Health Effects of LED Light Exposure among College Students: Insights from Sidama Regional State, Ethiopia

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KEYWORDS

LED light exposure, health effects, college students, sleep disturbance, visual discomfort, mental health, quantitative research, cross-sectional survey

ABSTRACT

This study investigates the health effects of LED light exposure among co students in Sidama Regional State, Ethiopia, employing a cross-sectional su design with a quantitative approach. Data were collected from 377 college stuc using self-administered questionnaire, and the results were analyzed using n standard deviation, and Analysis of Variance (ANOVA). The findings high significant negative effects of increased exposure to LED light sources, particu the blue-rich spectrum emitted by devices such as smartphones, televisions, computer screens. The study reveals that prolonged exposure disrupts circa rhythms by inhibiting melatonin production, leading to sleep disturbances, poor s quality, and daytime fatigue. Additionally, excessive LED light exposure contril to visual discomfort and potential retinal damage, which may result in long- effects such as retinal degeneration. The study further identifies a correlation betv prolonged screen time and mental health issues, including anxiety, stress, depression. These findings underscore the importance of addressing the health associated with LED light exposure among college students.

1. INTRODUCTION

Light-emitting diode (LED) technology has transformed the lighting industry with its compact size, durability, long lifespan, and ability to emit specific wavelengths (Darkó et al., 2014). Commonly used in lamps, screens, smartphones, and decorative lighting, LEDs emit blue-rich light, raising health concerns. Acute exposure to blue light is linked to short-term phototoxic effects, while prolonged exposure may increase the risk of age-related macular degeneration (ANSES, 2019). Additionally, UV-emitting and extremely bright LEDs can disrupt circadian rhythms, impair melatonin secretion, and cause health issues like retinal damage, sleep disorders, and thyroid problems (Chikhale, 2018).

In Ethiopia, the adoption of LED lighting has provided an energy-efficient and affordable alternative to traditional lighting systems, particularly in areas with limited electricity access. This transition has significantly improved the quality of life for many, as LED lighting supports sustainable development and reduces energy consumption (Gebremeskel et al., 2021). However, its widespread use has raised concerns about blue light exposure, particularly at night, which can disrupt sleep quality, mood, and eye health (Wahl et al., 2019). The balance between bright natural light during the day and darkness at night is essential for maintaining circadian rhythm and overall health. Conversely, nighttime exposure to LED light may interfere with this balance, potentially leading to sleep and health issues (Ticleanu, 2021).

The integration of LEDs into various technologies has significantly increased human exposure to short-wavelength visible light. College students are particularly susceptible to the negative health consequences of excessive exposure to light-emitting diode lighting due to their unique lifestyle and study habits. However, there is a contradictory view on the impact of LED lighting on human health. While some studies, such as Arjmandi et al., (2018), suggest that LED lighting can generate reactive oxygen species and cause cellular damage through apoptosis and necrosis, others, like Treichel (2016), argue that there is no statistical evidence linking LEDs to fatigue, eye strain, or headaches. These contradictory findings highlight the need for further investigation. Therefore, this study aims to examine the health effects of LED light exposure among college students in the Sidama Regional State, Ethiopia.

2. RESEARCH METHODOLOGY

2.1. Research Design

This study employed a cross-sectional survey research design to examine the health effects of LED light exposure among college students in Sidama Regional State, Ethiopia. The cross-sectional design was chosen for its effectiveness in capturing data at a single point in time, allowing the researchers to assess the prevalence and potential health outcomes associated with LED light exposure within the target population. This design facilitated the systematic collection of data from a diverse pool of participants, enabling the identification of LED usage and health effects such as sleep disturbances, visual discomfort, and mental health challenges. By utilizing this approach, the study provided valuable insights into the issue, contributing to the development of evidence-based strategies to mitigate the adverse impacts of LED light exposure on college students.

2.2. Sampling Design

The population of this study was public college students situated in Sidama Regional State, Ethiopia, constituting the target population. The geographical scope of Sidama Regional State provided a diverse pool of participants from 13 colleges within the region, contributing to the representativeness of the study. According to the Regional Educational Office (2023), there were 6,420 students in these 13 colleges. To derive an appropriate sample size for the research, the well-established Yamane (1967) formula was employed. This formula considered factors such as the size of the population (N) and the desired level of confidence (e), ensuring a scientifically sound sample.

