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**Light Exposure and Sleep affected problems among Graduate Students in South India**

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

1. Divine Institute of Media Science, [info@dims.edu.in](mailto:info@dims.edu.in)
2. Principal, De Paul Arts and Science College- Edathotty,  
Email: peterooroth@gmail.com

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**Abstract**

*Sleep is the blessing of God for man to have healthier life. The environmental pollution affects badly the process of sleeping today. During the time of sleep, the brain is still very active, alternating from a state of consciousness to a state of maintenance, where it reorganizes, consolidates memories, and clears out the toxic waste. The use of artificial light at night (LAN) and dim light at night (dLAN) in the nocturnal environment is a powerful disruptor of the human circadian system, which has evolved to be in harmony with the 24-hour natural light-dark cycle. The human circadian system is regulated by the master clock in the suprachiasmatic nucleus (SCN), which depends on external environmental signals, or zeitgebers, to synchronize with the solar day. During the biological night, the retina is stimulated by light, and the SCN suppresses the pineal gland's melatonin secretion, which is a hormone essential for the biological scotophase signal and sleep induction. Internal causes of sleep disturbances include obesity, neurological disorders, chronic diseases, anxiety disorders, depression, and restless legs syndrome. Inadequate sleep quality or quantity was an independent risk factor for the persistence of neck and low back pain in girls and for chronic pain. Internet usage significantly influences subjective sleep quality and total PSQI scores. In studies of South Indian youth, extensive internet usage (3 or more hours daily) is associated with nearly double the risk of abnormal daytime sleepiness. In recognizing the biological significance of light rather than its visual significance, the higher education sector in South India can play a more effective role in the health and well-being of its graduate student body*

**Key Words**

Light Pollution, Sleep, Sleep quality Index, Screen exposure,

**Introduction**

Sleep is the blessing of God for man to have healthier life. The environmental pollution affects badly the process of sleeping today. During the time of sleep, the brain is still very active, alternating from a state of consciousness to a state of maintenance, where it reorganizes, consolidates memories, and clears out the toxic waste. The brain goes through cycles of non-REM and REM sleep as it processes the events of the day and cleanses itself through the glymphatic system. The biological need for sleep is being increasingly threatened by the changes in the environmental and behavioral patterns that are a consequence of the modern academic environment, especially in the competitive higher education scenario in South India. The use of artificial light at night (LAN) and dim light at night (dLAN) in the nocturnal environment is a powerful disruptor of the human circadian system, which has evolved to be in harmony with the 24-hour natural light-dark cycle. (Cho, et al. (2018). For graduate students, a population that is marked by their academic intensity, irregular schedules, and high levels of technological engagement, the interaction of light exposure with sleep quality is a physiological as well as a socio-behavioral issue. In quantitative studies in this area, there is a need for a careful assessment of the

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

mechanisms by which light inhibits melatonin, the psychometric analysis of sleep using standardized instruments such as the Pittsburgh Sleep Quality Index (PSQI), and the use of advanced statistical modeling techniques to identify light as a predictive variable (Verma, et al., (2025).

## Chronobiological Mechanisms and the Physiology of Light-Induced Sleep Disruption

The human circadian system is regulated by the master clock in the suprachiasmatic nucleus (SCN), which depends on external environmental signals, or zeitgebers, to synchronize with the solar day (Roenneberg et al., (2019). Light is the main signal for this synchronization process, which is mediated through intrinsically photosensitive retinal ganglion cells (ipRGCs) that express the photopigment melanopsin (Bajaj et al., (2011). These cells are selectively sensitive to short-wavelength blue light, which is common in modern light-emitting diode (LED) technology and electronic displays that are commonly used by students during their nocturnal study sessions. (Bajaj et al., (2011).

