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Nighttime Smartphone Blue Light Exposure, Sleep Quality, and Metabolic Health in Adolescents and Young Adults

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RESEARCH QUESTION

What is the association between sleep quality and night-time exposure to smartphone-emitted blue light, as opposed to other forms of sleep disruption, with measures of metabolic outcomes in adolescents and young adults?

ABSTRACT

Nighttime smartphone use has become very common among adolescents and young adults in recent years, and this may affect both sleep quality and metabolic health. However, the specific effect of smartphone-emitted blue light is difficult to separate from behavioral forms of smartphone-related sleep disruption, especially when looking at adolescents and young adults. Smartphone-emitted blue light can disrupt circadian rhythms and melatonin secretion. This can potentially affect glucose regulation and insulin sensitivity, leading to specific metabolic outcomes in adolescents and young adults. However, other forms of sleep disruption (stress, room temperature, physical discomfort, and bedtime delay) can also contribute to these outcomes. This paper looks at the association between sleep quality and nighttime smartphone-emitted blue light, compared with other forms of sleep disruption, and metabolic outcomes in adolescents and young adults. This study uses a literature review and survey to analyze whether blue light has a specific role in these relationships. 70 individuals responded to the survey. Greater smartphone use after getting into bed was associated with poorer self-reported sleep quality ($\rho = -0.284$, $p = 0.017$). Difficulty stopping smartphone use before bed was also associated with more frequent bedtime delay ($\rho = 0.392$, $p = 0.001$). However, blue-light-reduction feature use was not significantly associated with sleep quality ($\rho = 0.176$, $p = 0.144$). Blue-light-specific associations were weaker in the survey, while the literature showed stronger evidence of blue light affecting sleep and metabolic regulation. This difference suggests that other behavioral, psychological, and environmental forms of sleep disruption may also contribute to these outcomes alongside blue-light exposure.

INTRODUCTION

Adolescence is the developmental stage that starts with puberty, between the ages of 8-14, and ends in the mid-20s (National Academies of Sciences, Engineering, and Medicine, 2019). During

this phase, getting 9–10 hours of good quality sleep is very important for the proper release of growth hormones, reduction in inflammation in the body, emotional regulation, and increased immune system function ("Teens and Sleep," 2008). Not getting enough sleep can disrupt hormones involved in appetite regulation and energy balance (Klok et al., 2007; Leproult & Van Cauter, 2010). It can also cause a decreased ability to respond to insulin, metabolic syndrome, and decreased physical activity. Several factors can influence sleep quality, including temperature, shift work disorder, caffeine consumption, restless leg syndrome, insomnia, and light, particularly nighttime exposure to electronic devices (Sleep Foundation, n.d.). In recent years, smartphone use has increased significantly, especially among adolescents.

Over 95% of adolescents in the US have access to smartphones (Anderson et al., 2024), and more than 70% to using their phones within 30 minutes of falling asleep (Rideout & Robb, 2019). Another study indicated that around 50% of adolescents use their phones during sleeping hours, averaging around 50 minutes of nocturnal screen time (Nagata et al., 2026). The usage of mobile phones does not only reduce sleep quality, but also influences insulin and glucose secretion. Studies show that artificial light at night (ALAN) makes body cells less responsive to insulin (Mason et al., 2022).

With this increase in screen time comes an increase in exposure to blue light. Blue light is a category of visible light with wavelengths of approximately 380 to 500 nanometers (nm), placing it at the short-wavelength, high-energy end of the visible spectrum (Encyclopaedia Britannica, n.d.). Blue light affects the body's circadian rhythm by suppressing melatonin secretion and increasing alertness and cortisol level. These responses are more evident in adolescents (Eto et al. 2021).

It has been clearly shown that the high exposure to smartphone emitted blue light before sleep might alter the levels of melatonin, cortisol, which will subsequently affect glucose and insulin sensitivity(Cheung et al., 2016; Garaulet et al., 2020; Robertson-Dixon et al., 2023). Several studies have discussed the relation between the total screen time before bed and the factors stated. However, the association between blue light exposure and insulin sensitivity and glucose levels has not been fully covered, especially in adolescents, and when comparing these effects to those of other forms of sleep disruption. As we are in the digital age and with the increased exposure to blue light emitted from devices, especially in adolescents, it is important to understand the effects of this increase on both sides of human health: sleep and glucose. This study aims to understand the association between sleep quality and nighttime exposure to smartphone-emitted blue light, as opposed to other forms of sleep disruption, with measures of insulin sensitivity and glucose regulation in adolescents.

LITERATURE REVIEW

Section 1:Effects of Smartphone-Emitted Blue Light on Sleep Quality

When the eye is exposed to blue light, many physiological responses are triggered across different photoreceptors in the retina, including the intrinsically photosensitive retinal ganglion cells (ipRGCs), which contain different proteins, such as the photopigment melanopsin (Lucas et al., 2014; ZEISS Vision Care, 2024). First, alertness increases as the blue light exposure causes these retinal photoreceptors, specifically the intrinsically photosensitive retinal ganglion cells (ipRGCs), which respond to short wavelength blue light, to suppress the production and secretion of the hormone melatonin (Altimus et al., 2008). This hormonal disruption is particularly heightened in adolescents because of their larger pupils and clearer crystalline lenses. Eto et al. (2021) found that adolescents allow almost twice as much blue light to their retina and they have clearer crystalline lenses. Demirci et al. (2015) discussed the association between phone overuse and the symptoms of depression/anxiety, which in turn might lead to sleep disruption in both duration and quality. Another study by Randjelović et al. (2023) highlighted the effect of reducing blue light in smartphones on sleep quality in a target population aged between 20 and 22 years old. The mean total Pittsburgh Sleep Quality Index (PSQI) score was shown to decrease significantly after the reduction of blue light exposure, supporting the correlation between blue light exposure and decreased sleep quality. In addition, poor sleep quality as measured by delayed sleep onset and shorter total sleep time was shown to be associated with screen time after going to bed (Brosnan et al. 2024). Macharla et al. (2025) found that excessive smartphone use before bedtime disrupts adolescent sleep by suppressing melatonin secretion, delaying sleep onset, and disturbing circadian rhythms through exposure to blue light emitted from smartphone screens. The review explains that blue light activates melanopsin-containing retinal ganglion cells, which signal the suprachiasmatic nucleus (SCN). This causes an alteration in the body's biological clock, also known as the circadian rhythm, and reduces sleep efficiency. It also concluded that these sleep disturbances are associated with reduced cognitive ability and an increased risk of type 2 diabetes.

