate logistic regression were employed to identify independent factors associated with asthenopia.

● **RESULTS:** Out of the 2502 participants, with an average age of 31±8y included in the analysis, asthenopia was prevalent in 35.2% of cases. Multivariate analysis revealed that the most influential risk factor was poor sleep and mental well-being, which encompassed shorter daily sleep duration, lower sleep quality, and more frequent feelings of heightened anxiety or depression [odds ratio (OR): 2.07, 95% confidence interval (CI): 1.88–2.29, *P*<0.001]. This was followed by each additional 2h of daily near vision activity relative to 4h (OR: 1.33, 95%CI: 1.21–1.45, *P*<0.001), and lower humidity and worse air quality in the residential area (OR: 1.10, 95%CI: 1.02–1.21, *P*=0.019).

● **CONCLUSION:** Asthenopia is a common issue among Chinese adults, and preventative measures should focus on improving sleep and mental well-being. Further research targeting physiological exposure, different age groups or longitudinal studies to establish causality are needed to explore the role of sleep and mental status as an influencing factor.

● **KEYWORDS:** asthenopia; sleep duration; sleep quality; mental status

DOI:10.18240/ijo.2025.04.19

Citation: Lin N, Chen X, Wu XT, Tian FY, Yang MY, Liu YS, Lyu F, Deng RZ. Sleep and mental status as key factors to asthenopia in Chinese adults. *Int J Ophthalmol* 2025;18(4):716-722

INTRODUCTION

Asthenopia, often described as a subjective sensation of visual fatigue or eyestrain, is not an independent disease[1]. Instead, it encompasses a range of subjective discomforts related to the eyes, vision, or general well-being, significantly affecting one's ability to concentrate, work efficiently, and carry out daily life[2]. An important development in the modern work environment and entertainment industry is the increasing demand for close-range visual tasks, especially when using video terminals, which has led to a rising global prevalence of asthenopia[3-6]. The symptoms of asthenopia can be severe enough to impede personal activities and may even contribute to the development of ocular diseases[7]. Therefore, the identification of risk factors for asthenopia is essential for enhancing visual well-being and minimizing the risk of experiencing asthenopia.

Previous investigations have associated asthenopia with various personal factors, such as age[8], the amount of time spent on close-range visual tasks[8], sleep quality[3], and rest periods after prolonged visual tasks[9]. Environmental factors, including excessive screen brightness[10] and disparities in lighting between the screen and its surroundings[11], have also been linked to asthenopia. A study involving 1500 Chinese college students reported a prevalence rate of 57.0%, and it identified reduced computer usage, good sleep and mental well-being, favorable living conditions, and a high intake of green leafy vegetables as significant predictors for decreasing the occurrence of asthenopia complaints[3]. However, inconsistencies arise due to variations in the questionnaires and asthenopia standards used in these studies, leading to different influencing factors and even contradictory results. Furthermore, existing research on factors affecting asthenopia predominantly focuses on young individuals and children, with limited attention given to the elderly population.

Our research team previously developed the 17-item Asthenopia Survey Questionnaire (ASQ-17) for the Chinese population, which has been validated for its reliability and validity[12-13]. With this foundation, we conducted a survey to investigate the prevalence and determinants of asthenopia among Chinese adults of various age groups, using a dependable and validated survey tool. This study aims to provide valuable insights for targeted prevention and treatment strategies for asthenopia.

PARTICIPANTS AND METHODS

Ethical Approval This study obtained ethical approval from the Institutional Ethics Committee of The Eye Hospital at Wenzhou Medical University (Approval No.KYK-2016-8) and adhered to the principles outlined in the Declaration of Helsinki. Prior to investigation, participants were informed about the survey's purpose, significance, content, and privacy protection.

Study Design This cross-sectional web-based survey was conducted in February 2020. Invitations were distributed to 2509 Chinese individuals aged 18 and above in 30 regions across China *via* the online survey tool WJX (Changsha, China). Quota and simple sampling methods were used to select participants who could comprehend and complete the questionnaire for analysis. The survey remained open for one week.

