



The relationship between screen time and sleep quality in adolescents: a quantitative survey study

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Article Information	Abstract
Submitted July 07, 2025 Revised July 07, 2025 Accepted July 08, 2025	Background: The widespread use of digital devices among adolescents has led to increased screen time, especially during the COVID-19 pandemic. This study investigates the relationship between screen time duration and sleep quality, highlighting how excessive exposure disrupts adolescents' sleep patterns. Aim: This study aims to analyze the relationship between the duration of electronic device use (screen time) and sleep quality among adolescents using a quantitative approach. The primary focus of this research is to determine whether screen time serves as a significant predictor of sleep disturbances in adolescents. Method: A quantitative cross-sectional survey design was employed in this study. A total of 120 adolescent respondents (aged 13–18 years) were selected using purposive sampling. Data were collected through an online questionnaire consisting of two main instruments: a daily screen time log and the Pittsburgh Sleep Quality Index (PSQI). The data were analyzed using descriptive statistics, the Kolmogorov-Smirnov normality test, Pearson correlation, and simple linear regression. Result: The results indicated that the respondents' average screen time was 4.88 hours per day, with 80% scoring above 5 on the PSQI, indicating poor sleep quality. A strong and statistically significant positive correlation was found between screen time and sleep quality scores ($r = 0.775$; $p < 0.001$). Regression analysis showed that screen time accounted for 60.1% of the variance in sleep quality ($R^2 = 0.601$), and each additional hour of screen time increased the PSQI score by approximately 1.039 points. Conclusion: The findings have important implications for interventions and educational efforts directed at adolescents, parents, and educators to manage screen time wisely in order to preserve sleep quality. Furthermore, the results may serve as a foundation for digital health policies and the promotion of sleep hygiene in school and family environments.

INTRODUCTION

The advancement of digital technology in the era of the Fourth Industrial Revolution has significantly transformed human lifestyles, particularly among adolescents (Beattie et al., 2015; Carter et al., 2016; Przybylski & Weinstein, 2019). The use of electronic devices such as smartphones, computers, laptops, and tablets has become an integral part of adolescents' daily routines, whether for educational purposes, entertainment, or social interaction (Beattie et al., 2015; Twenge et al., 2019). With the increasing accessibility of the internet and the dominance of social media, adolescent screen time has surged dramatically, especially during the COVID-19 pandemic, which accelerated the shift to online-based activities (Damaiyanti, 2023; G et al., 2024).

This phenomenon has raised concerns about the long-term impacts of excessive screen use, particularly on sleep health a vital component in the cognitive and emotional development of adolescents (Carter et al., 2016; Lemola et al., 2015). High-quality sleep plays a crucial role in memory consolidation, emotional regulation, and physical and mental growth (Beattie et al., 2015; Walker, 2017). However, declining sleep

quality among adolescents has become a global issue, with prolonged screen time identified as one of its primary contributing factors (Carter et al., 2016; G et al., 2024; Twenge et al., 2019).

Several studies have indicated that screen time exceeding two hours per day can disrupt the body's natural sleep cycle and contribute to problems such as insomnia, shortened sleep duration, and chronic daytime fatigue (Carter et al., 2016; G et al., 2024; Lemola et al., 2015). Sleep disturbances in adolescents have also been linked to decreased academic performance, emotional instability, and increased risks of anxiety and depression (Beattie et al., 2015).

One of the biological mechanisms underlying this phenomenon is exposure to blue light emitted by electronic screens, which suppresses melatonin production the hormone responsible for regulating the circadian rhythm or the body's biological clock (Damaiyanti, 2023; G et al., 2024). Consequently, adolescents who use digital devices before bedtime are more likely to experience delayed sleep phase and disruptions to their natural sleep-wake cycle (Cain & Gradisar, 2010; Carter et al., 2016). Moreover, stimulating digital activities such as playing online games, browsing social media, or watching videos late at night further elevate brain activity, thereby prolonging sleep latency (Beattie et al., 2015; Lemola et al., 2015; Twenge et al., 2019).