Section 2: Metabolic Consequences of Nighttime Phone use and Blue Light-Induced Sleep Disruption

Numerous studies have established the relationship between smartphone-emitted blue light and decreased sleep quality. Many have also examined the metabolic impacts of this blue light-caused sleep disruption. To begin with, not getting enough quality sleep can cause higher levels of hunger-controlling hormones leptin and ghrelin. According to Klok et al. (2007), leptin is a hormone that suppresses appetite and regulates long-term energy balance, whereas ghrelin is a fast-acting hormone that stimulates hunger and plays an important role in meal initiation. Mason et al. (2022) found that the exposure to room light resulted in much higher insulin secretion during

the first 30 minutes of the oral glucose tolerance test (OGTT). This reflects an alteration in glucose homeostasis due to malfunctioning pancreatic β-cells, potentially increasing the long-term risk of insulin resistance and type 2 diabetes. Another study indicated that evening light exposure had unfavourable effects on metabolic functions. These effects included glucose tolerance and decreased insulin sensitivity. It was also previously shown that blue-enriched light exposure in the morning and evening alters glucose metabolism, with an increase in insulin resistance compared to dim light exposure. In addition, evidence indicates that nighttime indoor light exposure in the hours-minutes leading up to sleep while awake, and during sleep itself, likely has significant metabolic effects (Mason et al., 2022). Furthermore, Cheung et al. (2016) found that in both morning and evening groups there was a significant increase in Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and subjective sleepiness was reduced with light with wavelengths closest to that of blue light, compared to dim lights. In the evening group, there was a higher glucose spike in participants that were exposed to blue light compared to dim light. However, in the morning group, there was a significantly smaller glucose spike. Wang et al. (2024), investigated a total of 18,738 cases of type 2 diabetes (T2D) were documented over a median follow-up of 13.04 years. Participants with higher blue light exposure had a much greater risk of developing T2D than those with lower exposure. The study found that the association remained just as significant even after adjusting for known risk factors and was not affected by physical activity, outdoor activity, or sleep quality.

Mark and Janssen (2008) analyzed data from 1,803 adolescents aged 12–19 years and found that greater screen time was associated with a higher likelihood of metabolic syndrome. Adolescents with ≥5 hours of daily screen time had over three times the risk of metabolic syndrome (OR = 3.07, 95% CI: 1.48–6.34) compared with those reporting ≤1 hour per day. These results remained significant independent of physical activity. Moreover, Huthsteiner (2022) studied the effects of smartphone-emitted short-wavelength blue light on sleep and circadian processes in 27 adolescent males (mean age 15.93 years) and 31 young adult males (mean age 21.97 years). In this study, participants were exposed to 1.5 hours of smartphone light without a blue-light filter (448 nm), with a blue-light filter (613 nm), or a printed book before bedtime. In the group of young adults there were reduced melatonin levels, poorer sleep quality, increased sleep fragmentation (this included reduced deep sleep), and a lower cortisol awakening response after exposure to unfiltered blue light. However, in the group of adolescents there were little to no significant effects.

However, much of this evidence comes from adult populations, and these findings cannot be directly generalized to adolescents.

Subsection: Evidence from Animal Studies

In a study on rats, Masís-Vargas et al. (2019) found that exposure to blue artificial light at night (bALAN; 490 ± 20 nm) can impair glucose metabolism by increasing blood glucose levels and reducing insulin secretion, particularly in male grass fed rats. In females, bALAN also increased

nonfasted blood glucose levels together with plasma corticosterone, which was associated with a stress-related metabolic response. This study also found that bALAN can affect metabolism and eating behavior. Male rats exposed to blue light ate more sucrose, while females did not show the same response. The study also found changes in glucose regulation, insulin secretion, and hormone levels, showing that nighttime blue light may contribute to metabolic dysfunction. This suggests that bALAN can alter eating behavior and hormone regulation in a sex-dependent manner, contributing to metabolic dysfunction. Gherman et al. (2025) conducted a study in 64 Wistar rats (32 males and 32 females) to mimic the puberty period in adolescents. Rats were exposed to blue light from different sources: a smartphone (iphone 11), computer screen, and or LED lamp. Prolonged blue light exposure made serum insulin and glucose levels higher in both sexes. Female rats exposed to mobile phones and LED blue light had much higher glucose levels than the control unexposed group, and the male rats exposed to all three blue light sources also showed high glucose levels. Insulin levels increased over the 30-day exposure period in both males and females. It also altered lipid metabolism and increased liver enzymes (ALT and AST). Female and male rats exposed to computer screens and LED lamps also gained much less body weight than the control group. The serum leptin levels only differed minimally between the blue-light-exposed and control groups.

Although these animal studies provide evidence of possible biological mechanisms, their findings cannot be directly generalized to metabolic effects in human adolescents.

Section 3: Blue Light Versus Other Causes of Sleep Disruption

There are many causes of sleep disruption. The most common effects on sleep quality include temperature, shift work disorder, distractions from smartphone contact, caffeine consumption, restless leg syndrome, needing to use the bathroom, different forms and sources of light among many others (Sleep Foundation, n.d: Suni, 2026.). Lucas et al. (2014) indicated that these forms of sleep disruption do not directly affect melatonin levels in the same way blue light does. Melatonin synthesis in the absence of light and in a dark room follows its natural uninterrupted base line curve. These forms of sleep disruption where the light was absent are known as non photic, whereas sleep disruption due to blue light is known as photic sleep disruption (Lucas et al. 2014). Blue light exposure suppresses melatonin and triggers immediate post-meal insulin resistance. Chang et al. (2015) studied 12 healthy adults. Participants read on a light-emitting eReader for about 4 hours before bedtime for 5 nights.. It was found that melatonin was suppressed, the circadian clock was delayed by more than 1.5 hours and participants took longer to fall asleep and were less alert the next morning. In a study by Cheung et al. (2016) on 19 healthy adults participants were exposed to 3 hours of blue-enriched light, resulting in increased HOMA-IR and total insulin levels. The evening treatment group also had a significantly higher glucose peak than under dim light. In addition, Leproult et al. (2014) studied 26 healthy adults, specifically shift workers. The participants completed 8 days of sleep restriction. The circadian misalignment group delayed bedtime by 8.5 hours in 4 days. Sleep duration was similar in both groups. They found that circadian misalignment doubled the reduction in insulin sensitivity and increased inflammation in male participants. Mason et al.

