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Original Research Article

Impact of LED vs fluorescent light on eye strain: A comparative study

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Abstract

Background: LEDs and fluorescent lights are widely used for their energy efficiency, but concerns exist regarding their impact on eye health, particularly eye strain and visual comfort.

Aims and Objectives: To compare the impact of LED and fluorescent lighting on eye strain, visual performance, and overall comfort among individuals with prolonged exposure.

Materials and Methods: This cross-sectional study recruited participants aged 14-50 who used either LED or fluorescent lighting for at least four hours daily. Data were collected via a structured online questionnaire. Statistical analyses were conducted using the Chi-Square and Mann-Whitney U tests, with statistically significant value set at $p < 0.05$.

Results: Among 364 participants, 318 (87.4%) used LED lighting and 46 (12.6%) used fluorescent lighting. LED users reported longer comfort durations, with 38.36% able to work for more than 2 hours, compared to 23.91% of fluorescent users ($p = 0.014$). Dry eye symptoms were more frequent in LED users (23.27% vs. 13.04%, $p = 0.048$). Headaches were more common among fluorescent users (45.65% vs. 31.45%, $p = 0.046$), while sleep disturbances were reported among LED users (50.63%) than fluorescent users (43.48%). LED lighting was linked to burning sensation in 20.75% of users.

Conclusion: The findings suggest that LED lighting is more conducive to longer work periods with reduced eye strain compared to fluorescent lighting, though concerns about dry eye and sleep disturbances persist.

Keywords: Light emitting diode (LED), Fluorescent light, Visual comfort, Ocular health, Dry eye.

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1. Introduction

The advent of modern lighting technologies has revolutionized the way we illuminate our homes, workplaces, and public spaces, ushering in a new era of efficiency and versatility. As we move away from traditional incandescent bulbs, which have long been criticized for their high energy consumption and relatively short lifespan, newer options such as Light Emitting Diodes (LEDs) and fluorescent lights have emerged. Both of these have become the most prevalent choices in lighting solutions, each playing a crucial role in the transition to more advanced and sustainable technologies.[1]

As lighting technology advances, the prevalence of eye strain—particularly among individuals who spend extended periods in artificial lighting environments—has become a growing concern. While both LEDs and fluorescent lights offer distinct advantages over traditional incandescent bulbs, their impact on visual comfort and eye health, specifically regarding eye strain, has garnered significant attention.[2]

Fluorescent lights, in use for decades, have been lauded for their relatively low energy consumption. These lights work by exciting mercury vapor with an electric current, which emits ultraviolet light that is then converted into visible light by a phosphor coating inside the bulb. A compact fluorescent lamp (CFL) is a type of fluorescent light designed to replace incandescent bulbs. The CFL uses a curved or folded tube and includes electronic ballast in its base to fit standard fixtures. CFLs consume 20-33% of the power of incandescent bulbs while lasting 8–15 times longer. However, like all fluorescent lights, CFLs contain mercury,

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which requires careful disposal and poses environmental and health risks.[3]

LEDs have rapidly become the preferred choice in residential, commercial, and industrial settings due to their superior energy efficiency, longevity, and versatility. These lights operate by passing an electric current through a semiconductor, which emits light when energized. Unlike traditional light sources, LEDs produce highly concentrated light with a specific wavelength, often in the blue spectrum. This characteristic, while beneficial for energy savings and creating bright, clear illumination, also raises concerns about its impact on eye health.[4] However, questions remain about the long-term effects of LED exposure on ocular health, particularly with regard to blue-light emissions.[5]

2. Objective

This study aims to analyse the visual performance in tasks such as reading or working, assesses overall comfort levels, and determine significant differences in eye strain between LED and fluorescent lighting.

3. Materials and Methods

This was a cross-sectional, comparative study conducted through an online questionnaire using Google Forms, ensuring broad accessibility and ease of participation. Participants were provided informed consent before proceeding with the survey.