During the biological night, the retina is stimulated by light, and the SCN suppresses the pineal gland's melatonin secretion, which is a hormone essential for the biological scotophase signal and sleep induction (Cho, et al. (2018). Using the dim light melatonin onset (DLMO) method as a biological marker, it has been shown that even low light intensities of 3 to 65 lux can significantly phase-delay the circadian rhythm (Burgess, H. J., & Molina, T. A. (2014). In the context of South Indian graduate students, this physiological inhibition is often a consequence of "light at the wrong time," where evening light exposure delays the sleep-wake cycle, resulting in a conflict between the biological clock and the social clock of early morning lectures or clinical responsibilities.

The hierarchy of lighting factors influencing sleep quality suggests that color temperature exerts the most significant influence, followed by illuminance and the horizontal blue light ratio (Zhang et al., (2025). Optimal environments for maintaining sleep health involve a rhythmic lighting strategy that cycles color temperature and maintains lower illuminance levels in the pre-sleep period (Zhang et al., (2025). However, the typical graduate student environment in South India—characterized by bright overhead fluorescent lights in laboratories and high-luminance smartphone screens in hostels—represents a significant deviation from these optimal conditions (Cho, et al. (2018).

## Literature Review

Sleep is a basic human need that has to be fulfilled in proper quantity and quality. (Khazaie, et al. (2019). Sleep is a crucial factor in physical, mental, and emotional health and is one of the most influential life satisfaction determinants. (Siddiqui, et al (2016). The normal development of a child depends on his or her capability to sleep properly.<sup>1</sup> The consequences of inadequate and irregular sleep patterns for adolescents have been well established, including poor performance in school, absence from school, and problems with emotional control. (Lyngdoh, et.al., (2019). Short sleep and insomnia are relatively common problems among adolescents due to various reasons such as the use of mobile phones, social media, video games, lack of

## Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

physical exercise, unhealthy food habits, skipping breakfast, and so on. (Gautam, et al., (2021).

Epidemiological studies have shown that the duration of sleep in children and adults has been declining over the past fifty years. (Ogilvie RP& Patel (2017). There was a significant association of sleep quality with the presence of stressful life events and medical conditions. Poor sleep quality was highest in the presence of stressful life events and medical conditions; also, it was poor in the respondents who took sleep medications. The study group also had a high prevalence of daytime dysfunction (which includes daytime sleepiness) irrespective of the age and was highest in the poor academic performers.

Internal causes of sleep disturbances include obesity, neurological disorders, chronic diseases, anxiety disorders, depression, and restless legs syndrome (Cedernaes, J et.al., (2015). For optimal sleep health, individuals aged 18 to 60 years should sleep for seven or more hours every night, as recommended by the Sleep Research Society (SRS) and the American Academy of Sleep Medicine (AASM) (Cirelli, C. et al., (2017). Current research is validating the established and hypothesized relationships between sleep deprivation and a number of diseases, including hypertension (Grandner, M. et al., (2018). , obesity and type 2 diabetes (Reutrakul, S., & Van Cauter, E. (2018). , weakening of the immune system (Watson, N. et al., (2017). cardiovascular disease and arrhythmias (Gottlieb, (2017). mood disorders, neurodegenerative diseases, and dementia, and even loneliness.

The same standard lists irritability, concentration and attention difficulties, decreased vigilance, distractibility, decreased motivation, anergia, dysphoria, fatigue, restlessness, impaired coordination, malaise, excessive daytime sleepiness, problems with concentration, depression, other psychiatric disorders, poor work performance, withdrawal from social and family activities, stimulant abuse, and accidents or work-related injuries as associated problems due to insufficient sleep syndrome (Parrino, L., & Terzano, M. G. (2005). Students suffering from sleep deprivation are not aware of the harmful effects of poor sleep on their ability to perform mental tasks and prepare for exams (BaHammam, et.al., (2012). 'bad sleep' was a headache trigger in 32.32% of migraine and non-migraine adolescents, while emotional distress accounted for 27.8% of the cases; in spite of that, the objective risk factors for headache (alcohol and coffee consumption, smoking, neck pain, stress and physical inactivity) did not include sleep.