Sample Size The minimum required sample size was calculated using the formula,

$$n=\frac{Z^2 P\,(1\text{-}P)}{\mathrm{E}^2},$$

where Z=1.96 (95% confidence interval, CI), P was set at 15.0% as the estimated minimum prevalence based on a similar survey in China[8], and E=0.1×P. Accordingly, the minimum sample size was determined to be 2177.

Definition of Asthenopia The ASQ-17[12-13], which is grounded in rasch measurement theory and recognized as a reliable and validated survey instrument for assessing asthenopia among the Chinese population, was employed. Participants assessed the presence of 17 ocular, visual, and systemic symptoms experienced in the past two weeks. The symptoms included Q1: Discomfort around the eye, Q2: Eye dryness, Q3: Eye pain, Q4: Eye soreness, Q5: Heavy eyelids, Q6: Eye tightness, Q7: Sensitivity to light; Q8: Discomfort due to screen brightness, Q9: Squinting, Q10: Reading difficulties, Q11: Near vision focus issues, Q12: Reading slower due to asthenopia, Q13: Eye discomfort when viewing moving objects, Q14: Concentration challenges, Q15: Difficulty remembering what was just read, Q16: Dizziness or headaches, and Q17: Feelings of anxiety or depression due to asthenopia.

Each question utilized a four-point response scale, ranging from "none" (0), "mild" (1), "moderate" (2), to "severe" (3). The total questionnaire score was the sum of individual question scores. Participants with a total score of 13 or higher were categorized as experiencing asthenopia.

Humidity and Ambient Air Quality of Residential Area The humidity in residential areas was categorized into three groups based on the annual precipitation in each provincial capital city for the year 2020. Areas with annual precipitation exceeding 400 mm were considered as moist regions (including Sichuan, Yunnan, Guangxi, Anhui, Guizhou, Hubei, Chongqing, Hunan, Shanghai, Hainan, Jiangsu, Fujian, Zhejiang, Jiangxi, and Guangdong). Regions with precipitation between 200 and 400 mm were termed semi-moist areas (including Shanxi, Xinjiang, Heilongjiang, Beijing, Jilin, Hebei, Shaanxi, Liaoning, Tianjin, Henan, and Shandong). Areas with less than 200 mm of precipitation were categorized as arid or semi-arid regions (including Gansu, Ningxia, Qinghai, and Neimenggu).

The ambient air quality in the residential area was classified based on the comprehensive ambient air quality index of each city in February 2020, as per the report from the China National Environmental Monitoring Centre[14]. It was categorized as good (when the index was <3), moderate (when the index ranged between 3 and 5), and polluted (when the index exceeded 5). The index was based on six ambient air pollutants, including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter with a diameter of ≤2.5 micrometers ($PM_{2.5}$), particulate matter with a diameter of ≤10 micrometers (PM_{10}), carbon monoxide (CO), and ozone (O_3).

Sleep Quality and Mental Status Participants assessed the sleep quality and perceived frequency of heightened anxiety or depression by five-point Likert response rating scale questions as previous studies[15-16].

Other Covariates Demographic information and living conditions, including age, gender, and residential location, were gathered. Participants were also asked about their average daily duration of near vision activities over the past two weeks, such as using microscopes and digital devices, as well as their mental status, daily sleep duration, quality of sleep, and any history of eye surgery.

Data Collection and Quality Control Data reproducibility, integrity, and dependability were ensured as part of quality control. This survey was administered online, allowing only one response per internet protocol address, and all questions had to be completed before submission. The response time was restricted to 1–15min, with submissions outside this range considered invalid. Meteorological data had no omissions.