(2022) studied 20 healthy young adults. Out of the twenty, ten participants slept one night under 100-lux room light, while the control group slept in dim light (<3 lux). The room-light group had higher next-morning HOMA-IR and insulin levels during the OGTT, Oral Glucose Tolerance Test. This shows higher insulin resistance, but melatonin levels were similar in both groups. This evidence suggests that nighttime light exposure can impair insulin sensitivity beyond the effects of sleep disruption alone. Furthermore, Cheung et al. (2016) found that the blue light exposure right after a late meal can cause immediate acute evening glucose spikes. The brain will therefore receive signals that it is day time. This will alter the immediate digestion capacity and insulin sensitivity (Aoyama & Shibata, 2020). This means that in certain non-photic sleep disruptions the high cortisol level will lead to elevated fasted glucose the following morning. The liver will release more glucose to handle the physical stress, leading to higher insulin resistance (Dinneen et al., 1993; Leproult et al., 2014). Finally, Eto et al. (2021) found that children had 1.48 times greater non-visual photoreception and 1.52 times greater melatonin suppression than adults because of their larger pupil size and because of the greater crystalline lens transmittance to short-wavelength blue light. This allows more blue light to reach the retina, making adolescents more susceptible to the circadian disruption and the subsequent metabolic effects of nighttime smartphone-emitted blue light. Overall, these studies support the idea that nighttime blue light exposure is associated with impaired sleep quality, altered glucose metabolism, reduced insulin sensitivity, and an increased risk of metabolic dysfunction. It has been clearly shown that exposure to smartphone emitted blue light before sleep might alter the levels of melatonin and cortisol, which will subsequently affect glucose and insulin sensitivity. However, this has not been examined in detail, and is the subject of this study.

METHODS

This study employed a literature review and a survey.

Literature Review

For the literature review, papers or studies were identified via PubMed and Google Scholar between early July and mid-August of 2026 by searching for keywords related to the research question, including adolescent sleep quality, young adults, smartphone-emitted blue light, insulin sensitivity, glucose regulation, circadian rhythm, photic sleep disruption, non-photic sleep disruption, and metabolic health. Publications were selected based on their relevance to the research question. Both human and animal studies were considered to compare findings across populations and reveal potentially different biological mechanisms, recognizing that animal findings cannot be directly generalized to humans. Studies that did not directly address the research question were excluded. Because the review was narrative rather than systematic, no formal risk-of-bias assessment was conducted. Google Search was also used to identify articles, reports, and statistics that were related to the study.

Survey Questionnaire

The age range of 13–24 years was selected based on the extended developmental definition of adolescence proposed by the National Academies of Sciences, Engineering, and Medicine (2019), which recognizes that developmental and social transitions may extend into the mid-20s. Therefore, the study population is described as adolescents and young adults to reflect the broader age range included in the survey.

A cross-sectional survey was conducted in Lebanon and Spain via Google Forms. Participants were recruited through online platforms, including WhatsApp and other social media applications, to complete the questionnaire voluntarily and anonymously. This represents a convenience sample. The inclusion criteria required participants to be between the ages of 13 years old and 24 years.The questionnaire was divided into three sections: (1) sleep habits and sleep quality, (2) nighttime smartphone use and screen exposure, and (3) blue light reduction features and metabolic health indicators. The questionnaire assessed nighttime smartphone use, screen brightness, and the use of blue-light reduction features as self-reported indicators of screen-related behaviors. However, actual blue-light exposure and screen-emitted wavelengths were not directly measured. The questionnaire included demographic information, including age, sex, and medical history. The questions focused on smartphone use before bedtime, including daily smartphone use, smartphone use after 6:00 p.m., smartphone use during the hour before sleep, duration of smartphone use after getting into bed, bedtime smartphone habits, smartphone location during sleep, and perceived effects of smartphone use on sleep quality. Additional questions assessed blue light exposure, including awareness of blue light, use of blue-light reduction features, screen brightness before bedtime, use of blue-light-blocking glasses, and whether participants noticed improvements in sleep after using blue-light filters. Sleep-related questions examined bedtime and wake-up time on weekdays and weekends, sleep duration, sleep onset latency, nighttime awakenings, time required to fall back asleep, subjective sleep quality, daytime sleepiness, nap frequency and duration, difficulty falling asleep or waking up, consistency of sleep schedules, chronotype, and factors contributing to sleep disruption. The questionnaire also assessed symptoms associated with poor sleep and metabolic health, including morning hunger, thirst, headaches, mental fog, fatigue, cravings for sugary and high-calorie foods and daytime energy levels. The final question was optional and asked about previous diagnosis of metabolic or endocrine disorders, such as prediabetes, diabetes, insulin resistance, obesity, metabolic syndrome, hypertension, and polycystic ovary syndrome. The customized questionnaire was inspired by previously validated sleep questionnaires and published literature. Responses were gathered using multiple choice, rating scale, 5-point frequency Likert scale, where 1 and 5 represented different extremes depending on the question.

These outcomes were based on self-reported symptoms and previously diagnosed conditions rather than concrete metabolic measurements. No glucose, insulin, or other biological markers were measured.

Data analysis

Smartphone use and self-reported sleep quality as well as other responses were compared across the four age categories (13–15, 16–18, 19–22, and 22–24 years). Age-related comparisons were conducted using

the four age categories included in the survey. A separate analysis comparing adolescents aged 13–18 years with young adults aged 19–24 years was not conducted because the study aimed to analyse associations across the broader study population of adolescents or young adults. Survey responses were exported to Google Sheets and analyzed using Python in Google Colab. Frequencies, percentages, means, and medians were calculated when needed. Spearman's correlation was used to analyze relationships between variables. Mann–Whitney U tests were used to compare two groups. Kruskal–Wallis tests were used to compare three or more groups. Statistical significance was set at $p < 0.05$. Available responses were used when data were missing.