Participants in this study ranged from 14 to 50 years old and came from a variety of occupational backgrounds, including IT professionals, doctors, tutors, students and homemakers. Inclusion criteria required consistent exposure to either LED or fluorescent lighting for at least four hours per day in a home, work, or educational setting. Exclusion criteria comprised individuals with known ocular diseases like glaucoma, cataracts, recent ocular surgery or laser treatment (within the last six months), and those with colour vision defects.

A standard questionnaire was developed to assess eye strain, visual performance, and comfort under different lighting conditions. The questionnaire included both qualitative and quantitative questions, with sections covering reading environments and habits such as the type and position of lighting, duration of reading or working, and presence of asthenopic symptoms. Additional sections addressed history of refractive errors or dry eye, lighting preferences and the potential impact of lighting on sleep quality. Demographic information related to room type (AC or non-AC) was also collected.

The data collection period lasted eight weeks, during which time responses were collected anonymously to protect participants privacy. Upon completion of the survey, responses were securely stored and processed for analysis. The study protocol was reviewed and approved by the ethics committee. Data confidentiality was strictly maintained.

Categorical variables are expressed as number of patients and percentage of patients and compared across the groups using Pearson's Chi Square test for Independence of Attributes/ Fisher's Exact Test as appropriate. The statistical software SPSS version 25 has been used for the analysis. An alpha level of 5% has been taken and p value less than 0.05 has been considered as significant.

4. Results

In our study, we had a total of 364 participants, with 318 individuals using LED lights and the remaining 46 using fluorescent lights.

Among the participants aged 14-20, 22 individuals (6.92%) used LED lights, while 6 (13.04%) used fluorescent lights. In the 21-30 age group, the majority, 201 participants (63.21%), preferred LED lights, and 33 (71.74%) used fluorescent lights. For those aged 31-40, 45 participants (14.15%) used LED lights, and 5 (10.87%) opted for fluorescent lights. In the 41-50 age group, 50 participants (15.72%) used LED lights, while 2 (4.35%) used fluorescent lights. The p-value was statistically significant at 0.044. (**Table 1**)

The study also assessed lighting preferences based on sex. Among female participants, 150 individuals (47.17%) used LED lights, and 16 (34.78%) preferred fluorescent lights. Among male participants, 168 individuals (52.83%) used LED lights, while 30 (65.22%) used fluorescent lights.

Regarding occupation, 12 (3.77%) participants using LED light were homemakers, 34 (10.69%) were office workers, 175 (55.03%) were professionals, and 97 (30.50%) were students. Among fluorescent light users, 1 (2.17%) was a homemaker, 2 (4.35%) were office workers, 21 (45.65%) were professionals, and 22 (47.83%) were students.

In terms of room conditions, 242 (76.1%) LED users worked in air-conditioned rooms, while 76 (23.9%) worked in non-air-conditioned rooms. For fluorescent light users, 24 (52.17%) were in air-conditioned rooms and 22 (47.83%) were in non-air-conditioned rooms. The p-value was found to be statistically significant at 0.001.(**Table 2**)

Out of 318 participants using LED light, 84 (26.42%) were positioned at approximately 2 meters from the reading point, 106 (33.33%) were positioned at 3 meters, and 128 (40.25%) were positioned at more than 3 meters. Among the 46 participants using fluorescent light, 8 (17.39%) were positioned at 2 meters, 17 (36.96%) were at 3 meters, and 21 (45.65%) were at more than 3 meters. (**Figure 1**)

In terms of comfort with respect to duration, 51 (16.04%) LED users were comfortable for 30 minutes, 70 (22.01%) for 1 hour, 75 (23.58%) for 2 hours, and 122 (38.36%) for more than 2 hours. In comparison, 5 (10.87%) fluorescent light users reported being comfortable for 30 minutes, 20 (43.48%) for 1 hour, 10 (21.74%) for 2 hours, and 11 (23.91%) for more than 2 hours. This difference was statistically significant with a p-value of 0.014. (**Table 3**)