Statistical Analysis Statistical analysis was conducted using SPSS 25.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean±standard deviation or as median (interquartile range, IQR), while categorical variables were expressed as counts and percentages. Associations between different factors and the prevalence of asthenopia were assessed using independent *t*-tests, Chi-square tests, or Bonferroni correction, as appropriate. Factor analysis was employed to reveal the underlying structure of significant variables and to estimate scores measuring latent factors through principal component analysis. The factors were rotated through an orthogonal transformation, and those with eigenvalues greater than 1.0 were extracted. The associations between asthenopia prevalence and the scores of these factors were examined using multivariate logistic regression analysis. All *P*-values were calculated as two-sided, with statistical significance established at <0.05.

RESULTS

A total of 2509 questionnaires were successfully collected. Out of these, 2502 (99.7%) questionnaires from 30 regions in China were considered valid, while 7 cases were deemed invalid due to exceeding the designated response time.

Asthenopia and Demographic Factors Among the 2502 participants, the overall prevalence of asthenopia was 35.2% (881 cases), with a median ASQ-17 score of 8 (IQR: 3, 16). Participants ranged in age from 18 to 72y, with a mean age of 31±8y. As detailed in Table 1, the majority were female (57.1%), approximately two-thirds (67.9%) resided in moist areas, and half (53.3%) lived in areas with good ambient air quality. Approximately 42.9% reported engaging in daily near vision activities for more than 8h, while the majority (60.9%) reported daily sleep durations between 6 and 8h. Sleep quality was reported as moderate by 40.8% of participants and as poor by 6.5%. Only 26.5% of respondents reported never experiencing higher levels of anxiety or depression than usual. A history of eye surgery was reported by only 6.4% of participants.

Furthermore, statistically significant risk factors for asthenopia were identified following independent *t*-tests or Chi-square tests, involving six variables. The prevalence of asthenopia was notably higher among participants living in areas with low humidity and poor air quality, those engaged in prolonged daily near vision activities, individuals with shorter sleep durations, those with lower sleep quality, and those experiencing more frequent episodes of heightened anxiety or depression. No significant differences in prevalence were observed based on age (χ^2=0.230, *P*=0.818), gender (χ^2=0.741, *P*=0.389), or history of eye surgery (χ^2=0.003, *P*=0.985).

Factor Analysis Through factor analysis of asthenopia prevalence, three factors were extracted, as presented in Table 2. Factor 1, termed "bad sleep and mental status" included three items: shorter daily sleep duration, lower sleep quality, and increased frequency of heightened anxiety or depression. Factor 2 represented "each additional 2h of daily near vision activity relative to 4h". Factor 3, referred to as "poor living environment conditions", included lower humidity and worse ambient air quality in the residential area.

Multivariate Analysis of Selected Factors In the multivariate analysis, three factors were found to be significantly associated with asthenopia, as demonstrated in Table 3. The most influential risk factor was "bad sleep and mental status" [odds ratio (OR): 2.07, 95%CI: 1.88–2.29, *P*<0.001], followed by "each additional 2h of daily near vision activity relative to 4h" (OR: 1.33, 95%CI: 1.21–1.45, *P*<0.001), and "poor living environment conditions" (OR: 1.10, 95%CI: 1.02–1.21, *P*=0.019).

Frequency of Asthenopia Symptoms Perceived by Asthenopia Participants and All Participants The most common asthenopia symptom reported by asthenopia participants and all participants was "discomfort due to screen brightness" (Question No.8, 97.8% and 66.9%, respectively), followed by "discomfort around the eye" (Question No.1, 96.3% and 66.4%), and "eye dryness" (Question No.2, 95.7% and 66.4%), as shown in Figure 1. The least commonly reported symptom was "dizziness or headaches" (Question No.16, 77.1%) among asthenopia participants and "eye discomfort when viewing moving objects" (Question No.13, 33.7%) among all participants.

DISCUSSION

This study represents a pioneering application of the reliable and validated ASQ-17 survey instrument among 2502 Chinese adults aged 18–72y. It reveals a prevalence of 35.2% for asthenopia in this group, with bad sleep and mental status emerging as the most critical risk factor for asthenopia, surpassing the impact of longer daily near vision activity.