Ethical considerations:

Participation in the survey was voluntary and anonymous. Participants were informed about the purpose of the study before completing the survey. No personal information was collected. All responses were kept confidential. Participants could choose not to answer optional questions, including questions about metabolic or endocrine conditions. Institutional Review Board (IRB) approval was not obtained because the survey was conducted as part of an independent student research project. Ethical standards were maintained by ensuring voluntary participation and that the participants remain anonymous throughout the study.

SURVEY RESULTS

Participant numbers and demographics

A total of 70 participants between the ages of 13 and 24 completed the survey. The demographic characteristics of the participants are presented in Table 1. The age group 16-18 recorded the highest percentage (42.9%), and the remainder was divided between the age groups 13-15 (14.3 %), and 19-22 (21.4%). Most of the participants were females, constituting 82.9% of the responses. 90% of the responses reported were from Lebanon, the other 10% of the participants were from Spain.

Smartphone use in survey participants

All of the survey participants own and regularly use a smartphone. When smartphone use was compared between male and female participants, both groups reported high levels of daily smartphone use. Among females, 44.8% (26/58) reported using their smartphones for 6 hours or more per day, compared with 50.0% (6/12) of males. Estimated daily smartphone use was similar across the four age groups (Figure 1). Participants aged 19–22 used phones slightly more, while the other age groups had similar median values. The differences between age groups were not significant (Kruskal–Wallis $H = 1.41$, $p = 0.703$).

In terms of night time cell phone use, most participants (62.9%, n = 44) reported using their smartphones before bedtime every night and 18.6% (n = 13) reported using them often (Figure 2). In contrast, 8.6% (n = 6) reported using their smartphones sometimes, and 8.6% (n = 6) rarely. Only 1.4% (n = 1) reported

never using their smartphone at bedtime. Overall, 81.4% of participants used their smartphones before bedtime often or every night.

Characteristic	Number	Percentage (%)
Age (years)		
13–15	10	14.3%
16–18	30	42.9%
19–22	15	21.4%
22–24	15	21.4%
Gender		
Female	58	82.9%
Male	12	17.1%
Smartphone use		
Own/regularly use a smartphone	70	100%
Do not own/regularly use a smartphone	0	0%
Location of responses		
Spain	7	10%
Lebanon	63	90%

Table 1: Demographic characteristics of the survey participants

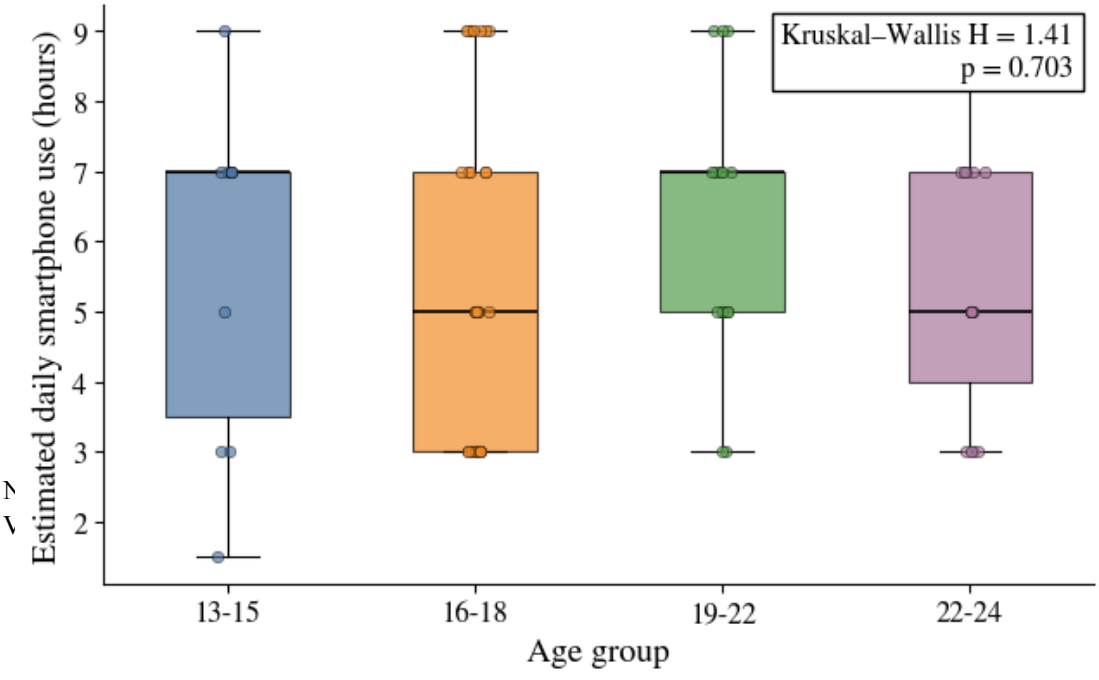


Figure 1: Estimated daily smartphone use across different age groups among survey participants.