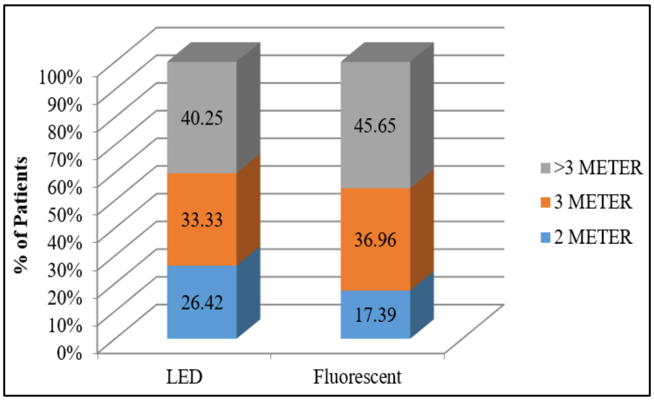

Figure 1: Showing approximate distance of light from reading point

Regarding posture during reading, 178 (55.97%) LED users read while sitting, 8 (2.52%) while lying down, and 132 (41.51%) uses both positions. Among fluorescent light users, 26 (56.52%) read while sitting, 1 (2.17%) while lying down, and 19 (41.3%) uses both positions.

Regarding the direction of the light in the reading/working room, 189 (59.43%) participants using LED light reported that the light was positioned above their head, 62 (19.50%) indicated it was behind them, and 67 (21.07%) stated it was in front of them. Similarly, among those using fluorescent light, 26 (56.52%) had the light above their head, 9 (19.57%) had it behind them, and 11 (23.91%) had it in front of them. (**Figure 2**)

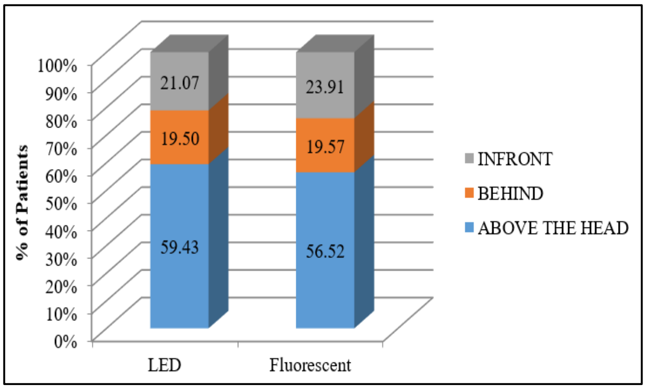

Figure 2: Showing the lighting positions

In terms of the background wall colour in the reading/working room, 12 (3.77%) participants using LED light had a dark-coloured wall, while 306 (96.23%) had a light-coloured wall. Among those using fluorescent light, 10 (21.74%) had a dark-coloured wall, and 36 (78.26%) had a light-coloured wall. This difference was statistically significant, with a p-value of <0.001. (**Table 4**)

Among LED users, 202 (63.52%) preferred reading or working during the day, while 116 (36.48%) favoured night time. Similarly, for those using fluorescent light, 27 (58.7%) preferred daytime, with 19 (41.3%) choosing to work or read at night.

Reading close to bedtime had no effect on sleep quality for 157 (49.37%) LED users, while 161 (50.63%) reported that it impacted their sleep. Similarly, 26 (56.52%) fluorescent light users experienced no effect, whereas 20 (43.48%) noticed disturbed sleep which was not significant. (**Figure 3**)

