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The Relationship of Long-Time Exposure to Blue Light Obtained from Laptop on the Sleep Quality of Students of the Faculty of Medicine, Indonesian Christian University

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ABSTRACT

Blue light has an important role in life, physiological functions, and visual processes, including color perception. Blue light is found in nature as natural light and also artificial (non-natural) light. The development of computer-based communication tools increases the possibility of seeing a screen that emits light for a long time. Today's screens on communication devices mostly use LED (Light Emitting Diode) technology; we can see this on smartphones, computer monitors, and TVs. Exposure to blue light at night will result in a reduction in the hormone that regulates circadian rhythm, resulting in decreased sleep quality. Prolonged exposure will cause visual fatigue and severe near sightedness. Symptoms that arise due to long exposure such as diplopia and inability to concentrate affect the learning process and work efficiency. Direct exposure can cause damage to the cornea, lens, and retina. because blue light increases the production of reactive oxidative species (ROS). Some experimental evidence shows that blue light exposure affects physiological functions and is useful for improving circadian rhythm and sleep quality. However, blue light can also cause photoreceptor damage. Therefore it is necessary to minimize the detrimental consequences of blue light exposure. This study aims to determine the relationship between long exposure to blue light from a laptop and sleep quality. The study method was cross-sectional; the respondents comprised the entire Faculty of Medicine, Indonesian Christian University student population. Data were collected using a Google Form questionnaire. Univariate analysis will provide an overview of demographics, sleep quality, and duration of exposure to blue light from the respondents' laptop use. Bivariate analysis for the relationship between long exposure to blue light from laptop use and sleep quality of respondents, using a chi-square test and measuring the relationship with Odd Ratio (OR).

Keywords: laptop, blue light, sleep

INTRODUCTION

Blue light is important because it triggers physiological responses and is important for visual processes, including color perception. Blue light is used to induce physiological rest. Memory, alertness, learning ability, and cognitive performance work much better under blue light, but it can also suppress melatonin secretion. The current development of computer-based communication tools increases the possibility of us looking at screens that emit light for long periods. [1]

The screens on the communication devices we use now mostly use LED (Light Emitting

Diode) technology; we can see this on smartphones, computer monitors, and TVs. Prolonged exposure to blue light can cause visual fatigue and poor near sightedness. Symptoms such as diplopia and inability to concentrate can affect learning and work efficiency. Direct exposure to blue light can cause damage to the cornea, lens, and retina because the nature of blue light increases the production of reactive oxidative species (ROS). [2]

Some experimental evidence suggests that exposure to blue light can influence many physiological functions and can be used to improve circadian rhythm and sleep. However, blue light can also cause photoreceptor damage. Therefore, it is important to minimize the harm caused by blue light. In various studies, it has been proven that exposure to blue light can cause various disorders; blue light exposure therapy can be used to relieve the symptoms of Seasonal Affective Disorder (SAD). [3]

Based on KOMINFO data in 2014, the level of gadget use in Indonesia is very high. The survey found that 98 percent of children and teenagers in Indonesia know about the Internet, and 79.5 percent are Internet users. Children who frequently use technology often ignore their surroundings. They prefer to face the sophisticated technology they have rather than play with their peers on the playground or in their surrounding environment. So, social communication between children and the environment is decreasing. [4]

Using a laptop or staring at a laptop screen for more than 2 hours without resting your eyes for 15 minutes can cause symptoms of Computer Vision Syndrome. The American Optometric Association (AOA) describes computer vision syndrome as eye problems related to close work that a person experiences while using or associated with computer use, such as eye strain, headaches, and blurred vision (for near vision). and/or far away), dry and irritated eyes, decreased ability to focus the eyes, neck pain, back area pain, and light sensitivity. [5]

In Indonesia, not many research has discussed the effects of blue light exposure on health. Considering the large number of users of modern communication devices in Indonesia, such as smartphones, tablets, laptops, and computers, researchers are interested in determining whether communication devices among Indonesian people can affect sleep quality. In addition, the current pandemic means that people have to spend time at home, increasing the time they use gadgets for entertainment. The problem formulation in this research is "Can using a laptop communication device that emits blue light affects sleep quality?" the research aims to determine the relationship between the duration of exposure to blue light from a laptop and sleep quality. The specific objectives of this research of students faculty of medicine, Indonesian Christian University are a) to determine the description of sleep quality, b) to determine the duration of exposure to blue light from using laptops and c) to determine the relationship between the duration of exposure to blue light from laptop use and the sleep quality.