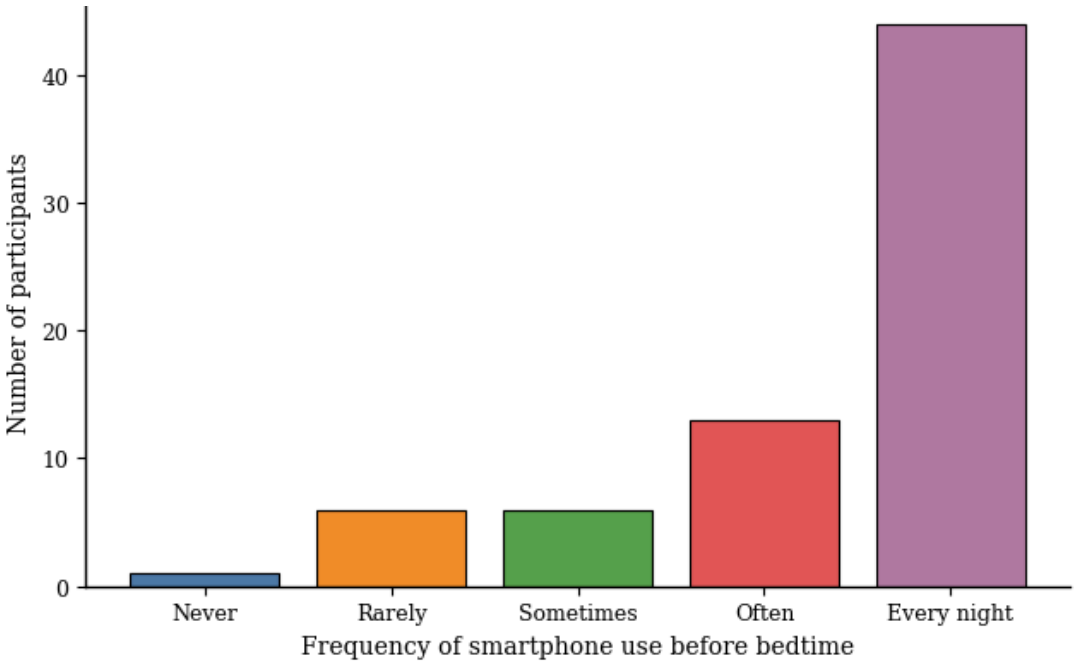


Figure 2: Frequency of smartphone use before bedtime among survey participants

Association of Smartphone use with sleep quality

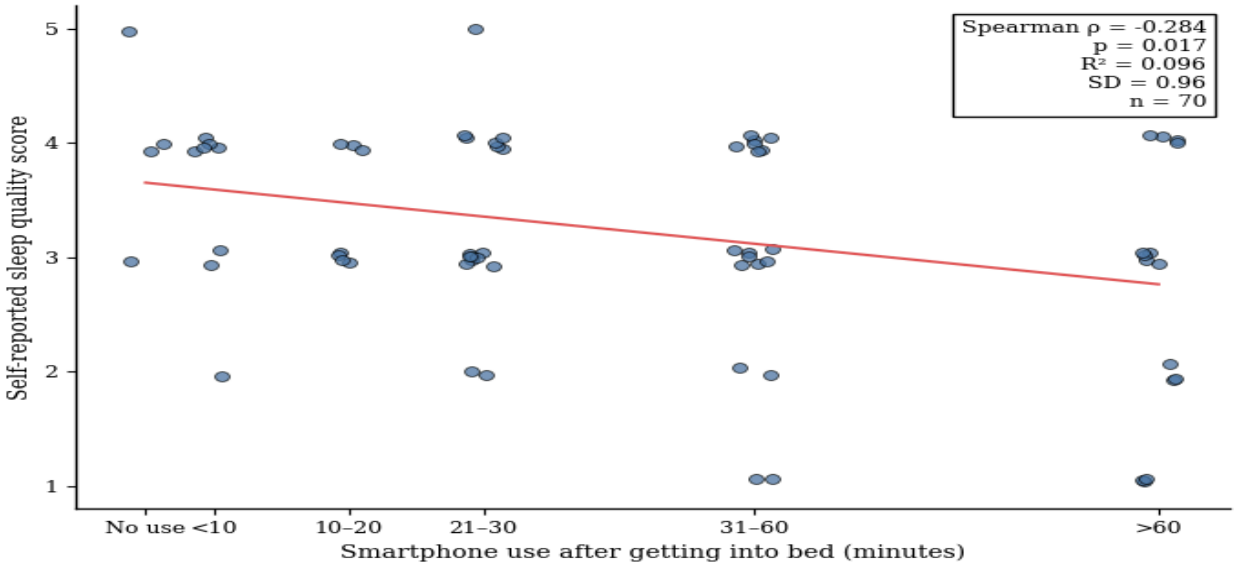
Survey responses indicated a negative association between smartphone use after getting into bed and self-reported sleep quality (Figure 3, Spearman's $\rho = -0.284$, $p = 0.017$), n=70. As reported smartphone use in bed increased, sleep quality scores tended to decrease. Figure 4 shows a small positive association between blue-light reduction feature use and self-reported sleep quality ($\rho = 0.176$, $p = 0.144$, $n = 70$). Participants who never used a blue-light reduction feature had a mean sleep quality score of 3.10, compared with 3.35 among those who always used one. Data shows that self-reported sleep quality was independent of age, being similar across all age groups (Figure 5). Participants aged 13–15 had a slightly higher median sleep quality score (3.5), while the other age groups had median scores around 3. However, these differences between age groups were not significant (Kruskal–Wallis $H = 3.48$, $p = 0.324$).

Figure 6 shows self-reported sleep quality across the reported sources of sleep disruption. Participants who reported physical discomfort as a sleep disruptor reported the lowest mean sleep quality (M = 3.00,

n = 16). This was followed closely by those reporting smartphone use (M = 3.05, n = 40). Participants reporting stress/anxiety (M = 3.18), school/work (M = 3.24), noise (M = 3.23), and room temperature (M = 3.32) had slightly higher mean sleep-quality scores. The highest mean sleep quality was observed among participants reporting caffeine (M = 3.73, n = 15).

To investigate the effects of light exposure, participants were asked about screen brightness and the use of blue light filters (figure 7). Participants reporting higher screen brightness and less frequent use of blue-light reduction features (n = 6) had a median sleep quality score of 3.0, compared with 4.0 among those reporting lower screen brightness and more frequent filter use (n = 25). However, this difference was not statistically significant (U = 55, p = 0.290). This shows a pattern in which participants who frequently used high screen brightness and rarely used a blue-light filter tended to report poorer sleep quality than those who used lower brightness and frequently used a blue-light filter (U = 55, p = 0.290).

Furthermore, it was reported in the survey that stress or anxiety was the most commonly reported sleep disruptor (n = 45). The second and third most commonly reported sleep disrupter was room temperature (n = 41) and smartphone use before bed (n = 40) respectively. School or work responsibilities were also commonly reported (n = 37). Needing to use the bathroom (n = 25), noise (n = 22), physical discomfort or pain (n = 16), and caffeine or energy drinks (n = 15), were reported less frequently (Figure 8).