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{6420}{1 + 6420(0.05)^2}$$

$$n \approx 377$$

To ensure a representative sample, a researcher will employ a stratified random sampling technique. This involves dividing the population into strata based on different colleges within the study area and selecting participants from each stratum using random selection methods. The strata will be determined based on academic departments and years of students. Individuals with pre-existing eye diseases, psychiatric disorders, or sleep disorders that can potentially affect the study outcomes will be excluded.

2.3. Data Collection Tool

The primary data collection tool for this study is a self-administered questionnaire designed to gather comprehensive information on the health effects of LED light exposure among college students in Sidama Regional State, Ethiopia. The questionnaire includes closed-ended and Likert scale-based questions to ensure clarity and consistency in responses. It is divided into sections covering demographic information, patterns of LED light usage, and perceived health effects (e.g., sleep quality, visual discomfort, and mental health). The instrument was developed based on existing literature and expert input to ensure its validity and reliability. Before deployment, a pilot test was conducted to refine the questions and ensure their appropriateness for the target population.

2.4. Data Analysis

The data collected through the questionnaire were analyzed using various statistical methods to examine the health effects of LED light exposure among college students in Sidama Regional State, Ethiopia. Descriptive statistics, including mean and standard deviation, were employed to summarize and describe the patterns of LED usage and the prevalence of reported health effects such as sleep disturbances, visual discomfort, and mental health issues. Additionally, a one-way analysis of variance (ANOVA) was conducted to identify significant differences in health outcomes among groups based on the duration of LED light exposure. These statistical techniques provided a comprehensive understanding of the extent and variability of LED-related health impacts within the study population.

3. RESULT AND INTERPRETATION

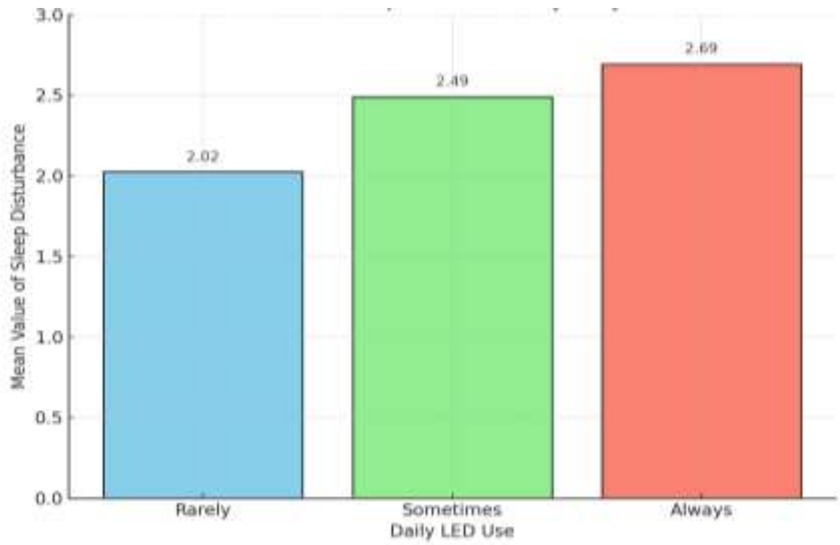
3.1. The Human Health Effects of LED Light

LED has revolutionized lighting with benefits like energy efficiency and longevity, but their widespread use has raised concerns about health effects. This section explores the impact of LED light exposure on sleep, visual discomfort, and mental health.

3.1.1. LED Light Effect on Sleep Disturbance

As LED is commonly used in devices such as smartphones, televisions, and computers, this section delves into examining its impact on sleep disturbance.

Figure 1: *Mean Value of Sleep Disturbance by Daily LED Use*



Data Source: Primary Survey, 2024

The figure (Figure 1) shows a positive relationship between daily LED use and the mean value of sleep disturbance. Individuals who rarely use LEDs report the lowest mean sleep disturbance (2.02), while those with moderate usage ("sometimes") experience higher disturbances (2.49) and consistent users ("always") report the highest level (2.69). This trend implies that increased exposure to LED light is associated with greater sleep disturbances, likely due to its impact on melatonin production and circadian rhythms.