LITERATURE REVIEW

Sleep is an actively regulated process and is significantly modulated by homeostatic influences that accumulate during periods of continuous wakefulness and dissipate during sleep and by circadian effects tied to the 24-hour day. [6] Each individual's sleep needs vary. Age is the factor that most influences a person's sleep needs. Young adults usually need 7 - 9 hours of sleep, while babies can spend 14 - 17 hours a day sleeping. Apart from age, several other factors that can also influence a person's sleep needs are the presence or absence of physical illness, lifestyle, environment, and activities carried out when the individual is awake. [7]

The human wake-sleep cycle is regulated by a reciprocal relationship between 3 (three) parts of the nervous system, namely the consciousness system by the Ascending Reticular Activating System (ARAS), the slow wave sleep center in the hypothalamus, which contains neurons that induce sleep, and the paradoxical sleep center in the trunk. The brain becomes active during Rapid Eye Movement (REM) sleep. Extensive subcortical networks and pathways support cortical activation required to maintain consciousness. As the center of consciousness, ARAS can carry out its function because there is the interaction of various neurotransmitters such as norepinephrine from the locus coeruleus, serotonin from the raphe nucleus, histamine from the tuberomammillary nucleus, dopamine from the ventral tegmentum area in the midbrain, acetylcholine from the pedunculopontine tegmentum and laterodorsal tegmentum and orexin from the perfornical. However, serotonin is believed to have a more important function because research shows that experimental animals given drugs that block serotonin formation will cause difficulty sleeping for the next few days. Sepapterin reductase deficiency (serotonin synthesis enzyme) can also cause irregular and ultradian sleep-wake cycles (shorter than 24 hours). [8]

Circadian rhythm refers to the daily physiology of the human body. Circadian rhythms regulate many human body activities, such as the sleep-wake cycle, nutritional needs, regulating body temperature, heart rate, muscle tone, and hormone secretion. This process occurs over 24 hours and is driven by the physiological clock in the brain. The suprachiasmatic nucleus (SCN), located anterior to the hypothalamus, is the brain's area acting as a biological clock. The SCN can act as a biological clock because light stimulates it. Incoming light will be received by intrinsically photosensitive retinal ganglion cells (ipGRC), light receptors in the retina that have melanopsin photopigments sensitive to dark-light conditions.

Sleep is important when the body releases many hormones that influence growth and energy and control metabolic and endocrine functions. When exposed to light, the SCN releases the hormone cortisol and inhibits the release of the hormone melatonin so that the individual is awake. In contrast, when it is dark, the SCN will release humoral factors that modulate the activation of cells in the pineal gland to produce the hormone melatonin, making the individual drowsy and sleepy. [9]

There are two stages of sleep, namely, Non-Rapid Eye Movement (NREM) sleep and Rapid Eye Movement (REM) sleep. NREM sleep is divided into stages 1, 2, 3, and 4, followed by the REM phase. The NREM and REM phases occur alternately, around 4-5 cycles in one night. [10]

The four NREM sleep stages are associated with different brain activity and physiology. In this phase, eyeball movements do not occur quickly; the body's physiological activity will decrease, such as a decrease in respiratory rate, heart rate, and blood pressure; and if examined using electroencephalography (EEG), slower waves with a larger amplitude will be found. The NREM phase is divided into four stages, namely:

NREM stage 1 sleep has a transitional role in the sleep cycle. It is the sleepy stage, where there is a transition between awake and falling asleep. This stage usually lasts 1 to 7 minutes in the initial cycle, which is 2 to 5 percent of total sleep, and is easily disturbed by disturbing sounds. Brain activity on the EEG in stage 1 transitions from wakefulness (characterized by rhythmic alpha waves) to low-voltage mixed-frequency waves. In stage 1, many people often experience muscle shocks or jerks, usually felt as a falling sensation.