The findings showed a prevalence of asthenopia among Chinese adults at 35.2%, which was higher than that reported in India (24.1%)[17] but lower than the prevalence observed in Shanghai (53.3%)[5], Saudi Arabia (76.0%)[6], and Iran (76.2%)[4]. These variations can be attributed to differences in the study populations. This study encompassed a broader age range, from 18 to 72y, while the study in India focused on children, and the studies in Shanghai and Iran primarily involved college students. Additionally, we employed the verified screening version of the asthenopia questionnaire (ASQ-17)[13], known for its good reliability and validity, which led to a more precise

Table 1 Participant demographics

Variables	Total (*n*=2502)	Asthenopia (*n*=881)	Non-asthenopia (*n*=1621)	*Z* or *t* or χ^2 value[d]	*P*
Prevalence, %		35.2	64.8	-	-
ASQ-17 score, mean (IQR)	8 (3, 16)	18 (16, 23)	5 (1, 8)	41.428[a]	<0.001[e]
Age, y (range)	31±8 (18–72)	31±8 (18–70)	31±8 (18–72)	0.230[b]	0.818
Gender, *n* (%)				0.741[c]	0.389
Male	1073 (42.9)	388 (44.0)	685 (42.3)		
Female	1429 (57.1)	493 (56.0)	936 (57.7)		
Humidity of residential area, *n* (%)				47.508[c]	<0.001[e]
Moist	1699 (67.9)	535 (60.7)	1164 (71.8)		
Semi-moist	688 (26.7)	268 (30.4)	400 (24.7)		
Arid and semi-arid	135 (5.4)	78 (8.9)	57 (3.5)		
Ambient air quality of residential area, *n* (%)				10.593[c]	0.005[e]
Good	548 (21.9)	161 (18.3)	387 (23.9)		
Moderate	1334 (53.3)	488 (55.4)	846 (52.2)		
Polluted	620 (24.8)	232 (26.3)	388 (23.9)		
Daily duration of near vision activity, *n* (%)				76.550[c]	<0.001[e]
≤4h	254 (10.1)	47 (5.3)	207 (12.8)		
4–6h (including 6)	503 (20.1)	141 (16.0)	362 (22.3)		
6–8h (including 8)	672 (26.9)	225 (25.5)	447 (27.6)		
>8h	1073 (42.9)	468 (53.2)	605 (37.3)		
Daily sleep duration, *n* (%)				38.284[c]	<0.001[e]
>8h	783 (31.3)	225 (25.5)	558 (34.4)		
6–8h (including 8)	1523 (60.9)	555 (63.0)	968 (59.7)		
≤6h	196 (7.8)	101 (11.5)	95 (5.9)		
Sleep quality, *n*(%)				111.289[c]	<0.001[e]
Very good	520 (20.8)	113 (12.8)	407 (25.1)		
Good	800 (32.0)	245 (30.6)	555 (34.2)		
Moderate	1020 (40.8)	427 (48.5)	593 (36.6)		
Bad	137 (5.5)	84 (9.5)	53 (3.3)		
Very bad	25 (1.0)	12 (1.4)	13 (0.8)		
Frequency of heightened anxiety or depression, *n* (%)					
None	662 (26.5)	113 (12.8)	549 (33.9)	194.359[c]	<0.001[e]
Rarely	534 (21.3)	163 (18.5)	371 (22.9)		
Sometimes	1107 (44.2)	484 (54.9)	623 (38.4)		
Always	152 (6.1)	89 (10.1)	63 (3.9)		
Most times	47 (1.9)	32 (3.7)	15 (0.9)		
History of eye surgery, *n* (%)				0.003[c]	0.985
Yes	161 (6.4)	57 (6.5)	104 (6.4)		
No	2341 (93.6)	824 (93.5)	1517 (93.6)		

ASQ-17: The 17-item Asthenopia Survey Questionnaire; IQR: Interquartile range. [a]Mann-Whitney *U* test; [b]Independent *t*-test; [c]Chi-square test; [d]Comparison of demographic information of participants with asthenopia and non-asthenopia; [e]Statistically significant.

and strict definition of asthenopia. In Iran's study, the definition of asthenopia relied on the presence of two or more symptoms without a predictive score.