Table 1: *Analysis of Variance (ANOVA) for Sleep Disturbance across Frequency of Daily LED Light Source Usage*

Variable	Source of Variable	Sum of Squares	df	Mean Square	F	Sig.
Sleep disturbance	Between Groups	34.724	2	17.362	30.357	.000
	Within Groups	213.900	374	.572		
	Total	248.624	376			

Multiple Comparisons

Dependent Variable	(I) Daily LED Use	(J) Daily LED Use	Mean Difference (I-J)	Std. Error	Sig.
Sleep disturbance	Rarely	Some times	-.46692*	.11843	.000
		Always	-.66843*	.08935	.000
	Some times	Rarely	.46692*	.11843	.000
		Always	-.20151	.12975	.267
	Always	Rarely	.66843*	.08935	.000
		Some times	.20151	.12975	.267

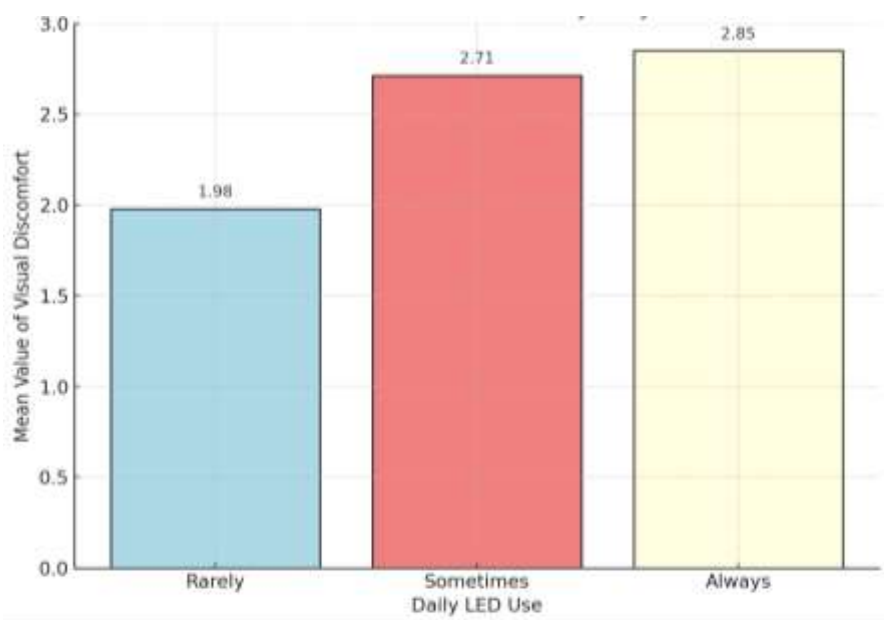
Note: * the mean difference is significant at a 0.05 level
Data Source: Primary Survey, 2024

The results of the ANOVA analysis ($F(2, 374) = 30.357$, $p < .001$) reveal a statistically significant difference in Sleep disturbance among groups based on the frequency of daily LED light source usage. This indicates that the observed differences in sleep disturbance are unlikely to be due to chance. Table 4.12 underscores a significant relationship between the frequency of LED light usage and sleep disturbance, with the analysis highlighting variations among individuals who rarely, sometimes, and always use LED light sources.
Post-hoc comparisons further clarify these differences. Individuals who rarely use LED light sources reported significantly less sleep disturbance than those who use them sometimes or always. However, there was no statistically significant difference in sleep disturbance between individuals who use LED lights sometimes and those who use them always. These findings suggest that reduced exposure to LED light sources is associated with improved sleep quality.

3.1.2. LED Light Effect on Visual Discomfort

As LED is commonly used in devices such as smartphones, televisions, and computers, this section delves into examining its impact on sleep disturbance.

Figure 2: *Mean Value of Visual Discomfort by Daily LED Use*



***Data Source*:** Primary Survey, 2024

The Figure (Figure 2) illustrates the mean values of visual discomfort associated with daily LED use among college students, categorized as "Rarely," "Sometimes," and "Always." The results indicate a clear positive relationship between the frequency of LED use and the level of visual discomfort. Students who reported "Rarely" using LED devices experienced the lowest mean visual discomfort (1.98), followed by those who used them "Sometimes" (2.71). The highest mean visual discomfort (2.85) was observed among students who "Always" used LED devices. This trend suggests that increased daily exposure to LED lighting correlates with higher levels of visual discomfort, highlighting the potential adverse effects of prolonged LED exposure on eye health.

