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ORIGINAL RESEARCH

# Short Sleep Duration Is Associated with Overestimated Myopia in University Students

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**Purpose:** To investigate the association between objectively monitored sleep patterns and overestimation of myopia among university students.

**Methods:** A cross-sectional study enrolled 144 university students aged 17–23 years. Sleep parameters (total duration, light sleep, deep sleep, bedtime/woke time) were objectively monitored for 7 consecutive days using smart wearable devices. Ocular biometric parameters were measured using an optical biometer. Spherical equivalent refraction (SE) was obtained via auto-refraction both before and after cycloplegia. Based on the difference in SE before and after cycloplegia (DIFF = SE_post-cycloplegia - SE_pre-cycloplegia), participants with DIFF $\geq$ +0.50 D were defined as the overestimated myopia group. Linear mixed-effects models (LMM) were used to analyze the association between sleep parameters and overestimated myopia, adjusting for confounders including age, sex, parental myopia history, and daily near work activities.

**Results:** A total of 126 participants completed data analysis. The prevalence of overestimated myopia was 26.19%. Compared to the non-overestimated myopia group, the overestimated myopia group exhibited the following significant characteristics: shorter total sleep duration by approximately 0.6 h (6.82 ± 0.84 h vs 7.43 ± 0.74 h, $P < 0.001$); shorter light sleep duration by 0.46 h (4.73 ±0.93 h vs 5.19±1.05 h, $P = 0.006$); and delayed bedtime by 0.80 h (1:42±1:04 vs 00:53 ± 00:52, $P < 0.001$). No statistically significant differences were observed between the groups in deep sleep duration or woke time.

**Conclusion:** Among university students, a sleep pattern characterized by shorter sleep duration and delayed bedtime is significantly associated with overestimation of myopia. This finding suggests that sleep behavior may be a potential factor influencing measurement error in non-cycloplegic refraction. Attention should be paid to the sleep status of examinees in clinical practice to enhance the accuracy of refractive measurements.

**Keywords:** sleep duration, overestimated myopia, accommodation, refractirefractive measurement, pseudomyopia

## Introduction

Myopia, the most prevalent type of refractive error globally, constitutes a significant public health burden.[1] More than one-third of adults continue to experience myopia progression between the ages of 20 and 30, with some cases progressing to high myopia.[2] High myopia significantly increases the risk of vision-threatening ocular diseases, including cataract, retinal detachment, glaucoma, and myopic macular degeneration (MMD).[3] Consequently, effective control of myopia onset and progression is crucial for reducing vision impairment associated with high myopia.

The stability of accommodation during refractive measurement has garnered considerable attention. Accommodation is an involuntary physiological process involving contraction and relaxation of the ciliary muscle to alter lens curvature, enabling the eye to focus precisely on objects at varying distances.[4] This process is finely regulated by the autonomic nervous system, with parasympathetic nerves primarily mediating ciliary muscle contraction for near focus, while sympathetic nerves dominate muscle relaxation for distance vision.[5] Sleep status can influence autonomic tone by altering the sympathetic-parasympathetic balance, potentially disrupting the stability of accommodation. Persistent overstimulation of accommodation may lead to a compensatory increase in refractive power,[6–8] clinically manifesting as overestimation of myopia—a

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phenomenon where non-cycloplegic refraction yields a higher myopic refractive error than the true value. This occurs due to residual accommodative activity even under distance viewing conditions and is eliminated following cycloplegia.[7,9] Epidemiological studies report the prevalence of myopic overestimation under non-cycloplegic conditions as 37.19% in adolescent myopes[10] and 23.74% in young adult myopes.[11] This phenomenon not only contributes to asthenopia, visual fluctuation, and inconsistent refractive measurements[7] but is also an independent risk factor for childhood myopia onset.[10] Therefore, in-depth investigation into the factors influencing myopic overestimation holds significant clinical importance for enhancing the accuracy of refractive measurement and optimizing myopia control strategies.