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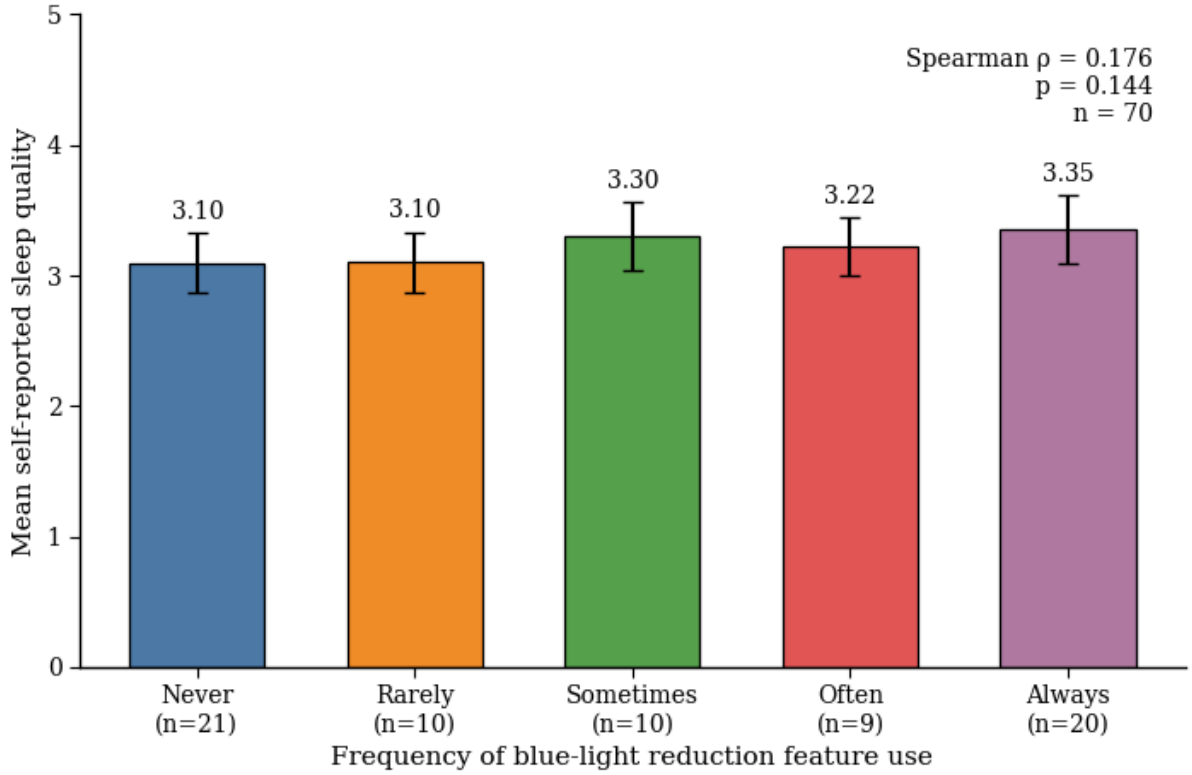


Figure 4: Association between frequency of blue-light reduction feature use and self-reported sleep quality among survey participants.

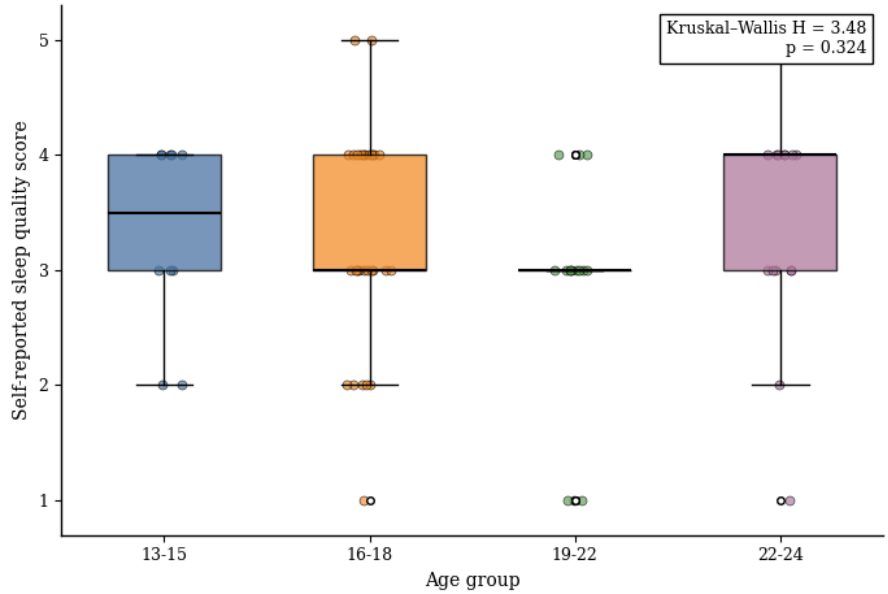


Figure 5: Comparison of self-reported sleep

quality scores across age groups among survey participants.

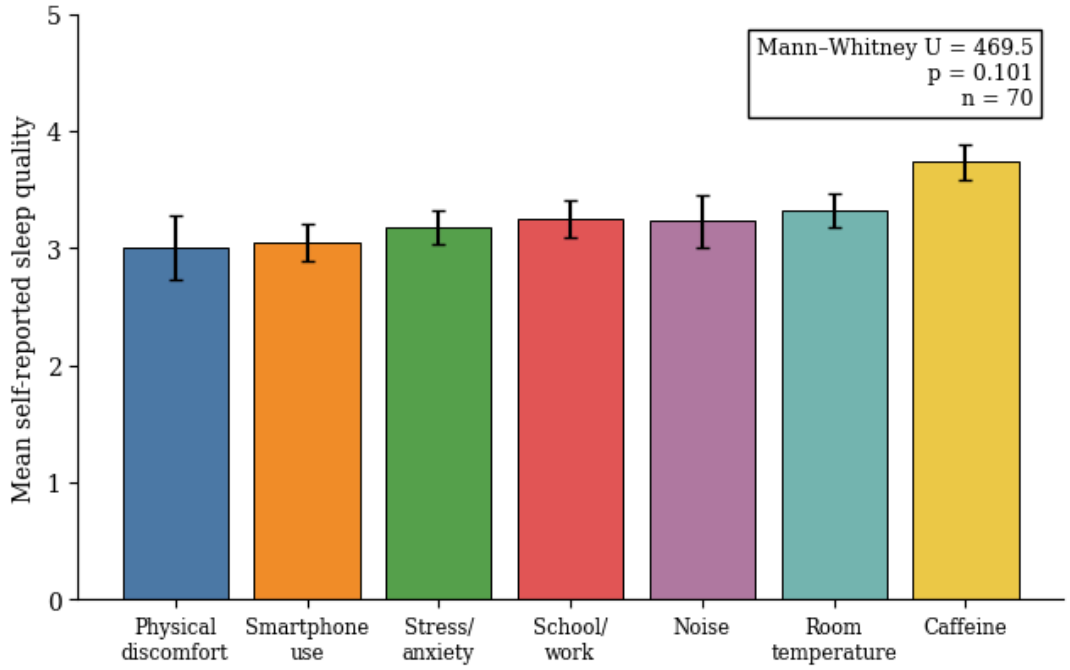


Figure 6: Comparison of mean self-reported sleep quality across different reported forms of sleep disruption.