Theoretically, this issue can be explained by the Time Displacement Theory, which posits that time spent on digital activities displaces time that could be allocated to other essential behaviors, such as sleep (Damaiyanti, 2023; G et al., 2024; Neuman, 1988). In this context, screen time not only directly reduces sleep duration but also affects sleep quality physiologically (Cain & Gradisar, 2010; Carter et al., 2016; Lemola et al., 2015). As a result, adolescents become one of the most vulnerable groups to sleep disturbances caused by excessive screen time, given their complex and transitional stage of biological and social development (Beattie et al., 2015; Damaiyanti, 2023).

Recent studies report that adolescents with excessive screen time are at a higher risk of experiencing sleep disturbances than those who maintain healthy screen habits (Carter et al., 2016; G et al., 2024; Twenge et al., 2017). Thus, a comprehensive and data-driven understanding of the relationship between screen time and sleep quality is essential to inform more effective preventive strategies and policy development (Beattie et al., 2015; Lemola et al., 2015). Such understanding is crucial not only for parents and educators but also for policymakers in the health and education sectors who must address the challenges posed by the digital lifestyles of adolescents in the modern era (Carter et al., 2016; Twenge et al., 2017).

Based on this background, the present study aims to analyze the relationship between screen time duration and sleep quality among adolescents using a quantitative, field-based survey approach (Damaiyanti, 2023; G et al., 2024; Lemola et al., 2015). By examining the correlation and predictive influence of screen time on sleep quality through valid and standardized instruments, this study is expected to contribute meaningfully to the development of educational interventions, screen time management strategies, and increased awareness of the importance of sleep quality among adolescents.

LITERATURE REVIEW

Theoretical Framework

Time Displacement Theory

The Time Displacement Theory, developed by Wilbur Schramm in 1961, posits that time is a limited resource, time spent on one activity inevitably displaces other potentially valuable activities (Kubey & Csikszentmihalyi, 2002; Neuman, 1988; Van den Bulck, 2004). In the context of media use, this theory explains that time allocated to digital screen consumption displaces time for essential activities such as sleep, studying, or social interaction (Hofferth, 2010; Przybylski & Weinstein, 2019).

Among adolescents, this phenomenon is particularly evident when high screen time through smartphones, tablets, or computers reduces both sleep duration and quality (Carter et al., 2016; Mireku et al., 2019; Twenge et al., 2017). Studies by Carter et al., (2016) and Mireku et al., (2019) support this theory by showing that increased screen time significantly correlates with decreased sleep duration and heightened sleep disturbances. Thus, Time Displacement Theory serves as a relevant theoretical basis for explaining the negative relationship between screen time and adolescent sleep quality, emphasizing how excessive digital engagement directly replaces essential rest time (Exelmans & Van den Bulck, 2016; Hale & Guan, 2015; Keles et al., 2020).

Circadian Rhythm Theory

The Circadian Rhythm Theory is a biological framework explaining how the human body operates on a 24-hour internal clock that regulates physiological functions, including sleep and wake cycles (Czeisler & Gooley, 2007; Foster et al., 2017; Touitou et al., 2016). Circadian rhythms are naturally influenced by environmental cues, especially light exposure, which acts as a zeitgeber (time-giver) to regulate hormone production such as melatonin critical for sleep initiation (Cajochen et al., 2011; Chang, 2014; Otsuka et al., 2021).

In the context of digital device use, blue light from screens at night disrupts circadian rhythms by suppressing melatonin secretion, causing delayed sleep onset, poor sleep quality, and even insomnia (Arora et

al., 2014; Touitou et al., 2016; Woods & Scott, 2016). Otsuka et al., (2021) found that nighttime digital device use significantly delays bedtime, prolongs sleep latency, and reduces overall sleep efficiency. Therefore, the circadian rhythm theory provides a strong biological foundation for understanding how screen time, particularly at night, disrupts natural sleep patterns and diminishes sleep quality in adolescents (Cajochen et al., 2011; Exelmans & Van den Bulck, 2016; Van den Bulck, 2004).