Sleep, a core process for maintaining physiological homeostasis, has been demonstrated to be associated with various health risks when its quality declines, including cognitive dysfunction,[12] obesity,[13] depression,[14] and an elevated risk of ocular diseases.[15] Within the visual domain, alterations in sleep patterns can impair binocular visual function[16] and visual-motor processing capabilities,[17] leading to reduced sustained attention.[18] This consequently exerts negative impacts on individual learning efficiency, physical and mental health, and quality of life.[19,20] Research by Woi PJ et al found that sleep quality affects positive fusional vergence at distance (PFV),[21] while acute sleep deprivation significantly impairs accommodative function and induces asthenopia symptoms.[22] However, previous research investigating the association between sleep and myopia has primarily focused on myopia incidence or progression,[23,24] with inconsistent findings and a general lack of quantitative assessment of accommodative function—a key mediating factor in myopia development. Given that accommodative dysfunction is a significant pathophysiological component in myopia onset,[10] systematically investigating its influencing factors may provide novel insights into the mechanisms underlying myopia development.

The mechanisms by which sleep patterns influence the core clinical manifestation of accommodative dysfunction—myopic overestimation—remain unclear. This study innovatively employs smart wearable devices for objective and continuous monitoring of sleep parameters, combined with standardized cycloplegic and non-cycloplegic refractive measurements. It aims to investigate the quantitative association between sleep pattern characteristics and overestimation of myopia, thereby providing an evidence-based foundation for optimizing refractive measurement strategies and myopia risk management.

# Methods

## Participants

This cross-sectional study recruited 144 participants aged 17 to 23 years. The investigation comprised a questionnaire survey, ophthalmic examination, and sleep parameter assessment. Inclusion criteria were restricted to the participants with best-corrected visual acuity (BCVA) better than 0.1 logMAR in both eyes. Participants were excluded if slit-lamp and fundus examinations revealed any ocular disease potentially affecting refractive status. Additionally, participants were required to voluntarily wear a smart wearable device for continuous sleep monitoring without significant discomfort during wear. Exclusion criteria included: a previous diagnosis of sleep disorders; current or recent use of medications potentially affecting sleep architecture; history of refractive surgery; or any other myopia control intervention within the past 6 months. These criteria ensured homogeneity of the study population and the purity of intervention effects. The study adhered to the principles of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Fujian Medical University (Ethics Approval No.: 2021–075). Written informed consent was obtained from all participants (parental consent for minors) prior to enrollment, and participants were informed of their right to withdraw at any time.

## Sample Size Calculation

Sample size was determined using a priori estimation in G*Power 3.1.9 to ensure sufficient statistical power to detect between-group differences. With power $(1 - \beta)$ set at 0.80, a two-sided significance level $(\alpha)$ of 0.05, and a medium effect size (Cohen's *d* = 0.3) as the benchmark,[25] the minimum required sample size was calculated to be 82 subjects. To compensate for potential follow-up attrition, 144 participants were ultimately recruited. This oversampling ensured the robustness of the findings and the reliability of statistical inferences.

## Ophthalmic Data Collection

Comprehensive ophthalmic examinations were performed on participants by ophthalmologists and optometrists trained to a standardized protocol. Cycloplegia was induced by instilling 0.5% Tropicamide Phenylephrine Eye Drops (Santen, Osaka, Japan) into both eyes three times, with 5-minute intervals between drops. After 30 minutes, pupil dilation and the pupillary light reflex were assessed to confirm complete cycloplegia (defined as pupil dilation ≥ 6 mm and absence of pupillary light reflex). If the pupillary light reflex persisted or pupil dilation was ≤ 6 mm, an additional drop of 0.5% Tropicamide Phenylephrine was administered to each eye.[26]

Ocular biometry, including axial length (AL), lens thickness (LT), central corneal thickness (CCT), and anterior chamber depth (ACD), was measured using the Colombo IOL2 biometer (Moptim Corp., China). Refractive parameters were measured before and after cycloplegia using a NIDEK autorefractor (ARK-510A; NIDEK Corp., Tokyo, Japan) with a measurement step size of 0.01 D. Refractive and ocular biometric measurements were performed five times, and the average value was used. If the difference in SE between any two measurements was ≥ 0.50 D or the difference in AL was ≥ 0.05 mm, the measurements were repeated. Spherical equivalent (SE) was calculated as the sphere power plus half of the cylinder power. The difference in refractive error (DIFF) was defined as the post-cycloplegia SE minus the pre-cycloplegia SE. Participants with DIFF ≥ +0.50 D were classified into the overestimated myopia group, while those with DIFF < +0.50 D constituted the non-overestimated myopia group.[27]