In stage 2, light sleep occurs, and the eyes stop moving. Stage 2 sleep lasts approximately 10 to 25 minutes in the initial cycle and lengthens with each successive cycle, accounting for 45 to 55 percent of the total sleep episode. A person in stage 2 sleep needs more intense stimulation than in stage 1 to wake up. Brain waves become slower with suddenly faster waves known as "speed spindles." At this stage, there is also a decrease in heart rate and body temperature. It is thought that spindle speed is important for memory consolidation.

This 3 stage is deeper than the previous stage. At this stage, the individual will find it difficult to wake up, but if they wake up, they will not immediately adjust and will feel confused for several minutes. Stage 3 only lasts a few minutes and covers about 3 to 8 percent of sleep. EEG shows increased high voltage and slow wave activity.

The final NREM stage is stage 4, which lasts about 20 to 40 minutes in the first cycle and accounts for 10 to 15 percent of sleep time. This stage is the deepest stage of sleep. An increase in high voltage, slow wave activity on the EEG characterizes this stage. [11]

Each person's need for sleep is different, depending on the individual's habits throughout life, work activities, age, health condition, and so on. Adults need 6-9 hours of sleep; elderly people need 5-8 hours to maintain health. [12] Sleeping less than necessary can affect the synthesis of proteins, which play a role in repairing damaged cells; their synthesis decreases. Insufficient sleep causes fatigue, increased stress and anxiety, and lack of concentration. A person who does not get enough REM sleep tends to be hyperactive the next day, less able to control himself and his emotions, and has an increased appetite. Not getting enough NREM sleep will make your physical condition less enthusiastic the next day. Whether a person can sleep is influenced by several factors, including the environment, health status, psychological stress, diet, lifestyle, and medication. [13]

Measuring sleep quality uses The Pittsburgh Sleep Quality Index (PSQI) method. PSQI is an effective instrument for measuring adult sleep quality and sleep patterns. PSQI was developed to measure and differentiate individuals with good and poor sleep quality. Determining good and bad sleep quality is seen by measuring seven scores as assessment parameters: sleep quality, sleep latency, sleep duration, sleep habits, sleep disorders, use of sleeping pills (excessive), and daytime dysfunction during the last month. A global score of 0-5 is considered good sleep quality, whereas a global score of>5 is considered poor sleep disorders. [14]

The light that humans or the visible spectrum can see has a 400-700nm wavelength. The light usually emitted by communication devices is part of the light that can be seen by humans or the visible light spectrum, whose wavelength is between 400-700nm. The human eye will see the colors in this spectrum, such as red, orange, yellow, green, blue, indigo, and violet, combining all these colors with the same intensity visible as white. Blue light is part of this color spectrum with a 430-480nm wavelength. [15]

Blue light can come from a variety of sources. The biggest source of blue light radiation is sunlight. Apart from that, blue light is often found in our daily lives, especially in electronic devices such as smartphones, televisions, and computer screens; LED lights and neon lights can also be a source of blue light radiation. Exposure to blue light provided by these devices is indeed low, but long and repeated exposure times can cause undesirable effects from blue light. [1]

The human eye can perceive light waves based on their wavelength; they can be divided into 3, namely long (red), medium (green), and short (blue). [1] Like other electromagnetic waves, the shorter the wavelength, the more energy the wave has, and the higher the radiation of this energy can cause abnormalities in the human body. [16]

Blue light can have negative effects if exposure to blue light is at a high intensity or for a long exposure time. [1] The impact of blue light on humans can generally be divided into 2, namely visual and non-visual effects. [1; 2]

The shape of the cornea and lens physiologically acts as the eye's defense against incoming light. The cornea can ward off radiation from UV rays (Ultra Violet), which have a wavelength below 300nm, while the lens can ward off UV radiation, which has a wavelength between 300-400nm. The eyes also have additional retinal pigmental epithelial (RPE) protection, which can absorb blue light radiation and provide nutrition to photoreceptor cells. Blue light can affect the cornea, lens, and retina; epidemiologically, it can be associated with refractive disorders. [1; 2]