Screen Time Among Adolescents

The rapid advancement of digital technology has led to a significant increase in screen time among adolescents, making it an integral part of their daily lives (Beattie et al., 2015; Carter et al., 2016; Damaiyanti, 2023). On average, adolescents spend more than six hours per day engaging in screen-based activities, including watching television, playing games, and using social media (Hale & Guan, 2015; Mireku et al., 2019; Supriani et al., 2022). These activities are often carried out late into the night, disrupting natural sleep patterns and overall health (Damaiyanti et al., 2023; Mak et al., 2014).

Screen time should not be assessed solely based on duration but also on content type and timing of use (Carter et al., 2016; Damaiyanti et al., 2023). Activities such as gaming or social media usage before bedtime have a more detrimental effect on sleep quality compared to academic-related screen use (Beattie et al., 2015). Emotional and cognitive involvement in digital activities keeps the brain alert into the late hours, hampering the transition into sleep (Carter et al., 2016; Damaiyanti et al., 2023; Lemola et al., 2015).

Exposure to blue light emitted from electronic screens is one of the main causes of circadian rhythm disruption, as it suppresses melatonin production, the hormone that regulates sleep (Lemola et al., 2015). This hormonal suppression causes adolescents to feel more awake at night, despite their physiological need for rest (Beattie et al., 2015; Damaiyanti et al., 2023). Furthermore, the habit of bringing devices into bed worsens this issue by creating negative associations between the bed and digital stimulation (Carter et al., 2016; Lemola et al., 2015).

The use of electronic devices before bedtime can delay sleep onset due to the mental and emotional stimulation caused by digital content (Otsuka et al., 2021). Additionally, blue light exposure from screens inhibits melatonin secretion, prolonging sleep latency. As a result, adolescents may experience difficulty falling asleep and suffer from poor sleep quality (Mak et al., 2014; Mireku et al., 2019).

Research has shown that nighttime screen-based media use is associated with reduced sleep quality among adolescents, characterized by shorter sleep duration and increased daytime sleepiness (Hale & Guan, 2015; Supriani et al., 2022). Moreover, excessive screen time has been linked to sleep disorders such as insomnia and sleep fragmentation (Otsuka et al., 2021).

Sleep Quality in Adolescents

Sleep quality refers to the effectiveness and efficiency of sleep in providing physical and mental restoration and is associated with sleep duration, latency, efficiency, and the feeling of refreshment upon waking (Carter et al., 2016; Damaiyanti, 2023). Adolescents require between 8 to 10 hours of sleep per night, yet most do not meet this standard due to lifestyle and digital environmental (Beattie et al., 2015; Lemola et al., 2015). Poor sleep quality significantly impacts various aspects of adolescent development, including academic achievement and emotional well-being (Carter et al., 2016; Damaiyanti, 2023).

Insufficient or low-quality sleep causes concentration difficulties, decreased motivation to learn, and mood disturbances such as irritability and stress (Beattie et al., 2015; Lemola et al., 2015). In the long term, chronic sleep disturbances increase the risk of mental health disorders such as depression and anxiety (Carter et al., 2016; Damaiyanti et al., 2023). Sleep disruption also has physiological consequences, including weakened immune function and hormonal imbalances (Beattie et al., 2015; Lemola et al., 2015).

Various factors affect sleep quality, ranging from academic stress and caffeine intake to the use of digital devices before bedtime (Carter et al., 2016; Damaiyanti, 2023). Digital device use at night is a major contributing factor, not only due to circadian rhythm disruption but also due to overstimulation of the mind (Beattie et al., 2015; Lemola et al., 2015). Studies have shown that the habit of using gadgets in bed negatively impacts sleep effectiveness and increases nighttime awakenings (Carter et al., 2016).

Sleep quality is commonly measured using the Pittsburgh Sleep Quality Index (PSQI), which has been validated and widely used in sleep research (Damaiyanti, 2023; Lemola et al., 2015). A PSQI score above 5 is indicative of poor sleep and warrants further attention.