## Sleep Parameter Collection

Sleep data were collected continuously over 7 full consecutive days using the Xiaomi Mi Band 7 (Xiaomi Corp., Beijing, China). This duration has been validated in previous studies as reliably reflecting habitual sleep patterns.[28] The Xiaomi Mi Band 7 integrates a triaxial accelerometer and distinguishes wakefulness, light sleep, and deep sleep stages by analyzing the intensity and frequency of wrist movements in real-time. The validity and feasibility of its algorithm for research purposes have been extensively verified.[29] To ensure data quality, only records meeting all the following criteria were included: ① Daily wear time ≥ 23 hours (excluding charging time); ② Continuous full wear for 7 days; ③ Absence of logical errors or significant outliers. The extracted sleep parameters included total sleep duration, deep sleep duration, light sleep duration, bedtime, and woke time. All data were synchronized daily via the Mi Fit App and cross-verified by two independent researchers. For each parameter, the 7-day mean value was first calculated. Subsequently, parameters were separately aggregated for "weekdays" (nights from Sunday to Thursday) and "weekends" (nights on Friday and Saturday) to assess sleep differences under varying social rhythms.

## Data Analyses

Data analysis was performed using SPSS (IBM SPSS 26.0) software. Due to the high correlation between SE values of the two eyes ($r = 0.864$, $p < 0.001$), only data from the right eye were analyzed. Differences between the overestimated myopia group and the non-overestimated myopia group in terms of SE, AL, LT, CCT, ACD, and age were compared using independent samples t-tests. Differences in sleep patterns between groups were analyzed using linear mixed models (LMM). The LMMs employed restricted maximum likelihood (REML) estimation and included the intercept as a random factor. They were used to compare sleep parameters across individual days of the week, as well as aggregated for weekdays and weekends. LMMs are appropriate for repeated-measures data as they simultaneously account for inter-individual variability and temporal correlations, thereby enhancing analytical accuracy. In the models, categorical variables were treated as fixed factors, while age, sex, daily near work activities, and parental myopia history were included as covariates. Main effects and two-way interactions were examined. For this analysis, the covariance structure for the repeated factor (day of the week) was assumed to be compound symmetry. For significant main effects and interactions identified in the models, Bonferroni-adjusted pairwise comparisons were conducted to explore the nature of the effects and assess differences in sleep duration across different time periods for each participant and between groups. Sleep timing parameters (bedtime and woke time) were analyzed using independent samples t-tests. $P < 0.05$ was considered statistically significant.

## Results

Of the 144 recruited participants, 18 were excluded for not meeting the predefined criteria: 5 withdrew due to personal reasons, 3 had missing data due to device malfunction, and 10 had incomplete data. Ultimately, 126 participants (mean age 19.15 ± 0.18 years, range 17–23 years) who completed all 7 days of wrist-worn sleep monitoring and the full ophthalmic examination were included. Their data quality met the requirements for statistical analysis. There were no statistically significant differences between the overestimated myopia group and the non-overestimated myopia group in terms of age, daily near work activities, SE, AL, LT, CCT, ACD (all $P > 0.05$) (Table 1).

As shown in Table 2, the mean total sleep duration over 7 days for all participants was 7.27 ± 0.81 h. Participants in the overestimated myopia group had 0.60 h less total sleep duration compared to the non-overestimated myopia group (6.82 ± 0.84 h vs 7.43 ± 0.74 h, $P < 0.001$). They also had 0.46 h less daily light sleep duration ($P = 0.006$). However, there was no statistically significant difference in deep sleep duration between the two groups ($P > 0.05$). Furthermore, the overestimated myopia group had a significantly later bedtime by 0.80 h (1:42±1:04 vs 00:53 ± 00:52, $P < 0.001$), but no significant difference was observed in woke time ($P = 0.217$). The overestimated myopia group had less daily sleep duration than the non-overestimated myopia group on each day of the monitoring period (all $P < 0.05$) (Figure 1A). There was no statistically significant difference in daily deep sleep duration between the two groups throughout the monitoring period (Figure 1B). The daily light sleep duration showed asynchronous fluctuations across the week between the groups (Figure 1C), indicating differences in the temporal dynamics of sleep architecture.

All participants had significantly longer total sleep duration on weekends compared to weekdays (7.67 ± 0.85 h vs 7.12 ± 0.75 h, $P < 0.001$). Woke time on weekends was also significantly later by 0.58 h than on weekdays (08:50 ± 01:07 vs 08:15 ± 01:04, $P < 0.001$). However, there was no statistically significant difference in bedtime between weekdays and weekends ($P = 0.601$). Additionally, regardless of whether it was weekdays or weekends, the overestimated myopia group had significantly later bedtimes than the non-overestimated myopia group (both $P < 0.001$) (Table 3).