Table 2: *Analysis of Variance (ANOVA) for Visual Discomfort across Frequency of Daily LED Light Source Usage*

Variable	Source of Variable	Sum of Squares	df	Mean Square	F	Sig.
Visual Discomfort	Between Groups	63.581	2	31.790	43.325	.000
	Within Groups	274.428	374	.734		
	Total	338.009	376			

Multiple Comparisons

Dependent Variable	(I) Daily LED Use	(J) Daily LED Use	Mean Difference (I-J)	Std. Error	Sig.
Visual Discomfort	Rarely	Some times	-.73798*	.13415	.000
		Always	-.87304*	.10121	.000
	Some times	Rarely	.73798*	.13415	.000
		Always	-.13506	.14696	.629
	Always	Rarely	.87304*	.10121	.000
		Some times	.13506	.14696	.629

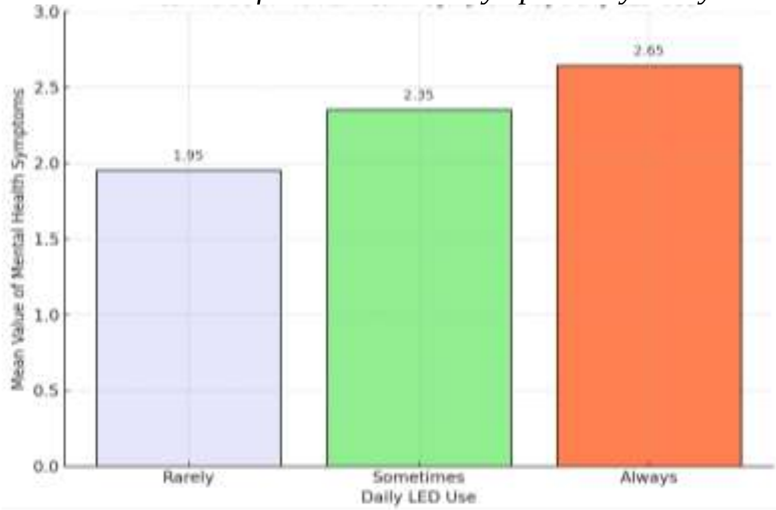
Note: * the mean difference is significant at a 0.05 level
Data Source: Primary Survey, 2024

The results (Table 2) indicate that there is a statistically significant difference in visual discomfort across the different frequencies of daily LED light source usage. The F-value of 43.325 with a corresponding p-value of 0.000 suggests that the variation in visual discomfort between groups of those who use LEDs "Rarely," "Sometimes," and "Always" is highly significant. The between-group sum of squares (63.581) is much larger than the within-group sum of squares (274.428), further emphasizing that daily LED usage frequency accounts for a considerable portion of the variation in visual discomfort.

Multiple comparisons were conducted to explore the differences between the groups. The analysis shows that individuals who use LEDs "Rarely" experience significantly less visual discomfort than those who use LEDs "Sometimes" (Mean difference = -0.738) and "Always" (Mean difference = -0.873), with both comparisons having a p-value of 0.000.

3.1.3. LED Light Effect on Mental Health Symptoms

Figure 3: *Mean Value of Mental Health Symptoms by Daily LED Use*



Data Source: Primary Survey, 2024

The graph demonstrates a clear association between daily LED use and the mean value of mental health symptoms. Individuals who reported using LEDs "Always" had a mean score of 2.65, indicating a higher likelihood of experiencing mental health symptoms, while those who used them "Rarely" had a mean score of 1.95, suggesting a lower likelihood. The "Sometimes" group had a mean score of 2.35, falling in between the other two groups. These findings suggest a potential link between increased LED exposure and a higher prevalence of mental health symptoms among the study participants.