A significant and intriguing discovery of this study is the substantial influence of bad sleep and mental status as the most critical risk factor for asthenopia, reaffirming that both mental and physical factors contribute to asthenopia[18]. Our research unveiled that individuals with bad sleep and mental status had a 2.07 times higher probability of experiencing asthenopia (OR=2.07, 95%CI: 1.88–2.29, *P*<0.001) compared to those with longer daily sleep durations, better sleep quality, and fewer occurrences of heightened anxiety or depression. This protective effect of good sleep and mental well-being was also observed in Chinese college students (OR=0.86,

Table 2 Eigenvalue, contributive rate, and cumulative contributive rate for all three factors *n*=2502

Parameters	Factor 1	Factor 2	Factor 3
Eigenvalue	1.60	1.15	1.02
Contributive rate (%)	26.71	19.12	17.08
Cumulative contributive rate (%)	26.71	45.83	62.91

Table 3 Effects of three factors on asthenopia: OR from multivariate binary logistic regression analysis *n*=2502

Common factor	Dominant variable	Meaning	OR (95%CI)	*P*
Factor 1	Less daily sleep duration, poorer sleep quality, and more frequent of heightened anxiety or depression	Bad sleep and mental status	2.07 (1.88–2.29)	<0.001[a]
Factor 2	Each additional 2h of daily near vision activity relative to 4h	Longer daily duration of near vision activity	1.33 (1.21–1.45)	<0.001[a]
Factor 3	Lower humidity of residential area, and worse ambient air quality of residential area	Poor living environment conditions	1.10 (1.02–1.21)	0.019[a]

OR: Odds ratio; CI: Confidence interval. [a]Statistically significant.