**Table 1** Characteristics of Study Participants

| | Total N=126 | Overestimated Myopia (N=33) | Non-Overestimated Myopia (N=93) | P |
|---|---|---|---|---|
| Age (years) | 19.15±1.08 | 19.03±1.13 | 19.19±1.07 | 0.458 |
| Non-cycloplegia SE(D) | −4.40±2.46 | −4.62±2.84 | −4.32±2.33 | 0.557 |
| Cycloplegia SE(D) | −3.96±2.47 | −3.68±2.79 | −4.07±2.35 | 0.439 |
| AL (mm) | 25.35±1.14 | 25.24±1.03 | 25.38±1.17 | 0.553 |
| CCT (mm) | 534.55±36.08 | 529.03±34.13 | 536.53±36.73 | 0.308 |
| LT (mm) | 3.48±0.22 | 3.51±0.27 | 3.46±0.20 | 0.342 |
| ACD (mm) | 4.04±0.29 | 4.04±0.29 | 4.02±0.29 | 0.199 |
| Near work activities(h) | 8.51±2.12 | 8.91±2.73 | 8.39±1.89 | 0.303 |

**Abbreviations**: SE, spherical equivalent; D, diopter; AL, axial length; CCT, central corneal thickness; LT, lens thickness; ACD, anterior chamber depth Data are presented as mean ± SD.

**Table 2** Comparison of Sleep Parameters Between Overestimated and Non-Overestimated Myopia Groups

| | Total | Overestimated Myopia | Non-Overestimated Myopia | P |
|---|---|---|---|---|
| Sleep duration(h) ▲ | 7.27±0.81 | 6.82±0.84 | 7.43±0.74 | <0.001 |
| Deep sleep time (h) ▲ | 1.34±0.33 | 1.33±0.31 | 1.34±0.34 | 0.835 |
| Light sleep time (h) ▲ | 5.07±1.02 | 4.73±0.93 | 5.19±1.05 | 0.006 |
| Bedtime | 1:06±0:59 | 1:42±1:04 | 0:53±0:52 | <0.001 |
| Woke time | 8:25±1:07 | 8:29±1:16 | 8:23±1:05 | 0.217 |

**Notes**: ▲Indicates the results of using LMM statistical methods after adjusting for age, near work activity, and parental myopia. Data are presented as mean±SD.

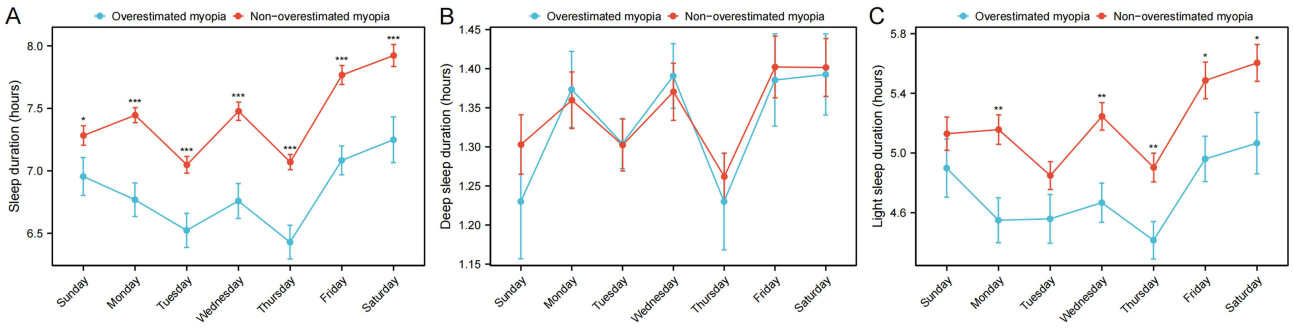


**Figure 1** Comparison of sleep parameters between Overestimated myopia and Non-overestimated myopia.
**Notes**: (**A**) Daily total sleep duration (**B**) Daily deep sleep duration (**C**) Daily light sleep duration. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$; Error bars represent 95% confidence intervals.

## Discussion

This study utilized wearable devices to collect objectively quantified sleep parameters, assessing the association between sleep characteristics and overestimated myopia among young adults. This approach minimized recall bias and subjective reporting errors. The results demonstrated that, compared to the non-overestimated myopia group, the overestimated myopia group exhibited significantly shorter total sleep duration, both on weekdays and weekends, along with a significantly delayed bedtime.