The Relationship Between Screen Time and Sleep Quality

Multiple studies have revealed a negative association between screen time and sleep quality: the longer the screen time, the poorer the adolescent's sleep quality (Hale & Guan, 2015; Keles et al., 2020; Siste et al., 2021). One of the primary mechanisms is the inhibition of melatonin production due to blue light exposure, which delays the onset of sleepiness (Cajochen et al., 2011; Chang, 2014; Touitou et al., 2016). Emotional engagement with digital content keeps the brain alert even when it is time to sleep, thereby delaying the transition to sleep (Arora et al., 2014; Exelmans & Van den Bulck, 2016; Przybylski & Weinstein, 2019).

Siste et al., (2021) found that screen time exceeding three hours per day, especially before bedtime, is significantly correlated with increased sleep disturbances in adolescents (Hale & Guan, 2015; Siste et al., 2021).

A meta-analysis by (Keles et al., 2020) concluded that nighttime screen exposure has a greater impact on sleep rhythm disruption than daytime screen use (Exelmans & Van den Bulck, 2016; Keles et al., 2020; Woods & Scott, 2016). Arora et al., (2014) also noted that digital content types such as social media and online games contribute more to sleep disruption than watching television or videos (Arora et al., 2014; Hale & Guan, 2015; Przybylski & Weinstein, 2019).

Beyond duration, the emotional and cognitive intensity of digital activities is also a crucial factor reinforcing the relationship between screen time and sleep quality (Exelmans & Van den Bulck, 2016; Touitou et al., 2016). Interactive activities such as gaming or social media discussions trigger stronger psychological arousal compared to passive activities like reading articles or watching informational videos (Cajochen et al., 2011; Chang, 2014; Woods & Scott, 2016). Therefore, monitoring not just the length, but also the content type and timing of screen use is essential in designing effective interventions to improve adolescent sleep quality.

METHODS

Design

This study employed a quantitative descriptive-correlational approach using a cross-sectional survey design. The primary objective of this design was to examine the relationship between screen time duration and sleep quality among adolescents at a single point in time. This design was chosen for its efficiency in identifying and analyzing relationships between variables within a specific population.

Participants

The study population consisted of adolescents aged 13–18 years enrolled in junior and senior high schools in Bandar Lampung City. A purposive sampling technique was used to select participants who met the following inclusion criteria: (1) aged between 13 and 18 years, (2) actively using electronic devices for a minimum of 1 hour per day, and (3) willing to complete the questionnaire honestly. A total of 120 respondents were targeted, in accordance with the minimum sample size requirement for Pearson correlation and simple regression analysis.

Instruments

The instruments used in this study consisted of two main components:

Screen Time Questionnaire: Developed by the researcher based on references from Carter et al., (2016) and Mireku et al., (2019) this instrument measured the average daily duration of digital device use (smartphones, tablets, computers, and TVs), categorized by morning, afternoon, and evening use.

Pittsburgh Sleep Quality Index (PSQI) – Adolescent Version: This standardized instrument assessed sleep quality across 19 items, covering aspects such as sleep duration, sleep efficiency, sleep latency, sleep disturbances, and subjective sleep quality. A total score >5 indicates poor sleep quality.

Data Analysis

The collected data were analyzed using SPSS version 25. The data analysis procedures included:

Descriptive Statistics: To describe data distribution, average screen time, and sleep quality scores.

Normality Test: The Kolmogorov-Smirnov test was used to assess the normality of data distribution.