Exposure to blue light on the cornea can increase reactive oxygen species (ROS) in corneal epithelial cells, which then causes an oxidative reaction, resulting in inflammation damage and necrosis of corneal epithelial cells. Besides that, blue light, especially those approaching ultraviolet wavelengths, can inhibit the mitotic process of corneal epithelial cells, thereby disrupting the epithelial cell microvilli, whose function is to stabilize tears. Ultimately, it can cause dry eyes, which is often experienced when using gadgets or other electronic screen devices for too long. [2]

Cataracts on the lens can also occur if exposed to excessive blue light. The lens has many proteins and enzymes that absorb light with short wavelengths. In the lens, these proteins and enzymes form a yellow pigment, which ultimately inhibits the destructive effects of blue light. However, if exposure exceeds the protective limit, the yellow pigment accumulating on the lens can cause clouding, leading to cataract formation. Besides that, blue light can also cause an increase in ROS production in the mitochondria of lens epithelial cells, which can also cause cataract formation. [1; 2]

If blue light reaches the retina, it will cause activation of microglial cells, which will then migrate and phagocyte the outer nuclear layer of the retina, resulting in cell death. This phenomenon is often found in people who experience Age-Related Macular Degeneration (AMRD). Apart from that, it can also cause damage to cone cells, which stimulates the emergence of macrophage cells and the activation of microglia. Furthermore, this will cause edema and disruption of the blood-retinal barrier function due to the accumulation of pro-inflammatory factors. As in the cornea and lens, blue light that reaches the retina will also cause an oxidative reaction due to increased ROS production; this causes damage and necrosis to photoreceptor cells and retinal pigment. [2]

In a recent study, there was a relationship between refractive disorders (myopia and hyperopia) in school-aged children and increased use of gadgets. Although pathophysiologically there is no definite correlation between gadget use and refractive disorders, epidemiological data shows that the rate of refractive disorders, especially myopia, is high in populations that use gadgets a lot. [17]

Non-Visual Effects - The role of light is not only for the body's visual function (vision) but also for many non-visual functions. The greatest function is as a regulator of circadian rhythm. Circadian rhythm is the human body's biological rhythm, which regulates body temperature, endocrine system, cardiovascular, sleep, alertness, immune system, and cognitive abilities. Circadian rhythms are regulated by the anterior hypothalamus's suprachiasmatic nucleus (SCN). [24]

Human circadian rhythms interact with light and dark conditions by releasing melatonin and serotonin hormones. Melatonin, also known as the sleep hormone, is secreted by the pineal gland. It usually increases in conditions without light, reaches its peak early in the morning, and falls slowly until just before sunrise. Melatonin is secreted into the bloodstream and then delivered to the cerebrospinal fluid by binding to receptors in the SCN. There are 2 (two) receptors for melatonin, namely MT1 and MT2, and both are G protein-coupled receptors (GPCR). MT1 is an inhibitor of adenylyl cyclase, which causes drowsiness, while MT2 is a phosphoinositide hydrolysis stimulator, which may function to synchronize the light-dark cycle. [26]

The increase in melatonin is then followed by an increase in cortisol (stress hormone), which improves the immune system and controls blood pressure. Serotonin, as a mood hormone, is also released during sleep. However, its amount decreases by 10% every decade, and serotonin is also believed to have a more important role in the sleep-wake process, which is the basis for many studies linking serotonin and the occurrence of circadian system neurodegenerative disorders. [18]