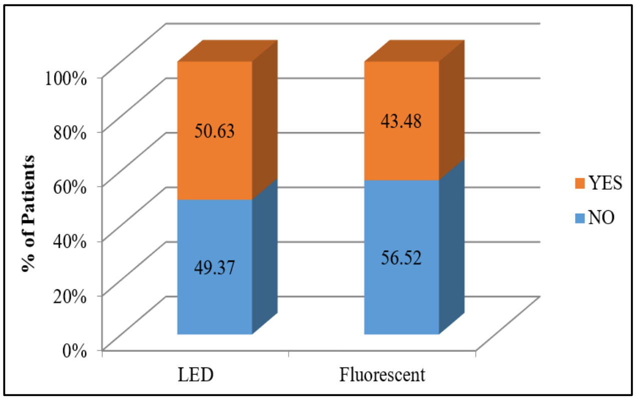

Figure 3: Shows the impact of lighting on sleep quality

Among users of LED lighting, 208 individuals (65.41%) reported no eye irritation, whereas 110 individuals (34.59%) experienced. In contrast, among fluorescent light users, 26 individuals (56.52%) reported no eye irritation, and 20 individuals (43.48%) experienced it. (**Figure 4**)

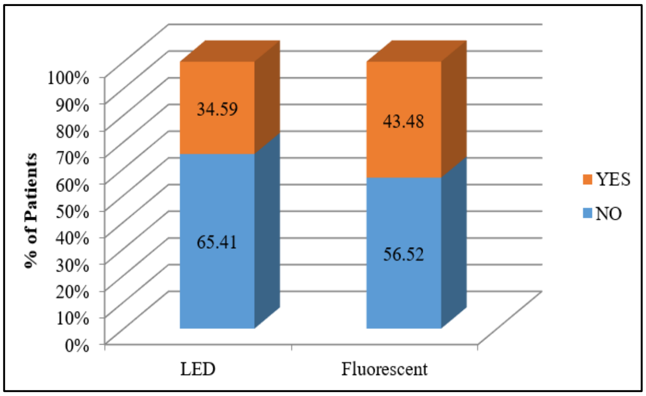

Figure 4: Showing effect of lighting on eye irritation

In terms of lacrimation, 241 LED users (75.79%) did not encounter this symptom, whereas 77 (24.21%) did. For fluorescent light users, 34 (73.91%) did not experience eye watering, while 12 (26.09%) did. (**Figure 5**)

For those using LED lighting, 252 individuals (79.25%) reported no burning sensation in their eyes, whereas 66 individuals (20.75%) did experience it. In comparison, among fluorescent light users, 41 individuals (89.13%) did not report a burning sensation, and 5 individuals (10.87%) did.

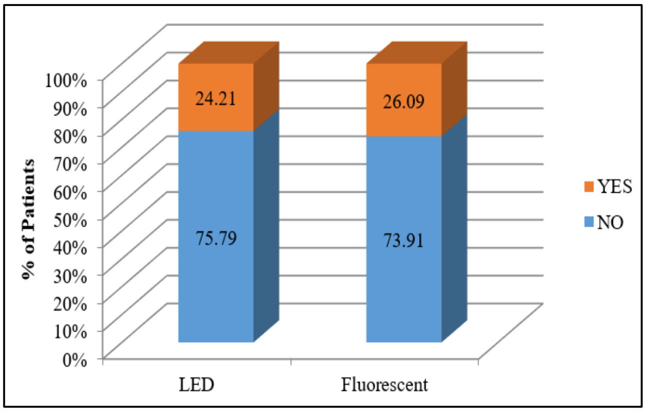

Figure 5: Showing prevalence of lacrimation

Among those exposed to LED lights, 102 (32.08%) did not feel fatigued, but 216 (67.92%) did. In contrast, 11 users of fluorescent lighting (23.91%) reported no exhaustion or sleepiness, while 35 (76.09%) did. (**Figure 6**)

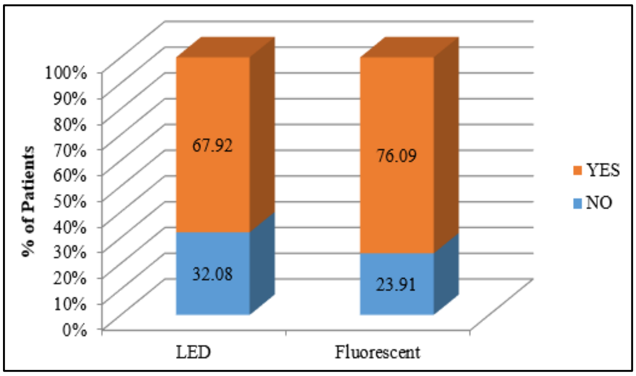

Figure 6: Showing effects of tiredness under different lighting conditions

A total of 100(31.45%) users of LED lighting reported experiencing headaches, while 218 users (68.55%) did not. For fluorescent lighting, 21 users (45.65%) experienced headaches, and 25 users (54.35%) did not. The statistical analysis revealed a significant difference between the two groups, with a p-value of 0.046. (**Table 5**)