This study found that the mean total sleep duration for all participants was 7.27 ± 0.81 hours. Significant differences in sleep patterns were observed between weekdays and weekends: participants exhibited earlier woke times and shorter sleep durations on weekdays. In contrast, sleep duration was extended by approximately 0.5 h on weekends, with a significantly later woke time. This pattern aligns with findings from previous studies.[30,31] When analyzing the correlation between the difference in refractive error before and after cycloplegia (DIFF) and sleep parameters, the overestimated myopia group was found to have significantly shorter total mean sleep duration - whether daily average, weekday, or weekend - by approximately 0.6 hours compared to the non-overestimated myopia group. This finding suggests that myopic overestimation, associated with accommodative dysfunction, may be linked to reduced sleep duration. Previous research has indicated that sleep status affects multiple visual functions, including accommodative function,[22] vergence,[32] and fusional coordination.[21] A normal circadian rhythm plays a crucial role in regulating ocular growth and development. Reduced sleep duration may disrupt the circadian rhythm, thereby interfering with the physiological mechanisms governing eye development and potentially causing fluctuations in accommodative function.[33] Furthermore, adequate sleep is essential for the repair of muscle tissues, including the ciliary muscle. Reduced sleep duration may impair the recovery capacity of the ciliary muscle after loading,[34] leading to sustained higher accommodative tone. Collectively, the findings of this study support the notion that insufficient sleep duration may be an important contributing factor to myopic overestimation.

**Table 3** Differences in Sleep Parameters Between the Overestimated-Myopia and Non-Overestimated-Myopia Groups on Weekdays Versus Weekends

| | Weekday | | P | Weekend | | P |
|---|---|---|---|---|---|---|
| | Overestimated Myopia | Non-Overestimated Myopia | | Overestimated Myopia | Non-Overestimated Myopia | |
| **Sleep duration▲** | 6.69±0.80 | 7.27±0.67 | <0.001 | 7.17±0.85 | 7.84±0.77 | 0.003 |
| **Deep sleep▲** | 1.31±0.30 | 1.32±0.33 | 0.872 | 1.39±0.31 | 1.40±0.36 | 0.813 |
| **Light sleep▲** | 4.62±0.87 | 5.06±0.94 | 0.003 | 5.01±1.00 | 5.54±1.15 | 0.089 |
| **Bedtime** | 1:42±1:05 | 0:52±0:52 | <0.001 | 1:41±1:02 | 0:56±0:52 | <0.001 |
| **Woke time** | 8:20±1:17 | 8:12±1:01 | 0.190 | 8:53±1:07 | 8:50±1:07 | 0.762 |

**Notes**: ▲Indicates the results of using LMM statistical methods after adjusting for age, near work activity, and parental myopia.
Data are presented as mean ± SD.


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This study also observed that the overestimated myopia group had significantly later bedtimes than the non-overestimated myopia group on a daily basis, as well as specifically on weekdays and weekends, while no statistically significant difference in woke time was observed between the groups. This pattern of later sleep timing but relatively fixed wake-up times may partially reflect the constraints of modern educational systems, particularly given that the study population consisted of university students whose woke times are often strictly dictated by academic schedules.[35] Habitual late bedtime may increase opportunities and duration for engaging in near work activities (such as reading or using electronic screens) during the evening and prolong exposure to a nocturnal artificial lighting environment.[36] It is noteworthy that a well-established primary trigger for myopic overestimation is excessive near work. This induces persistent ciliary muscle spasm and accommodative dysfunction, consequently leading to overestimation of refractive error.[37] Furthermore, organisms rely on the environmental light-dark cycle to synchronize their endogenous circadian rhythm with the sleep-wake cycle. Exposure to light at night has been clearly demonstrated to cause circadian phase delay[38] and can alter the phase of both peripheral tissue clocks and the central circadian pacemaker.[39] Therefore, habitual late bedtime not only shortens the physiologically required period of darkness but may also lead to desynchronization between endogenous biological rhythms and the environmental light-dark cycle. This can result in circadian disruption, affecting the function of multiple systems, including the visual system.[40] Although no direct evidence currently confirms that late bedtime is a direct cause of myopic overestimation, the significant association between later bedtime and the overestimated myopia group observed in this study suggests that late sleep timing may be a potential correlate of myopic overestimation.