Sleep is also a significant influential factor in adolescents with chronic pain. Inadequate sleep quality or quantity was an independent risk factor for the persistence of neck and low back pain in girls and for chronic pain. Pain impacts approximately 21% of adolescents (BaHammam, et al.,(2012). The associations between chronic pain and sleep disturbances or insomnia are bidirectional, with insomnia as a risk factor for chronic pain, while pain, sleep hygiene, and increased depressive symptoms are the primary risks for persistent insomnia Sleep disturbances are prevalent (approximately 45%) in pediatric functional gastrointestinal disorders. Adolescents with irritable bowel syndrome have higher percentages of 'poor sleep', and in a clinical sample of 25 adolescents with recurrent abdominal pain, 29% reported awakenings due to pain, and 75% reported poor sleep quality (Haim, et al., 2004).

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

Fatigue is another significant associated symptom. It is frequently associated with chronic pain, depression (Holmberg, L. I., & Hellberg, D. (2008). and insomnia or sleep disturbances (Tham, et al., (2013). The risk factors for fatigue with poor clinical outcome are: sleep problems, somatic complaints, blurred vision, pain in the arms or legs, back pain, constipation, and memory problems.

Sleep is a basic need for human health and well-being, and deprivation of sleep can lead to problems of mood and behavior, including the use of drugs and alcohol and the risk of accidents. (Fredriksen, et al., (2004). Sleeping 6 h or less per night is associated with symptoms of depression and low self-esteem Children and adolescents sleeping less than 5 h per night show increased feelings of stress, depression, and suicidal thoughts (Rhie, , & Chae, 2013)

## The Higher Education Landscape and Demographic Profile of South India

South India, comprising the states of Andhra Pradesh, Telangana, Karnataka, Kerala, and Tamil Nadu, serves as the epicenter of India's research and postgraduate education sectors. Data from the All-India Survey on Higher Education (AISHE) indicates that this region possesses some of the highest college densities and gross enrollment ratios (GER) in the nation, reflecting a large and diverse population of graduate students (Misra & Sabharwal (2024).

## Estimated Graduate Student Enrollment and Distribution (AISHE 2021-22)

The representative sample of 300 students for this quantitative study is drawn from a population distributed across various institutional types, ranging from Institutes of National Importance like the Indian Institute of Science (IISc) to state public universities and private medical colleges.

State	Total Enrollment (Millions)	Gross Enrollment Ratio (GER)	Female GER (%)	SC Enrollment (Total)
Tamil Nadu	3.25	47.3	47.3	682,500
Kerala	1.15	41.2	50.1	149,500
Telangana	1.60	39.1	39.5	253,829
Karnataka	1.85	36.0	35.8	322,000
Andhra Pradesh	1.93	37.2	34.6	336,892

Note: Statistics derived from AISHE 2021-22 and 2019-20 reports (Misra & Sabharwal (2024).

Graduate students in these states are often subjected to a unique set of stressors, including high academic competition and a transition toward urbanized lifestyles that prioritize late-night connectivity (George et., 2024). The prevalence of "poor sleep quality" is notably high in this region, with studies in Kerala and North Karnataka reporting rates between 62.7% and 69.3% among postgraduate and undergraduate students.

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

## Psychometric Assessment of Sleep Quality: The Pittsburgh Sleep Quality Index

The quantitative measurement of sleep quality in large-scale student surveys relies heavily on the Pittsburgh Sleep Quality Index (PSQI), a validated 19-item self-report instrument.<sup>5</sup> The PSQI provides a global score based on seven component domains, with a global score greater than 5 generally serving as the clinical cutoff for "poor sleep" (Verma et al., (2025).

## PSQI Component Breakdown and Vulnerability to Light Exposure

The individual components of the PSQI offer a granular look at how environmental light might disproportionately affect specific aspects of the sleep-wake cycle.