Regarding blurring of vision, 60 LED users (18.87%) reported this symptom, while 258 (81.13%) did not. For fluorescent light users, 8 individuals (17.39%) experienced blurring of vision, and 38 individuals (82.61%) did not.

Among those who experienced symptoms, 43 participants (11.81%) had symptoms lasting 1 month, with 38 (11.95%) under LED lighting and 5 (10.87%) under fluorescent. A smaller group of 23 participants (6.32%) reported symptoms for 2 months, of which 18 (5.66%) were under LED and 5 (10.87%) under fluorescent lighting. Lastly, 138 participants (37.91%) experienced symptoms for 3 months or more, with 122 (38.36%) under LED lighting and 16 (34.78%) under fluorescent lighting.

Regarding the use of special glasses, 63 (17.31%) reported using anti-glare glasses or screens, with 54 (16.98%) working under LED lighting and 9 (19.57%) under fluorescent. Another 77 participants (21.15%) used blue light filter glasses, with 67 (21.07%) under LED and 10 (21.74%) under fluorescent lighting. Additionally, 30 (8.24%) participants relied on tinted glasses, with 26 (8.18%) exposed to LED lighting and 4 (8.7%) to fluorescent. (**Figure 7**)

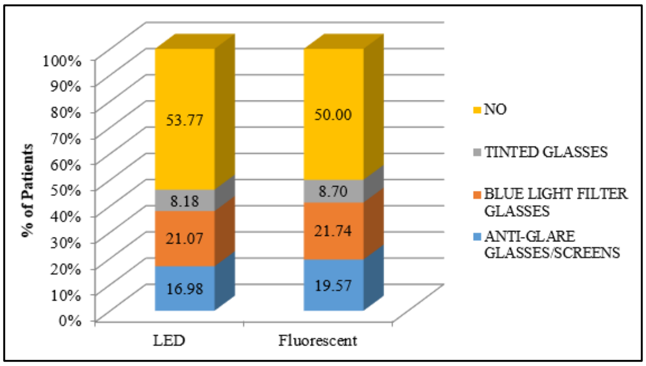

Figure 7: Showing use of specialized glasses among participants

Out of 284 (78.02%) participants, 244 (76.73%) worked under LED lighting and 40 (86.96%) under fluorescent lighting had no history of dry eye symptoms. Among the 80 participants (21.98%) with the history of dry eye, 74 (23.27%) were under LED lighting and 6 (13.04%) under fluorescent lighting. The p-value was 0.048, indicating a statistically significant difference. (**Table 6**)

Table 1: Distribution of respondents by age group

Age groups			**Total**		
	LED	**Fluorescent**		**p value**	**Significance**
14-20	22(6.92)	6(13.04)	28(7.69)	0.044	Significant
21-30	201(63.21)	33(71.74)	234(64.29)		
31-40	45(14.15)	5(10.87)	50(13.74)		
41-50	50(15.72)	2(4.35)	52(14.29)		
Total	318(100)	46(100)	364(100)		

Table 2: Shows the comparison of environmental conditions under different lighting

Environmental conditions				Total		
		LED	Fluorescent		p value	Significance
	AC Room	242(76.1)	24(52.17)	266(73.08)	0.001	Significant
	NON- AC Room	76(23.9)	22(47.83)	98(26.92)		
Total		318(100)	46(100)	364(100)		

Table 3: Duration of comfortable reading or working under different lighting conditions