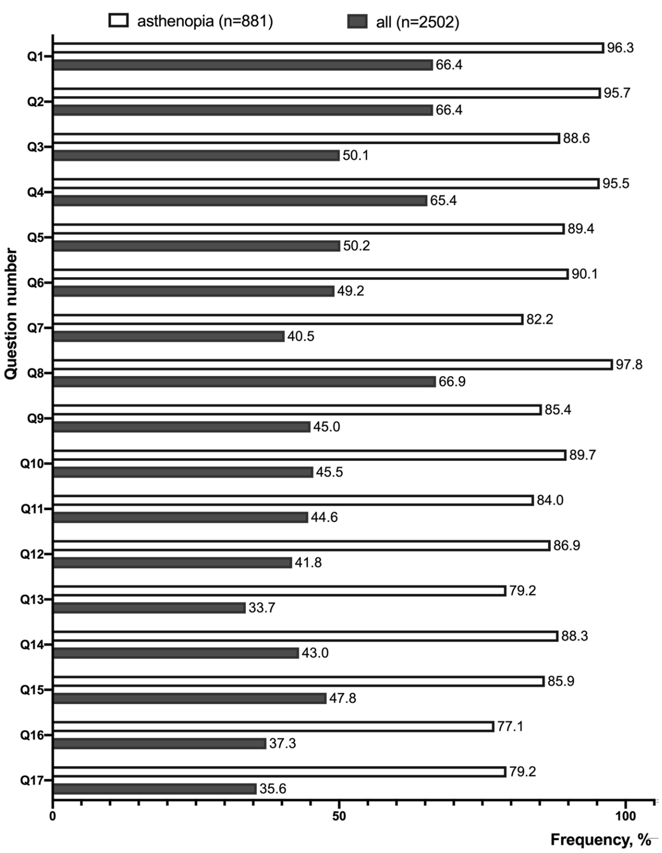

Figure 1 Frequencies of perceived asthenopia symptoms among asthenopia participants (*n*=881) and all participants (*n*=2502) The most common asthenopia symptom reported by asthenopia participants and all participants was Q8, followed by Q1 and Q2. The least commonly reported symptom was Q16 among asthenopia participants and Q13 among all participants. The evaluated symptoms include Q1: Discomfort around the eye, Q2: Eye dryness, Q3: Eye pain, Q4: Eye soreness, Q5: Heavy eyelids, Q6: Eye tightness, Q7: Sensitivity to light; Q8: Discomfort due to screen brightness, Q9: Squinting, Q10: Reading difficulties, Q11: Near vision focus issues, Q12: Reading slower due to asthenopia, Q13: Eye discomfort when viewing moving objects, Q14: Concentration challenges, Q15: Difficulty remembering what was just read, Q16: Dizziness or headaches, Q17: Feelings of anxiety or depression due to asthenopia.

95%CI: 0.76–0.97, *P*<0.001)[3]. Other studies[19-20] have suggested that while poor sleep quality may not directly cause asthenopia, it can exacerbate the condition by impacting mood and worsening depressive symptoms. In our study, 79.2% of asthenopia respondents reported that eye discomfort contributed to anxiety and even depression (Q17). In some cases, symptoms associated with asthenopia, such as dry eyes and headaches, can adversely affect sleep quality, thereby exacerbating asthenopia[21]. A 10-year follow-up study in 3054 public employees[22] demonstrated a significant association between asthenopia and perceived anxiety (OR=7.40, 95%CI: 1.77–31.30, *P*<0.001) and psychosocial factors (OR=1.03, 95%CI: 1.01–1.07, *P*=0.026). Other studies[23-24] have also indicated that good mental well-being serves as a protective factor against asthenopia.

Numerous studies have consistently shown that prolonged daily near vision activity can elevate the prevalence of asthenopia[5,24-25]. However, different studies have established varying time thresholds. Early investigations noted that the prevalence of asthenopia significantly increased when daily near vision activity exceeded 4h[26]. Recent studies have extended this threshold to 6h[8] or imposed a limit of 0.5h for using digital devices in bed[5]. This study identified that each additional 2h of near vision activity led to a 1.33 times higher probability of asthenopia when compared to a daily duration of 4h. The causes of asthenopia resulting from prolonged near vision activity are linked to insufficient accommodation or convergence[8], a reduction in blink frequency, and an increase in the proportion of incomplete blinks[27], as well as inappropriate reflected light from screens and inadequate background brightness[10]. These findings emphasize the importance of using our eyes reasonably and in moderation, reducing the time spent on near vision activities to alleviate asthenopia symptoms and decrease its occurrence.

Additionally, this study revealed that lower humidity and worse ambient air quality in the residential area are risk factors for asthenopia (OR=1.10, 95%CI: 1.02–1.21, *P*=0.019). The assessment of residential air quality employed the ambient air quality index, which comprehensively considers six types of pollution, including SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, and O_3. There is a growing body of evidence indicating that environmental factors like humidity and ambient air pollution can exacerbate ocular surface diseases[28-30], resulting in asthenopia[18]. Various mechanisms have been proposed to explain the association between air pollutants and ocular surface diseases. For instance, acidic pollutants like SO_2 and NO_2 may affect the pH of tears as they come into contact with the eyes, leading to inflammation[31]. The pollutant O_3 can cause ocular surface damage through oxidation and is associated with the over-expression of inflammatory cytokines such as interleukin 6 and tumor necrosis factor in the conjunctiva, resulting in allergic symptoms like eye swelling and conjunctival inflammation[32].