Table 3: *Analysis of Variance (ANOVA) for Mental Health Symptoms across Frequency of Daily LED Light Source Usage*

Variable	Source of Variable	Sum of Squares	df	Mean Square	F	Sig.
Mental Health Symptoms	Between Groups	35.563	2	17.781	33.245	.000
	Within Groups	200.037	374	.535		
	Total	235.600	376			

Multiple Comparisons

Dependent Variable	(I) Daily LED Use	(J) Daily LED Use	Mean Difference (I-J)	Std. Error	Sig.
Mental Health Symptoms	Rarely	Some times	-.39815*	.11453	.002
		Always	-.69144*	.08641	.000
	Some times	Rarely	.39815*	.11453	.002
		Always	-.29328	.12547	.052
	Always	Rarely	.69144*	.08641	.000
		Some times	.29328	.12547	.052

Note: * the mean difference is significant at a 0.05 level
Data Source: Primary Survey, 2024

The Analysis of Variance (ANOVA) results presented in Table 3 reveal a significant difference in mental health symptoms across varying frequencies of daily LED light source usage. The F-value of 33.245, with a p-value of 0.000, indicates that the mean mental health symptom scores significantly differ between the three groups: "Rarely," "Sometimes," and "Always." The between-group sum of squares (35.563) is much larger than the within-group sum of squares (200.037), further supporting the conclusion that the frequency of LED usage has a notable impact on mental health symptoms.

Further analysis through multiple comparisons indicate that individuals who use LEDs "Rarely" report significantly fewer mental health symptoms compared to those who use them "Sometimes" (mean difference = -0.398, p = 0.002) and "Always" (mean difference = -0.691, p = 0.000). However, no significant difference in mental health symptoms was found between the "Sometimes" and "Always" usage groups, as the mean difference of 0.293 (p = 0.052) is only marginally non-significant. These findings suggest that the frequency of LED usage is associated with mental health symptoms, with "Rarely" users experiencing fewer symptoms than those in the "Sometimes" and "Always" groups.

4. DISCUSSION

The study's findings imply that increased exposure to LED light sources has a detrimental effect on sleep disturbance. A similar study by Oh et al. (2015), Gringras et al. (2015), and Wood et al. (2012) argued that one of the primary concerns surrounding LED light sources is their impact on sleep patterns and circadian rhythms. The blue-rich spectrum emitted by many LED-backlit devices, such as smartphones, tablets, and computer screens, has been shown to suppress the production of melatonin, a critical hormone that regulates the sleep-wake cycle (Argys et al., 2020). This disruption can lead to difficulties falling asleep, poor sleep quality, and daytime fatigue, all of which can have significant consequences for overall health and cognitive function.

Excessive exposure to LED light, particularly blue-rich LED light, has been associated with various health concerns including visual discomfort (Darkó et al., 2014; Tsao et al., 2016). The spectral distribution of LED light, with a specific focus on the wavelengths that interact with intrinsically photosensitive retinal ganglion cells, can have significant implications for human health including retinal degeneration (Volf et al., 2020). Constant exposure to different wavelengths and intensities of light, as promoted by light pollution, may produce retinal degeneration as a consequence of photoreceptor or retinal pigment epithelium cell death. (Contín et al., 2015).

Increased exposure to LED light sources appears to have a significant impact on mental health symptoms. This suggests that prolonged or frequent exposure to LED lighting may be associated with a higher risk of experiencing mental health issues, such as anxiety or stress (Argys et al., 2020). Similarly, excessive screen time is linked to reduced physical activity, which can lead to obesity and other health problems. Furthermore, the increased use of electronic devices can contribute to sleep deprivation and exacerbate mental health concerns, such as anxiety and depression (Hassan et al., 2018).

6. CONCLUSION

The findings of the study highlight the significant negative effects of increased exposure to LED light sources on sleep, visual discomfort, and mental health. Specifically, the blue-rich spectrum emitted by LED-backlit devices, such as smartphones, television, and computer screens interferes with the body's natural circadian rhythms by inhibiting melatonin production, a hormone essential for regulating the sleep-wake cycle. This disruption can lead to difficulties falling asleep, poor sleep quality, and daytime fatigue, which in turn can affect cognitive function and overall well-being. In addition to sleep disturbances, excessive exposure to LED light has been linked to visual discomfort, as well as potential retinal damage due to the wavelengths interacting with the retina. This can result in long-term effects such as retinal degeneration, particularly with continuous exposure to varying intensities of light. Furthermore, prolonged use of electronic devices often leads to reduced physical activity, contributing to health concerns such as obesity. The compounded impact of sleep deprivation, physical inactivity, and the psychological strain associated with excessive screen time can exacerbate mental health issues, including anxiety, stress, and depression, ultimately underscoring the importance of moderating LED exposure to mitigate these adverse effects.

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