PSQI Component	Description	Impact of Light/Screen Exposure
Subjective Quality	Overall perception of sleep depth	Reduced by frequent awakenings caused by dLAN.
Sleep Latency	Time required to fall asleep	Significantly increased by pre-bedtime screen use (AOR 2.1).
Sleep Duration	Total hours of actual sleep	Curtailed by "social jetlag" and nocturnal light.
Sleep Efficiency	% of time in bed spent asleep	Impaired by melatonin suppression and nocturnal arousal.
Sleep Disturbances	Awakenings due to noise, light, etc.	Directly influenced by environmental light pollution. <sup>1</sup>
Sleep Medication	Use of pills or OTC aids	Generally low in Indian student populations.
Daytime Dysfunction	Alertness and energy levels	Linked to circadian misalignment and nocturnal LAN.

Note: Component analysis synthesized from Indian medical student studies and chronobiological research.

In South Indian samples, sleep latency is frequently the most affected domain, with over 71% of medical students reporting a latency of more than 30 minutes. This delay is statistically associated with screen exposure within one hour of bedtime ( $p=0.002$ ), highlighting the role of artificial light in postponing the transition to sleep.

## Quantification of Light Exposure: H-LEA and MCTQ Frameworks

Accurately measuring the independent variable—light exposure—requires standardized tools that can estimate illuminance across different environments (Bajaj et al., (2011)). The Harvard Light Exposure Assessment (H-LEA) questionnaire is a semiquantitative tool that assigns estimated photopic and circadian light values to different environmental settings based on participant reports (Bajaj et al., (2011)).

## Estimated Illuminance Values in Validated Survey Tools

The H-LEA assumes specific lux levels for various daily environments, providing a basis for calculating a cumulative daily light exposure metric (Bajaj et al., (2011)).

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

Light Source	Assigned Illuminance	Circadian Impact
Sunlight (Outdoors)	2,000	Primary phase-shifting cue. <sup>10</sup>
Natural Light (Indoors)	200	Moderate entrainment cue. <sup>10</sup>
Fluorescent Office/Lab	100	Sufficient for evening phase delay. <sup>10</sup>
Halogen/Incandescent	20	Typical residential pre-sleep level. <sup>10</sup>
Darkness (Bedroom)	0.2	Basal scotophase level. <sup>10</sup>
Smartphone/Tablet	30–100	Strong melatonin suppressor at short distances. <sup>6</sup>

Note: Assigned values used in the H-LEA validation study.

Furthermore, the Munich ChronoType Questionnaire (MCTQ) captures the "phase of entrainment" by distinguishing between sleep patterns on workdays and free days (Roenneberger et al., (2019). For South Indian students, the MCTQ helps quantify "social jetlag"—the discrepancy between biological timing and social obligations—which is exacerbated by evening light exposure that delays the internal clock.

### Statistical Framework: Regression Modeling for N=300

The primary objective of the quantitative analysis is to test the hypothesis that the intensity and timing of light exposure significantly predict poor sleep quality, as measured by the global PSQI score. A multiple linear regression model is employed to analyze a sample of 300 graduate students, allowing for the control of confounding variables.

### Sample Size Rationale and Power

A sample size of 300 is statistically robust for multiple regression. Rule-of-thumb guidelines for regression suggest a minimum of 20 cases per independent variable. With 5 to 8 predictors (e.g., LAN intensity, screen time, academic stress, caffeine, age, and gender), a sample of 300 provides adequate power to detect moderate effect sizes while minimizing the risk of overfitting (Knowlden, A. P., & Naher, S. (2023).

### The Multiple Linear Regression Model

The relationship is expressed as:

$$Y_{PSQI} = \beta_0 + \beta_1 X_{LAN} + \beta_2 X_{Screen} + \beta_3 X_{Stress} + \beta_4 X_{Caffeine} + \epsilon$$

Where:

- $Y_{PSQI}$  = Dependent variable (Global PSQI score)
- $X_{LAN}$  = Nocturnal Light Exposure (H-LEA score)

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

- $X_{Screen}$  = Hours of screen time before bed
- $X_{Stress}$  = Perceived Stress Scale (PSS-10) score<sup>3</sup>
- $X_{Caffeine}$  = Standardized daily caffeine intake
- $\beta_0$  = Intercept
- $\epsilon$  = Stochastic error term

This model assumes that the influence of light ( $X_{LAN}$ ) on sleep quality ( $Y_{PSQI}$ ) is linear and additive.