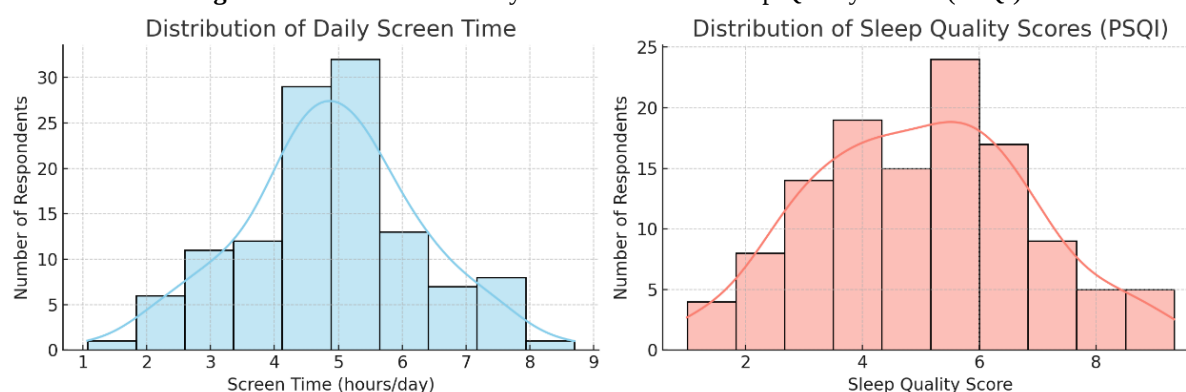
Pearson Correlation Test: Conducted to determine the relationship between screen time and sleep quality.

Simple Linear Regression Test: Performed to assess the extent to which screen time predicts sleep quality.

RESULTS AND DISCUSSION

Result

Figure 1. Distribution of Daily Screen Time and Sleep Quality Scores (PSQI)



Descriptive statistical analysis of data collected from 120 adolescent respondents revealed that the average daily screen time was 4.88 hours, with a standard deviation of 1.39 hours. The minimum reported screen time was 1.07 hours per day, while the maximum reached 8.69 hours. This indicates that most adolescents in this study spent a relatively high amount of time on digital device usage each day. The

distribution of screen time values appeared fairly even, with a median of 4.89 hours and an upper quartile (Q3) of 5.57 hours, suggesting that more than 25% of respondents used digital devices for more than five and a half hours daily.

In terms of sleep quality, the Pittsburgh Sleep Quality Index (PSQI) scores showed an average score of 5.01, with a standard deviation of 1.86. The minimum score recorded was 1.00, while the maximum was 9.34, with a median of 5.20. According to PSQI guidelines, a total score above 5 indicates poor sleep quality. Therefore, it can be concluded that the majority of respondents experienced suboptimal sleep quality. The lower quartile (Q1) was 3.66, and the upper quartile (Q3) was 6.29, meaning that 50% of respondents had PSQI scores within this range.

To examine the relationship between the variables, a Pearson correlation test was conducted:

Table 1. Results of Pearson Correlation Test

Variable 1	Variable 2	Pearson Correlation (r)	p-value
Screen Time (hour/day)	PSQI (Pittsburgh Sleep Quality Index)	0.775	< 0.001

The results of the Pearson correlation test indicate a statistically significant relationship between screen time and sleep quality among adolescents. The correlation coefficient (r) was 0.775, suggesting a strong and positive association between the two variables. This means that the longer adolescents spend on digital device usage (screen time), the higher their PSQI scores—indicating poorer sleep quality. The p-value of < 0.001 confirms that this correlation is highly statistically significant, implying that the observed relationship is unlikely to be due to chance. Therefore, it can be concluded that screen time is strongly correlated with decreased sleep quality in adolescents.

A simple linear regression analysis was conducted not only to determine the presence of a relationship between screen time and sleep quality but also to assess the magnitude of screen time's impact on sleep quality. This analysis provides a predictive model that can be used for estimation, informs the development of data-driven intervention strategies, and strengthens the correlational findings through quantitative and inferential analysis, thereby enhancing the accuracy and applicability of the research outcomes.

Table 2. Results of Simple Linear Regression Test

Regression Model	Regression Coefficient (b)	Intercept (a)	R-squared
PSQI = 1.039 × (Screen Time) – 0.058	1.039	-0.058	0.601

Based on the regression output, the following regression equation was obtained:

$$\text{PSQI} = 1.039 \times (\text{Screen Time}) - 0.058$$

This equation indicates that each additional hour of screen time per day is estimated to increase the PSQI score by approximately 1.039 points. Since higher PSQI scores reflect poorer sleep quality, this suggests that increased screen time among adolescents is associated with a greater likelihood of experiencing sleep disturbances.