MATERIALS & METHODS

The research design is cross-sectional. This research was carried out by observing the cause and effect variables in the research object in a certain period. This research was conducted at the Faculty of Medicine, Indonesian Christian University, Jakarta. This research was conducted from September 2021 to October 2021 and included research preparation and reporting of research results. The population of this study were students from the Faculty of Medicine, Indonesian Christian University. The samples were filtered through inclusion and exclusion criteria. The sampling technique is total. The research instrument used was a questionnaire on the length of use of communication tools that emit blue light. This questionnaire aims to determine how long the respondent was exposed to blue light in hours. The questionnaire data was then added to determine the total duration of the respondent's exposure to blue light. The questionnaire has been tested for validity and reliability using the IBM Statistics 25 application. The validity test results show that the three components of the question are valid because the calculated r-value is greater than the r-table value with a significance level of 0.355. This validity test's range of calculated r values is 0.376 - 0.809. The reliability test results showed that the question components are valid and reliable with a Cronbach Alpha coefficient value of 0.406, so the questionnaire can be used as a valid research instrument. The next instrument is the PSQI (Pittsburgh Sleep Quality Index) Questionnaire. PSQI is a questionnaire used to measure adults' quality and sleep patterns, which can be categorized as good or bad. This questionnaire contains nine questions that measure seven components: subjective Sleep Quality, sleep latency, sleep duration, sleep efficiency, sleep disorders, use of sleeping pills, and daytime activity disorders. Each question has a score of 0 – 3, with 0 being the sign of no disturbance and 3 being the worst disturbance. The results of each question are then summed up as a global score with a maximum number of 21. KT is categorized as good if the global score is 0 – 5, while bad if the global score is 6 – 21.14. According to Spira et al in English version the PSQI questionnaire has undergone a reliability test for this version with a Cronbach Alpha coefficient value of 0.69 and $\alpha = 0.63$ according to Sukmawati et al. for the Indonesian version. The results of the validity test carried out by Ratnasari on 18 PSQI questions showed that the calculated r value was greater than the r table, with a significance of 0.361, while the calculated r value was 0.365 – 0.733 so that the PSQI questionnaire could be used as a valid research instrument. The data processing processes carried out in this research are editing, tabulating, cleaning, scoring, and analyzing. This study used univariate and bivariate analysis. Univariate analysis was used to see the length of use of communication devices emitting blue light (laptops) and the respondents' sleep quality. Bivariate analysis was used to find the relationship between the independent variable (length of use of communication devices that emit blue light) and the dependent variable (sleep quality). If the p value $\leq \alpha$ (α=0.01), then it can be said that there is a significant relationship between the length of use of communication tools that emit blue light and sleep quality. Conversely, if $p > \alpha$, it can be interpreted that there is no significant relationship between the time of use of communication tools emitting blue light and sleep quality. Hypothesis testing uses the Pearson correlation coefficient test to determine if the data distribution is normal and the Spearman rank coefficient test to determine if the data distribution is not normal.

RESULT

This research data was obtained from the relationship between the duration of exposure to blue light from laptop use and the sleep quality of medical students at the

Faculty of Medicine, Indonesian Christian University, which was shared via personal chat. The number of research samples obtained was 142 respondents.

Table 1. Frequency Distribution of Respondents' Age

Age	Frequency	Percentage (%)
17	1	0.7
18	1	0.7
19	28	19.7
20	82	57.7
21	26	18.3
22	4	2.8
Total	142	100

Table 1 shows the age distribution of respondents who participated in the research. Based on the table, the most common respondents were 20 years old, with 82 respondents (57.1%), followed by 19 years old, with 28 respondents (19.7%). It is in line with research conducted by Reni at CV Nusantara Karang Anyar, which found that the average age of respondents was 20-30 years, with a total of 23 respondents (79.31%). [19] However, this research differs from Aninsa's, with 75 research subjects from 300 students at SMA Al Falah Ketintang Surabaya, most of whom were 16 years old, 35 respondents (46.67%). [28] It could be due to different habits and behavioral factors in each person.

Table 2. Frequency Distribution of Respondents' Gender

Genders	Frequency	Percentage (%)
Female	102	71,8
Male	40	28,2

Table 2 shows the gender frequency distribution of respondents who participated in the research. Most respondents were female, with 102 (71.8%), while there were 40 male respondents (28.2%).

It aligns with research conducted by Fransiska at the Faculty of Medicine, University of North Sumatra, which found that 62 students (62%) were female respondents. However, this research is different from that carried out by Annisa, with 75 research subjects from a total population of 300 students at SMA Al Falah Ketintang Surabaya, most of whom were found to be male, 39 respondents (52%). [20]

Table 3. Respondents' sleep quality

Sleep Quality	Frequency	Percentage (%)
Good	30	21
Bad	112	79

Table 3 shows that the sleep quality of Indonesian Christian University Faculty of Medicine students was mostly poor, namely 112 (79%) respondents, while those with good sleep quality were 30 (21%) respondents.