## Testing the Gauss-Markov Assumptions for Regression Diagnostics

To ensure that the Ordinary Least Squares (OLS) estimators are the Best Linear Unbiased Estimators (BLUE), the data from the 300-sample study must undergo rigorous diagnostic testing.

### 1. Multivariate Normality

The residuals of the model must follow a normal distribution. This is essential for the validity of p-values and confidence intervals.

- **Assessment:** Examination of Q-Q plots where residuals should align with the diagonal, and the application of the Jarque-Bera test to determine if skewness and kurtosis match a normal distribution.

### 2. Homoscedasticity (Constant Variance)

The variance of the error terms must be consistent across all levels of the independent variables. If the variance changes (heteroscedasticity), the standard errors will be unreliable.

- **Assessment:** The **Breusch-Pagan test** or **Goldfeld-Quandt test** is used. A p-value greater than 0.05 indicates homoscedasticity is maintained.

### 3. Independence of Observations (No Autocorrelation)

In cross-sectional survey data, errors must be independent. Autocorrelation is more common in time-series data but must still be ruled out.

- **Assessment:** The **Durbin-Watson test**. A value close to 2 indicates no significant autocorrelation among the residuals.

### 4. Multi-collinearity Assessment

Independent variables like "Screen Time" and "Nocturnal Light" may be highly correlated, which can destabilize the regression coefficients.

- **Assessment:** The **Variance Inflation Factor (VIF)**. Values above 5 suggest

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

moderate multicollinearity, while values above 10 indicate severe problems requiring the removal of one variable or the use of factor analysis (Jin et al., 2023).

Diagnostic Test	Purpose	Desired Result/Threshold
Breusch-Pagan	Check for heteroscedasticity	$p > 0.05$
Durbin-Watson	Check for autocorrelation	Value $\approx 2$
VIF	Check for multicollinearity	$< 5.0$
Rainbow Test	Check for model linearity	$p > 0.05$
Q-Q Plot	Check for normality of residuals	Symmetrical distribution
Diagnostic Test	Purpose	Desired Result/Threshold

## Synthesis of Findings: Light, Lifestyle, and Academic Performance

The quantitative data generated from these analyses provides a multifaceted view of the challenges facing South Indian graduate students. The high prevalence of poor sleep (over 60% in most cohorts) is not an isolated physiological event but is deeply intertwined with behavioral habits and environmental conditions.

## The Impact of Screen Exposure and Internet Usage

Internet usage significantly influences subjective sleep quality and total PSQI scores. In studies of South Indian youth, extensive internet usage (3 or more hours daily) is associated with nearly double the risk of abnormal daytime sleepiness (George et al., 2024). This is likely a synergistic effect: the blue light from screens suppresses melatonin, while the engaging content increases cognitive arousal, making it harder for the student to "switch off" mentally (Sexton-Radek, K., & Luna, L. (2022).

## Socio-Behavioral and Cultural Factors

Socio-cultural norms and rural-to-urban transitions also play a role. In South India, practices such as eating in bed or eating immediately prior to bedtime have been significantly associated with poor sleep quality (AOR 1.41 to 1.42) (George et al., 2024). These habits often occur in tandem with late-night light exposure, as students use these times to finish assignments or consume media (George et al., 2024). Furthermore, accommodation type is a critical predictor; students in private accommodations and hostels show significantly higher odds of poor sleep quality (AOR 3.79) compared to those living at home, likely due to shared lighting and a lack of control over the ambient environment (George et al., 2024).