Duration of comfortable reading or working				Total		
		LED	Fluorescent		p Value	Significance
	30 Mins	51(16.04)	5(10.87)	56(15.38)	0.014	Significant
	1 Hour	70(22.01)	20(43.48)	90(24.73)		
	2 Hours	75(23.58)	10(21.74)	85(23.35)		
	>2 Hours	122(38.36)	11(23.91)	133(36.54)		
Total		318(100)	46(100)	364(100)		

Table 4: Showing the distribution of wall background colour in participants

Wall background Colour				Total		
		LED	Fluorescent		p Value	Significance
	Dark	12(3.77)	10(21.74)	22(6.04)	<0.001	Significant
	Light	306(96.23)	36(78.26)	342(93.96)		
Total		318(100)	46(100)	364(100)		

Table 5: Association between lighting conditions and headache frequency

				Total		
		LED	Fluorescent		p Value	Significance
	No	218(68.55)	25(54.35)	243(66.76)	0.046	Significant
	Yes	100(31.45)	21(45.65)	121(33.24)		
Total		318(100)	46(100)	364(100)		

Table 6: Showing history of dry eye or any treatment for the same

				Total		
		LED	Fluorescent		p Value	Significance
	No	244(76.73)	40(86.96)	284(78.02)	0.048	Significant
	Yes	74(23.27)	6(13.04)	80(21.98)		
Total		318(100)	46(100)	364(100)		

5. Discussion

In this survey, the majority of participants (318) used LED illumination and only 46 used fluorescent lighting, indicating a shift toward LED technology in household and professional settings. The extensive use of LED especially among students and professionals is most likely due to its energy efficiency, longer lifespan, and greater lighting quality.[3]

According to Walls HL et al., fluorescent lighting emits ultraviolet (UV) radiation which poses vision related problems. Prolonged UV exposure can lead to phototoxic damage, raising the incidence of cataracts. Given these issues, switching to LED lighting provides a safer and more sustainable long-term solution, reducing potential eye health risks while retaining efficiency and visual comfort.[6]

Interestingly, in our study, the LED light users were predominantly in the higher age group (31–50 years) compared to fluorescent light users, with a statistically significant difference (p = 0.044). This aligns with findings by Algvere et al., who demonstrated that as the eyes age, their ability to filter blue light and adapt to brightness changes diminishes. This decline increases the vulnerability of retinal cells to oxidative stress, particularly from blue light, which is more intense in LED lights than in fluorescent ones. Consequently, older adults are at a greater risk of experiencing discomfort, eye strain, and potentially accelerated macular degeneration due to prolonged exposure to LED lighting.[7]

A study by Tosini et al. showed that blue light at night suppresses melatonin production, delaying sleep onset and disrupting sleep patterns. It can shift circadian rhythms, making it harder to fall asleep and reducing sleep duration and quality. This effect is due to the absorption of blue light by intrinsically photosensitive retinal ganglion cells (ipRGCs), which regulate circadian rhythms and melatonin levels.[8] In our study also, we found that individuals using LED (50.63%) experienced more sleep disturbances than in the fluorescent light group (43.48%).

In this study, the incidence of headaches, eye watering, and irritation was higher among participants using fluorescent lighting compared to LED users. Notably, 45.65% of participants in the fluorescent group reported experiencing headaches, with a statistically significant difference (p = 0.046). Silvani et al. noted that fluorescent lights flicker at high frequencies, which, while often imperceptible, can still trigger symptoms such as eyestrain, watering, and irritation.[9] According to Digre et al., the blue-green wavelengths emitted by many fluorescent lights are also strongly associated with photophobia and can exacerbate headaches. Moreover, glare from reflective surfaces can further impair visibility and increase discomfort.[10]