The findings of this study indicate that the sleep pattern characteristic of the overestimated myopia group is significantly shorter sleep duration and delayed bedtime. Adequate sleep duration is suggested to have the potential to correct temporary shifts in refractive status towards myopia.[41] Conversely, insufficient sleep may deprive the eye of sufficient time to alleviate the cumulative accommodative load resulting from prolonged near work, potentially contributing to the occurrence of myopic overestimation. A meta-analysis encompassing 31 studies with 205,907 participants confirmed that sufficient sleep duration (OR = 0.63, 95% CI = 0.51–0.78) was significantly associated with a lower risk of myopia, while reduced sleep duration (OR = 1.66, 95% CI = 1.14–2.42) was significantly associated with a higher risk of myopia.[41] At the mechanistic level, reduced sleep duration may induce autonomic nervous system (ANS) hyperactivity.[42] Altered parasympathetic activity can impact ciliary muscle function,[43] leading to ciliary muscle fatigue and disruption of accommodation,[44] thereby increasing the risk of myopic overestimation. Furthermore, a large cohort study in Shandong, China, involving 2,323 children, confirmed that accommodative tone, characterized by myopic overestimation (often described as "pseudomyopia"), is a significant risk factor for the subsequent development of true myopia.[10] Integrating our findings with existing evidence, we postulate an indirect biological pathway linking insufficient sleep duration, myopic overestimation, and the onset and progression of myopia. A mechanism supporting this hypothesis is that the ciliary muscle enters a state of physiological relaxation during sleep, which is believed to help prevent or delay myopia progression.[45] Although there is currently insufficient evidence to suggest that accommodative excess directly drives myopia progression, the imprecision in accommodative response reflected by myopic overestimation may impair the stability of clear retinal imaging. Sustained retinal blur is a well-established critical stimulus promoting the onset and progression of myopia.[46] Additionally, studies indicate that over-minused spectacle prescriptions may exacerbate myopia progression.[47] Therefore, obtaining accurate refractive correction is paramount. In clinical practice, to enhance the accuracy of non-cycloplegic refraction, it may be warranted to consider the examinee's recent sleep status when assessing refractive error. Alternatively, prioritizing refractive examinations in the morning could help minimize the influence of diurnal cumulative accommodative fatigue on measurement outcomes.

## Limitations

The primary strength of this study lies in its use of wearable devices to objectively quantify participants' sleep parameters. This approach effectively circumvents the inherent limitations of subjective measurement methods in accurately capturing true sleep status and significantly reduces the risk of recall bias. However, this study also has the following limitations. First, the participant cohort was limited to university students, whose sleep patterns may differ from those of other age groups. Although this population benefits from a relatively uniform living environment (university dormitories), making it a suitable initial group for investigating the impact of environmental factors, future

studies should expand the age range to enhance the generalizability of the findings. Second, while 7-day actigraphy monitoring is widely used to assess habitual sleep patterns, longer-term monitoring data would be more beneficial for comprehensively capturing within-individual variability in sleep parameters and its dynamic association with refractive status. Third, the current study had a relatively small sample size. Furthermore, the widespread deployment of wearable devices for long-term sleep monitoring in large-scale population studies presents practical operational challenges related to cost, compliance, and data management. Additionally, although this study collected total near work activities, it did not further distinguish between different types of electronic screen use or specific periods of near work. This failure to differentiate may introduce potential confounding factors, affecting the precise delineation of the complex relationships between sleep patterns, near work, and refractive status. Finally, the cross-sectional design employed in this study, while revealing significant associations between sleep pattern characteristics and the overestimated myopia group, cannot establish the direction of causality between these factors.

## Conclusions

Through objective sleep monitoring, this study found that shorter sleep duration and delayed bedtime are significantly associated with overestimated myopia among university students. Fluctuations in accommodative function related to sleep patterns may be an important factor influencing measurement error in non-cycloplegic refraction. Therefore, during refractive measurement and large-scale screenings, particularly when cycloplegic refraction is not feasible, it is advisable to consider the examinee's recent sleep status. This approach may enhance the accuracy of non-cycloplegic refractive measurement.

## Data Sharing Statement

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

## Ethics Statements

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was provided by the Ethics Committee of Fujian Medical University (2021-075).

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## Author Contributions

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Xiaohu Ding: Conceptualization, Data curation, Visualization, Resources, Writing–review & editing.

Luoming Huang: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing-original draft, Writing – review & editing.

All authors gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The author(s) have no proprietary or commercial interest in any materials discussed in this article.

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