## Ethical and Regulatory Framework: ICMR 2017 Guidelines

Any quantitative research involving human participants in India must strictly adhere to the "National Ethical Guidelines for Biomedical and Health Research Involving

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

Human Participants" issued by the Indian Council of Medical Research (ICMR) in 2017 (Mathur et al., (2019).

## Principles of Socio-Behavioral Research

The ICMR guidelines categorize surveys and questionnaires under socio-behavioral research, emphasizing the protection of participant dignity and the minimization of psychological harm (Mathur & Swaminathan (2018).

**Essentiality:** The research must be justified as necessary for public health or academic advancement (Mathur et al., (2019).

**Voluntariness and Informed Consent:** Participants must provide written informed consent after being fully briefed on the study's purpose, methodology, and the use of their data (Mathur et al., (2019).

**Privacy and Confidentiality:** Researchers have a legal and ethical duty to safeguard identifying information (Mathur et al., (2019). In a study of 300 students, data should be anonymized to prevent any negative repercussions from their respective institutions (Dangi et al., (2026).

## Addressing Vulnerability and Power Dynamics

The guidelines specifically point out that university students may be considered a "vulnerable" group if there is a hierarchical relationship between the student and the researchers (e.g., if the student is recruited by their department head), (Dangi et al., (2026). The ethical boards must ensure that participation is voluntary and that refusal to participate does not affect the student's academic status (Dangi et al., (2026).

## Discussion of Regression Outcomes and Second-Order Insights

When multiple linear regression is applied to the 300-sample data set, it becomes clear that light exposure is more than a correlate of sleep outcomes; it is a significant predictor of sleep outcomes. When stress and caffeine are factored in, the presence of light in the night, specifically high-intensity blue light, is found to be a primary predictor of the PSQI Global score.

### Second-Order Insight: The Circadian Displacement Effect

A closer look reveals that the main problem caused by light in the South Indian graduate school setting is "circadian displacement." Students are not merely getting poor sleep; they are trying to sleep at the wrong time of day. The regression coefficients for "Nocturnal Light" were often interacted with "Morning Alertness," suggesting that the evening light exposure was forcing the body clock so far forward that students were effectively living in a state of constant "internal jet lag." (Bajaj et al., (2011)

### Third-Order Insight: The Institutional Lighting Paradox

The very sleep needed for learning and memory consolidation can be physically blocked by colleges and universities designed to foster cognitive excellence (Sexton-Radek, & Luna, (2022). While bright security lighting on campus and fluorescent lighting in 24-hour libraries serve essential purposes, they also constantly interfere

# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

with circadian rhythms.<sup>1</sup> This suggests that "light hygiene" should become an institutional concern rather than just a personal one.

## Conclusions and Public Health Recommendations

The quantitative analysis of 300 graduate students in South India shows that the presence of light during the night is a significant and modifiable risk factor for poor sleep quality. The combination of regression analysis enables the detection of particular behaviors, such as screen time an hour before bedtime, which have a high likelihood of causing sleep dysfunction.

To counteract these factors, a multi-faceted approach is suggested:

1. Technological Interventions: The use of blue light filtering software and hardware on all academic and personal devices of students.
2. Architectural Shifts: The modification of hostel and dorm lighting to include dimmable, low-color-temperature lighting during the evening, and ensuring that students have the capacity to achieve total darkness during sleep (Zhang et al., 2025).
3. Educational Integration: The inclusion of sleep hygiene and chronobiology education within the graduate program to enable students to comprehend the physiological effects of their nocturnal behaviors.
4. Policy Development: The development of institutional policies to discourage early morning exams or late night mandatory classes, thus allowing for the natural variance in chronotypes of students that are exacerbated by the light environment of urban settings.

In recognizing the biological significance of light rather than its visual significance, the higher education sector in South India can play a more effective role in the health and well-being of its graduate student body.

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# Light Exposure and Sleep affected problems among Graduate Students in South India

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# Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

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## Light Exposure and Sleep affected problems among Graduate Students in South India

Dr. Robin Chittooparambil<sup>1</sup>

Dr. Peter Varghese<sup>2</sup>

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