The R-squared (R^2) value of 0.601 implies that the regression model explains 60.1% of the variance in sleep quality scores (PSQI) based on screen time duration. This is a substantial proportion, indicating that screen time is a significant predictor variable for adolescent sleep quality.

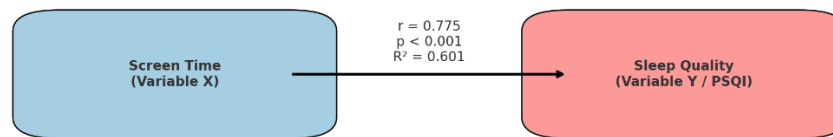
Furthermore, the p-value < 0.001 demonstrates that the regression model is statistically significant, meaning the relationship between screen time and sleep quality is unlikely to be due to random chance and reflects a genuine and meaningful contribution.

Discussion

This study aimed to examine the relationship between screen time and sleep quality among adolescents. Based on the descriptive analysis, the average daily screen time among respondents was 4.88 hours, with the maximum reaching 8.69 hours. These figures indicate that the majority of adolescents in this study spent a considerable amount of time on electronic devices such as smartphones, laptops, or televisions. Meanwhile, the average PSQI score was 5.01, suggesting that most respondents experienced poor sleep quality (PSQI > 5). This finding is supported by data distribution, showing that more than 80% of respondents had PSQI scores above 5, indicating disturbances in sleep duration, efficiency, and perceived restfulness.

Figure 2. Visualization of the Relationship Between Screen Time and Adolescent Sleep Quality

Visualization of the Relationship Between Screen Time and Adolescent Sleep Quality



The results of the Pearson correlation test revealed a strong and statistically significant positive correlation between screen time and sleep quality scores, with a correlation coefficient of $r = 0.775$, and $p < 0.001$. This positive association implies that as adolescents' screen time increases, their PSQI scores also increase indicating worsening sleep quality. This finding is consistent with prior studies by Carter et al., (2016) and Mireku et al., (2019), which also found that extended use of digital devices, particularly before bedtime, was closely linked to sleep disorders such as insomnia, delayed sleep onset, and poor sleep quality. Furthermore, the simple linear regression analysis confirmed that screen time is a significant predictor of sleep quality, as reflected in the regression equation:

$$\text{PSQI} = 1.039 \times \text{Screen Time} - 0.058$$

The regression coefficient of 1.039 indicates that for every additional hour of screen time, the PSQI score increases by approximately 1.039 points, suggesting a deterioration in sleep quality. The R-squared value of 0.601 indicates that 60.1% of the variance in sleep quality can be explained by screen time duration, while the remaining 39.9% may be attributed to other factors such as stress, dietary habits, late-night study routines, or environmental influences. The p -value < 0.001 further confirms that the regression model is statistically significant and reliable as a basis for prediction and intervention.

These findings align well with Time Displacement Theory, which posits that excessive screen time tends to "displace" sleep time that would otherwise be used for rest. In this context, adolescents who spend long hours engaging in social media, watching videos, or gaming are more likely to delay bedtime or reduce total sleep duration. In addition, Circadian Rhythm Theory provides a complementary explanation by highlighting how exposure to blue light from electronic screens at night can suppress melatonin production—a hormone that regulates sleepiness and the body's biological clock. As a result, the body experiences difficulty entering the natural sleep phase, leading to reduced sleep quality.

By integrating these two theoretical frameworks, it can be concluded that screen time impacts sleep quality not only quantitatively (in terms of sleep duration) but also qualitatively (in terms of sleep efficiency, depth, and subjective satisfaction). This serves as a critical reminder for educators, parents, and adolescents that managing screen time is an essential component of a healthy digital lifestyle.