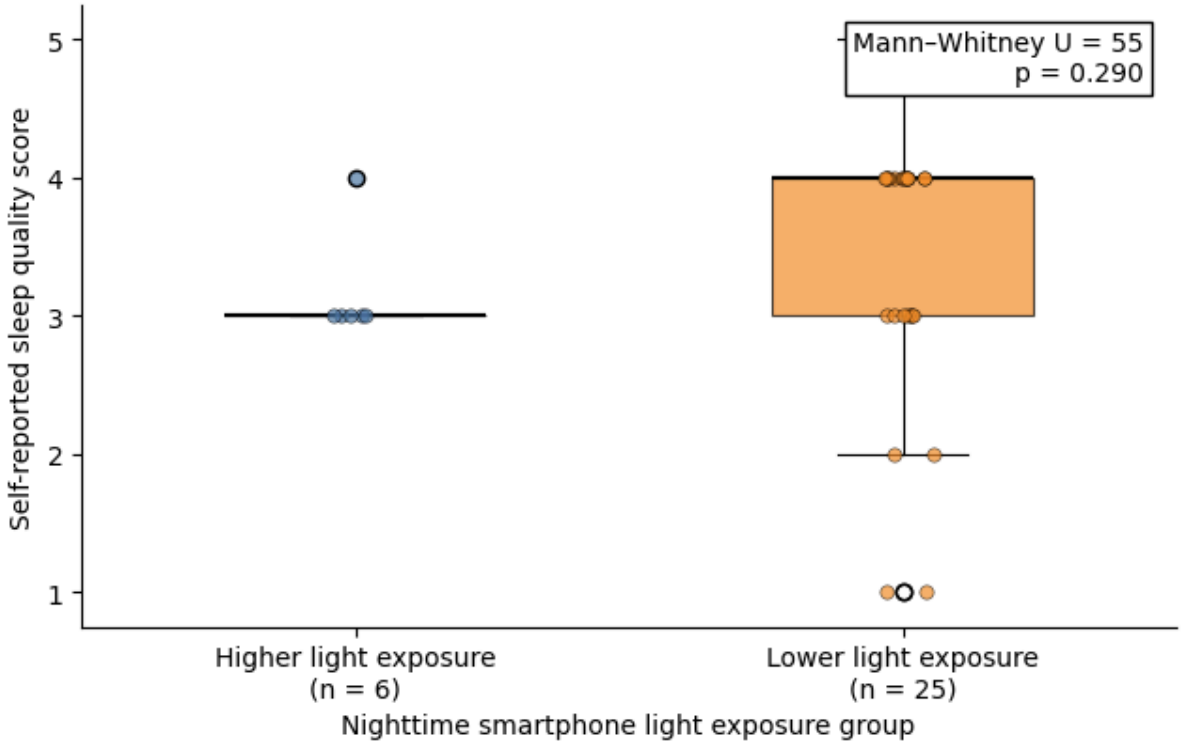
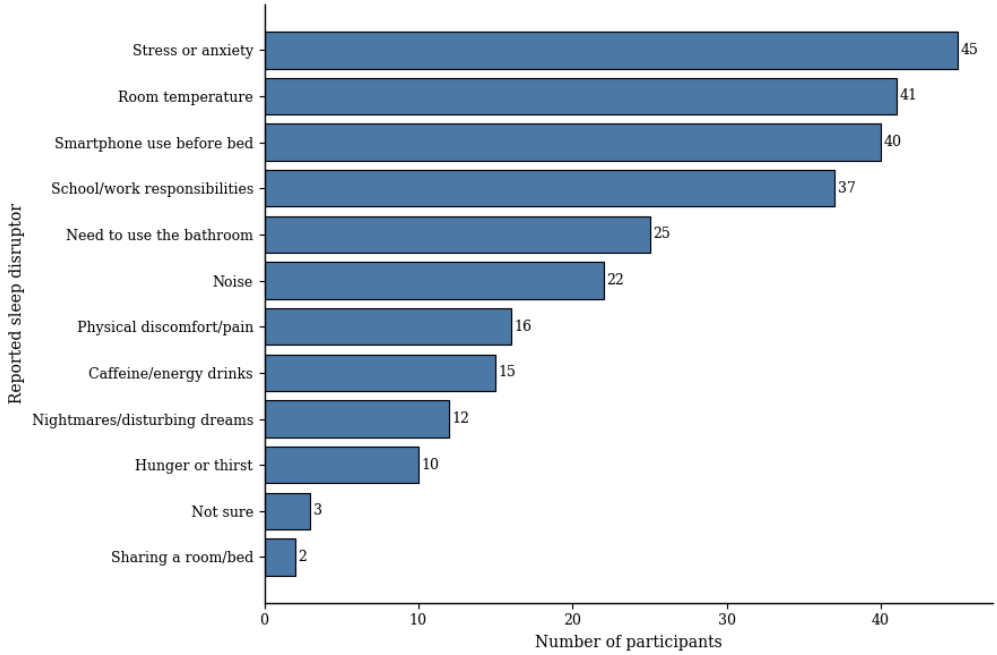