Nevertheless, this study had several limitations. First, our exposure measure is limited because it does not account for interindividual exposure differences. The humidity and ambient air quality of residential area data were collected from fixed-site outdoor monitors and reflected the overall exposure levels of residents in a given area. Physiological exposure to humidity and ambient air varies widely between individuals due to access to air conditioners and cleaners, indoor and outdoor exposure, or location patterns, potentially leading to misclassification. Second, we evaluated sleep and mental status, living environment conditions, and daily duration of near vision activity as potential risk factors, which may overlook other confounding factors, such as socioeconomic status, screen time across occupations, and strategies for alleviating asthenopia. Third, the assessment of mental status relied on a five-point Likert response rating scale, which may not capture all pertinent details for addressing asthenopia. Other limitation includes the cross-sectional design, which does not allow for causal inferences, and potential inaccuracies associated with self-reporting. Nonetheless, the study benefited from a substantial sample size designed to mitigate bias and utilized the reliable and validated ASQ-17 survey tool. Additionally, the evaluation of subjective symptoms over the preceding two weeks aimed to minimize recall bias.

In summary, this study identified a 35.2% prevalence of asthenopia among Chinese adults aged 18 to 72y. Strategies for prevention should focus on improving sleep and mental well-being. Further research targeting physiological exposure, different age groups or longitudinal studies to establish causality are needed to explore the role of sleep and mental status as an influencing factor.

ACKNOWLEDGEMENTS

Foundations: Supported by Wenzhou Science and Technology Bureau Project (No.Y20240062); the National Natural Science Foundation of China (No.82000861).

Conflicts of Interest: Lin N, None; **Chen X,** None; **Wu XT,** None; **Tian FY,** None; **Yang MY,** None; **Liu YS,** None; **Lyu F,** None; **Deng RZ,** None.

REFERENCES

1 Chinese Optometric Association of Chinese Ophthalmological Society, Optometry Group of Chinese Ophthalmologist Association. Chinese expert consensus on the diagnosis and treatment of asthenopia (2024). *Zhonghua Yan Ke Za Zhi* 2024;60(4):322-329.

2 Alhasan AS, Aalam WA. Magnitude and determinants of computer vision syndrome among radiologists in Saudi Arabia: a national survey. *Acad Radiol* 2022;29(9):e197-e204.

3 Han CC, Liu R, Liu RR, *et al*. Prevalence of asthenopia and its risk factors in Chinese college students. *Int J Ophthalmol* 2013;6(5):718-722.

4 Hashemi H, Saatchi M, Yekta A, *et al*. High prevalence of asthenopia among a population of university students. *J Ophthalmic Vis Res* 2019;14(4):474-482.

5 Xu YP, Deng GY, Wang WH, *et al*. Correlation between handheld digital device use and asthenopia in Chinese college students: a Shanghai study. *Acta Ophthalmol* 2019;97(3):e442-e447.

6 Alabdulkader B. Effect of digital device use during COVID-19 on digital eye strain. *Clin Exp Optom* 2021;104(6):698-704.

7 Pointer JS, Gilmartin B. Clinical characteristics of unilateral myopic anisometropia in a juvenile optometric practice population. *Ophthalmic Physiol Opt* 2004;24(5):458-463.

8 Deng R, Zhu Y, Zhang J, *et al*. Investigation of asthenopia and related factors in the general public in China. *Chinese Journal of Optometry Ophthalmology and Visual Science* 2019;21(9):668-676.

9 Abusamak M, Jaber HM, Alrawashdeh HM. The effect of lockdown due to the COVID-19 pandemic on digital eye strain symptoms among the general population: a cross-sectional survey. *Front Public Health* 2022;10:895517.

10 Agarwal S, Goel D, Sharma A. Evaluation of the factors which contribute to the ocular complaints in computer users. *J Clin Diagn Res* 2013;7(2):331-335.

11 Chawla A, Lim TC, Shikhare SN, *et al*. Computer vision syndrome: darkness under the shadow of light. *J L'association Can Des Radiol* 2019;70(1):5-9.

12 Deng RZ, Tian L, Sun XQ, *et al*. Development of an asthenopia survey questionnaire for general surveys. *Zhonghua Yan Ke Za Zhi* 2023;59(6):452-459.