This research is similar to Umi Romayanti at SMKN 1 Terbanggi Besar Lampung, namely that most respondents had poor sleep quality. Namely 77 people (64.7%), and research conducted by Armaya Jarmi at SMP Negeri 1 Banda Aceh also showed poor sleep quality among 49 people (53.3%). Several factors influence the quantity and quality of sleep. Physiological and environmental factors can change the quality and quantity of sleep, including physical illness, medication, lifestyle, emotional stress, the environment, physical exercise, fatigue, and food and calorie intake. Apart from the factors above, excessive use of gadgets such as laptops can interfere with thinking, concentration, and work and affect daily life by disrupting sleep quality. [21]

Table 4. Duration of use of communication devices that emit blue light (laptops)

Long Exposure to Laptop Blue Light	Frequency	Percentage (%)
< 5 hours	21	14.8
5-6 hours	38	26.8
6-7 hours	35	24.6
>7 hours	48	33.8
Total	142	100

Table 4 above shows the length of time the respondents have used laptops. The results showed that 21 respondents (14.8%) used laptops for less than 5 hours, and 142 (33.8%) used laptops for more than 7 hours.
According to research conducted by Giatman M in 2020 during the COVID-19 pandemic, teaching and learning activities for school and college students were carried out online using laptop electronic devices (66.7%), and only 4.6% used electronic devices beyond cell phones and laptops. [22]

Bivariate Analysis

Long Exposure to Laptop Blue Light	Sleep Quality				Total		P-*value*
	Good		Bad				
	N	%	N	%	N	%	
>7 hours	10	7,04	38	26,76	48	33,80	
6-7 hours	5	3,52	30	21,13	35	24,65	
5-6 hours	7	4,93	31	21,83	38	26,76	0.189
	8	5,63	13	9,15	21	14,79	
Total	30	22	112	79	142	100	

This research used bivariate analysis to find the relationship between the independent variable (This research used bivariate analysis to find the relationship between the independent variable (length of use of communication devices that emit blue light/laptops) and the dependent variable (sleep quality). The results of the correlation test obtained a p-value. If the p-value is > 0.05, there is no significant correlation between the two variables in the correlation test. From these results, it can be concluded that there is no significant relationship between the independent variable (length of use of communication devices that emit blue light/laptops) and the dependent variable (sleep quality). [23]
The results of this study are in line with the results of research conducted by Brunborg et al. (2011); 816 samples were conducted on random Norwegian people aged 18-40 years, and the results showed that there was no relationship between the use of computers and smartphones before bed and disturbed sleep quality. [24] The results of this study are not in line with research conducted by Moh. Saifullah (2017) titled "The relationship between gadget use and sleep patterns among school children at UPT SDN Gadingrejo II Pasuruan," states that if gadget usage time increases, sleep pattern disturbances also increase. Some factors might cause this research to show no relationship between the length of use of communication devices that emit blue light/laptops and sleep quality because communication devices that emit blue light are laptops that are not used continuously, in contrast to gadgets that can be used more frequently, even to before going to bed as well as from differences in the ages of respondents in the population used. [25]

CONCLUSION

Based on research results, 79% of Indonesian Christian University Faculty of Medical students had poor sleep quality and 33.8% of the duration of exposure to blue light due to laptop use was more than 7 hours. Based on the results of this study, there was no relationship found between the duration of blue light exposure from laptop use and sleep quality (P value 0.189).
From the results of this research, it is recommended that educational institutions provide rest periods when exposed to long periods of blue light when using laptop instruments. Then, research needs to be done on other communication devices, such as TVs and cell phones, so that the total exposure to blue light in a day can be seen. Finally, it is recommended to reduce the use of laptops for recreational purposes, especially now, by resting your eyes for a moment.

Declaration by Authors

Ethical Approval: Approved

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