The findings of this study are consistent with previous research by Otsuka et al., (2021), which demonstrated that excessive use of digital devices is correlated with sleep disturbances among adolescents. Notably, Mireku et al., (2019), in a large-scale population-based study, found that screen time exceeding three hours per day significantly increased the risk of sleep disorders and reduced overall quality of life. Thus, the present study not only reinforces existing evidence but also provides contextual data from the Indonesian adolescent population, which has been relatively underexplored.

Implication

The implications of these findings are critical from both academic and practical perspectives. Academically, the results strengthen the theoretical foundation that digital behavior significantly influences biological aspects such as sleep. Practically, the findings can inform the development of digital literacy and sleep hygiene education programs targeted at adolescents. Schools, families, and communities must collaborate to establish balanced digital device usage policies, particularly in the hours leading up to bedtime.

Limitation and Suggestion for Further Research

Despite yielding meaningful findings, this study is not without limitations. First, the cross-sectional design limits the ability to infer causal relationships between screen time and sleep quality. While a significant correlation was observed, longitudinal studies are needed to determine whether prolonged screen time directly leads to poor sleep quality over time. Second, the use of self-reported questionnaires, including the screen time log and PSQI, introduces potential bias due to inaccurate recall or social desirability. Objective measures, such as digital device tracking or actigraphy, would improve the reliability of future research. Third, the sample was limited to adolescents aged 13–18 years within a specific regional context in Indonesia, which may restrict the generalizability of the findings to broader populations or cultural settings. Lastly, the study did not control for other variables that may affect sleep quality, such as physical activity, caffeine consumption, mental health status, or content type (e.g., gaming vs. academic use), which could confound the observed relationship.

Future studies should consider adopting a longitudinal or experimental design to explore the causal mechanisms between screen time and sleep disturbances more robustly. Incorporating objective data collection tools such as wearable sleep trackers or screen monitoring applications can enhance data accuracy and minimize self-report bias. Moreover, research should explore moderating or mediating variables, such as emotional well-being, academic stress, or parental screen use regulation, to deepen understanding of how screen time interacts with broader psychosocial factors.

It is also recommended that future investigations include diverse demographic groups and consider different types of screen activity (e.g., social media, gaming, studying), as not all screen use may have the same impact on sleep. Expanding the scope to include qualitative approaches might also uncover adolescents' subjective experiences and coping strategies related to digital device use and sleep habits.

CONCLUSIONS

Based on the findings of this study, it can be concluded that screen time has a significant and influential relationship with sleep quality among adolescents. The average daily screen time among respondents was 4.88 hours, with the majority of participants (over 80%) recording PSQI scores above 5, indicating poor sleep quality. The Pearson correlation test revealed a strong and significant positive relationship between screen time and PSQI scores ($r = 0.775$; $p < 0.001$), meaning that the longer adolescents engage in screen-related activities, the poorer their sleep quality tends to be.

This finding was further supported by the results of simple linear regression analysis, which showed that 60.1% of the variation in sleep quality could be explained by screen time, as reflected in the regression equation:

$$\text{PSQI} = 1.039 \times \text{Screen Time} - 0.058$$

Theoretically, these results support both the Time Displacement Theory and the Circadian Rhythm Theory, which explain that excessive screen time displaces essential sleep hours and disrupts the body's natural biological rhythm due to exposure to electronic screen light, particularly at night.

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AUTHOR CONTRIBUTIONS STATEMENT

The author independently designed and carried out all stages of this research, including problem formulation, the development of the quantitative survey methodology, and the construction and validation of research instruments. Data collection was conducted independently through an online survey, with adherence to research ethics protocols. The author also performed statistical data analysis using SPSS, which included descriptive analysis, Pearson correlation, and simple linear regression.

All sections of the article including the initial draft, revisions, table construction, and graphical visualizations were written and organized solely by the author. The author is fully responsible for the interpretation of the results and the alignment of the manuscript with scientific publishing standards. No external parties were involved in the process, and the author declares no conflicts of interest.

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