13 Lin N, Li XM, Yang MY, *et al*. Development of a new 17-item Asthenopia Survey Questionnaire using Rasch analysis. *Int J Ophthalmol* 2023;16(11):1867-1875.

14 China national environmental monitoring centre. national city air quality report in February 2020. http://meeb.sz.gov.cn/attachment/0/500/500574/7148547.pdf

15 DiFrancisco-Donoghue J, De Las Heras B, Li O, *et al*. Gaming in pandemic times: an international survey assessing the effects of COVID-19 lockdowns on young video gamers' health. *Int J Environ Res Public Health* 2023;20(19):6855.

16 Singh J, Saini, Bhau S, *et al*. Evaluation of the analgesic efficacy of surgically assisted Linea semilunaris block for post-operative analgesia in patients undergoing Caesarean section under spinal anaesthesia. *Cureus* 2023;15(8):e43900.

17 Tiwari RR, Saha A, Parikh JR. Asthenopia (eyestrain) in working children of gem-polishing industries. *Toxicol Ind Health* 2011;27(3): 243-247.

18 Wolffsohn JS, Lingham G, Downie LE, *et al*. TFOS Lifestyle: impact of the digital environment on the ocular surface. *Ocul Surf* 2023;28:213-252.

19 Hom MA, Stanley IH, Rogers ML, *et al*. The association between sleep disturbances and depression among firefighters: emotion dysregulation as an explanatory factor. *J Clin Sleep Med* 2016;12(2):235-245.

20 Schakel W, Bode C, van de Ven PM, *et al*. Understanding fatigue in adults with visual impairment: a path analysis study of sociodemographic, psychological and health-related factors. *PLoS One* 2019;14(10):e0224340.

21 Stack RJ, Southworth S, Fisher BA, *et al*. A qualitative exploration of physical, mental and ocular fatigue in patients with primary Sjögren's Syndrome. *PLoS One* 2017;12(10):e0187272.

22 Larese Filon F, Drusian A, Ronchese F, *et al*. Video display operator complaints: a 10-year follow-up of visual fatigue and refractive disorders. *Int J Environ Res Public Health* 2019;16(14):2501.

23 Lin N, Zhu Y, Wu XT, *et al*. Prevalence and determinants of asthenopia among ophthalmologists in China: a national cross-sectional survey. *Front Public Health* 2023;11:1290811.

24 Li L, Zhang J, Chen MX, *et al*. Contribution of total screen/ online-course time to asthenopia in children during COVID-19 pandemic *via* influencing psychological stress. *Front Public Health* 2021;9:736617.

25 Lema AK, Anbesu EW. Computer vision syndrome and its determinants: a systematic review and meta-analysis. *SAGE Open Med* 2022;10:20503121221142402.

26 Rossignol AM, Morse EP, Summers VM, *et al*. Video display terminal use and reported health symptoms among Massachusetts clerical workers. *J Occup Med* 1987;29(2):112-118.

27 Kamøy B, Magno M, Nøland ST, *et al*. Video display terminal use and dry eye: preventive measures and future perspectives. *Acta Ophthalmol* 2022;100(7):723-739.

28 Chen RC, Yang J, Zhang CL, *et al*. Global associations of air pollution and conjunctivitis diseases: a systematic review and meta-analysis. *Int J Environ Res Public Health* 2019;16(19):3652.

29 Azari AA, Arabi A. Conjunctivitis: a systematic review. *J Ophthalmic Vis Res* 2020;15(3):372-395.

30 Zhang L, Jiang H, Wang KH, *et al*. Long-term effects of weather condition and air pollution on acute hemorrhagic conjunctivitis in China: a nationalwide surveillance study in China. *Environ Res* 2021;201:111616.

31 Andrés S, García ML, Espina M, *et al*. Tear pH, air pollution, and contact lenses. *Am J Optom Physiol Opt* 1988;65(8):627-631.

32 Jung SJ, Mehta JS, Tong L. Effects of environment pollution on the ocular surface. *Ocul Surf* 2018;16(2):198-205.