Studies by Ouyang et al. and Yamaguchi et al. have shown that long-term exposure to blue light leads to oxidative damage and apoptosis in the cornea. Excessive reactive oxygen species (ROS) not only impair mitochondrial function but also trigger the production of inflammatory cytokines and recruit macrophages. This activates the NLRP3 inflammasome, which processes and releases active interleukin (IL)-1. IL-1 further stimulates IL-6 secretion via the P38 and JNK signaling pathways. This inflammatory cascade contributes to dry eye disease by reducing tear and mucin production, destabilizing the tear film, increasing tear evaporation, and creating a hyperosmotic environment on the ocular surface.[11,12] In our study, we observed a significantly higher incidence of dry eye symptoms in the LED lighting group (23.27%) compared to the fluorescent group (13.04%), with a statistically significant p-value of 0.048. Furthermore, we found a strong association between dry eye symptoms and the experience of burning sensations and irritation in the presence of LED lighting compared to the other group, with the p-value less than 0.001.

Our study found that participants under LED lighting experienced significantly greater comfort during extended periods of reading and work (>2 hours: 38.36% vs. 23.91%, p = 0.014), highlighting its suitability for tasks requiring sustained focus. This is consistent with findings by Kazemi et al., who demonstrated that LED lighting, particularly with a color temperature of 6500 K, significantly enhances task performance, alertness, and visual comfort compared to compact and warm fluorescent lamps. Additionally, subjective assessments of visual comfort and preference also favored LED lighting, with participants reporting it as more comfortable and better suited for office tasks.[13]

In our study, we found that 76.09% of participants exposed to fluorescent lighting reported feeling more tired or sleepy, compared to 67.92% of those under LED lighting. This highlights the significant impact that different lighting conditions can have on perceived fatigue and alertness levels among individuals. According to the study by Viola et al., participants exposed to fluorescent white light (4000 K) reported increased daytime sleepiness as measured by the Karolinska Sleepiness Scale (KSS). In contrast, those under blue-enriched light (17000 K) exhibited significantly lower levels of sleepiness (p = 0.0004). The study indicated that exposure to fluorescent light was associated with greater mental strain, as well as lower levels of alertness and performance, ultimately contributing to increased daytime fatigue.[14]

At the Fifth Meeting of the Conference of the Parties to the Minamata Convention (COP-5), organized by the United Nations Environment Programme (UNEP), held in Geneva on November 4, 2023, over 800 delegates adopted 23 crucial decisions aimed at reducing mercury pollution. Among the most significant was the decision to implement a global phase-out of fluorescent lamps by 2025, due to the health and environmental risks posed by their mercury content. This transition to mercury-free alternatives, such as LED lighting, is expected to greatly reduce both pollution and energy consumption, marking a major step forward in global environmental protection efforts.[15]

6. Limitations

The shorter duration of this study might not capture the long-term effects of prolonged exposure to different lighting types. The outcomes of this study may have been impacted by the lack of strict control over environmental conditions, especially screen usage. Regardless of the lighting, eye strain may be caused by differences in screen exposure duration, display settings, screen brightness and different types of devices (computers, tablets, cell phones, etc.). To more accurately evaluate how screen exposure interacts with lighting, future research should think about standardizing screen exposure or including it as a variable. Furthermore, the study did not account for variations in the power of wattage among the different lighting types, which could also impact the findings.

7. Conclusion

As lighting technologies continue to evolve, understanding their impact on visual comfort and eye health becomes increasingly crucial. Both LED and fluorescent lights have their own advantages and disadvantages, with LEDs offering enhanced energy efficiency and reduced glare, while fluorescent lights may lead to flickering and visual discomfort for some users. In our study, the limited number of fluorescent users prevents us from drawing definitive conclusions about the effects of fluorescent lighting on individuals. However, our findings indicate that blue light emitted by LEDs can negatively affect the tear film, retina, and contribute to visual discomfort. Additionally, participants exposed to fluorescent lighting reported increased sleepiness, as well as sensations of burning and irritation in the eyes. These observations underscore the need for further research to explore the comprehensive effects of different lighting types on eye health.

8. Source of Funding

None.

9. Conflicts of Interest

Nil.

10. Ethical

Ethical No.: IEC/VMMCH/2024/APR/91.

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