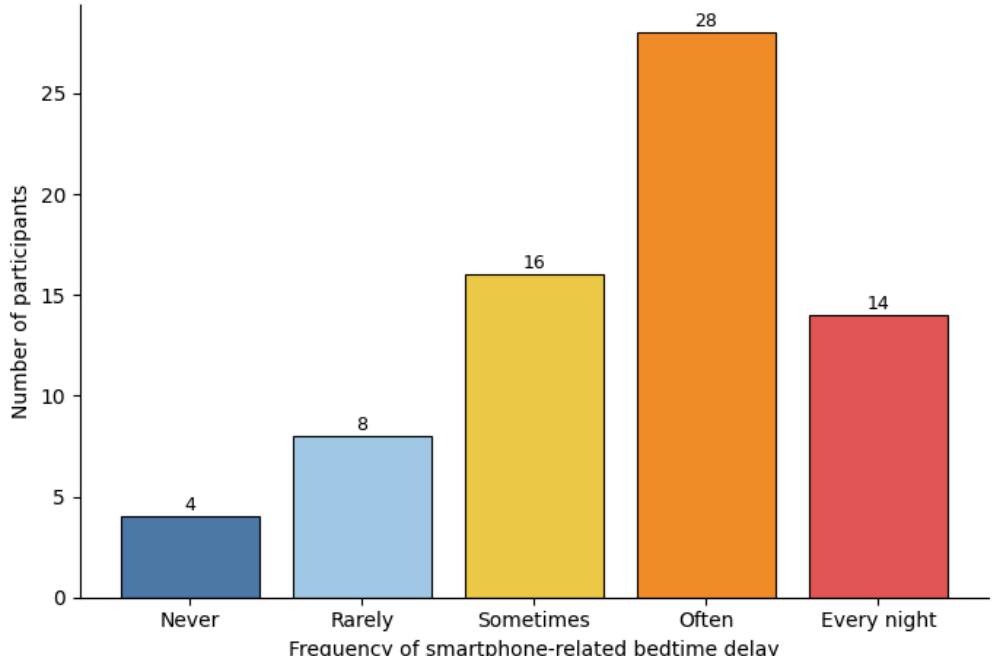
Figure 7: Comparison of self-reported sleep quality according to screen brightness and blue-light reduction feature use.



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Most ipants (40.0%) report t. Another 16 partic se. In contrast,

only 8 participants (11.4%) reported this rarely and 4 participants (5.7%) never. 60% of participants reported smartphone-related bedtime delay often or every night. In addition, there was a positive correlation between difficulty stopping smartphone use before bed and smartphone-related bedtime delay (Spearman's $\rho = 0.392$, $p = 0.001$). Participants that reported a higher difficulty stopping smartphone use before bed reported delaying their bedtime more frequently (Figure 12). Among participants who found it very difficult to stop using their smartphone before bed, 10 reported delaying bedtime often and 4 reported delaying bedtime every night (Figure 12).



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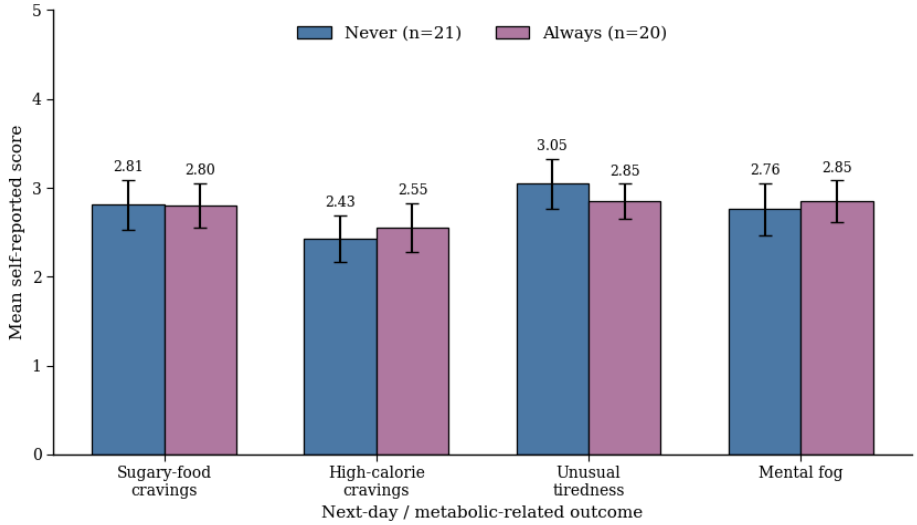


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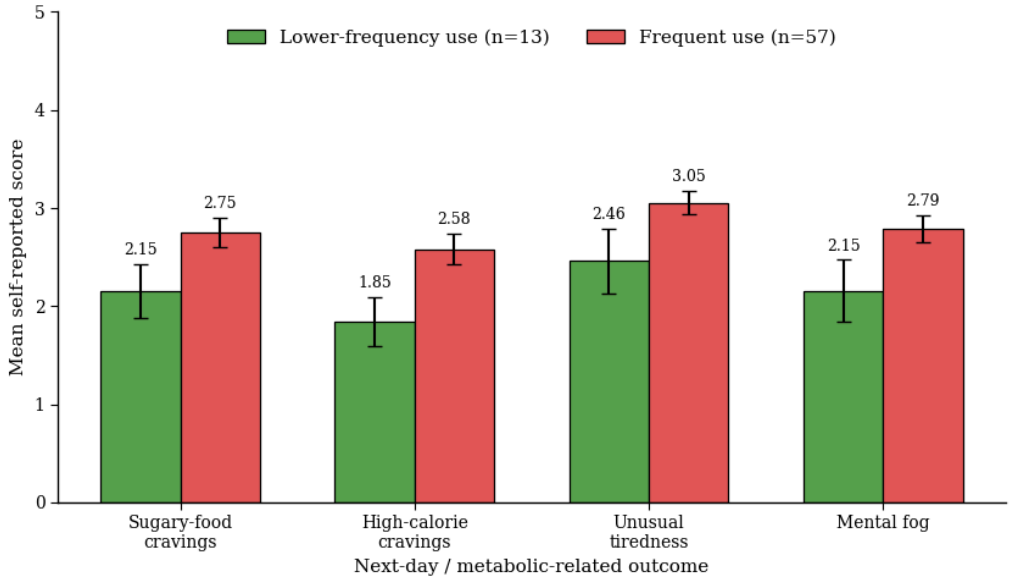


Figure 11: Comparison of next-day self reported metabolic-related outcomes between participants with lower-frequency and higher frequency nighttime smartphone use.

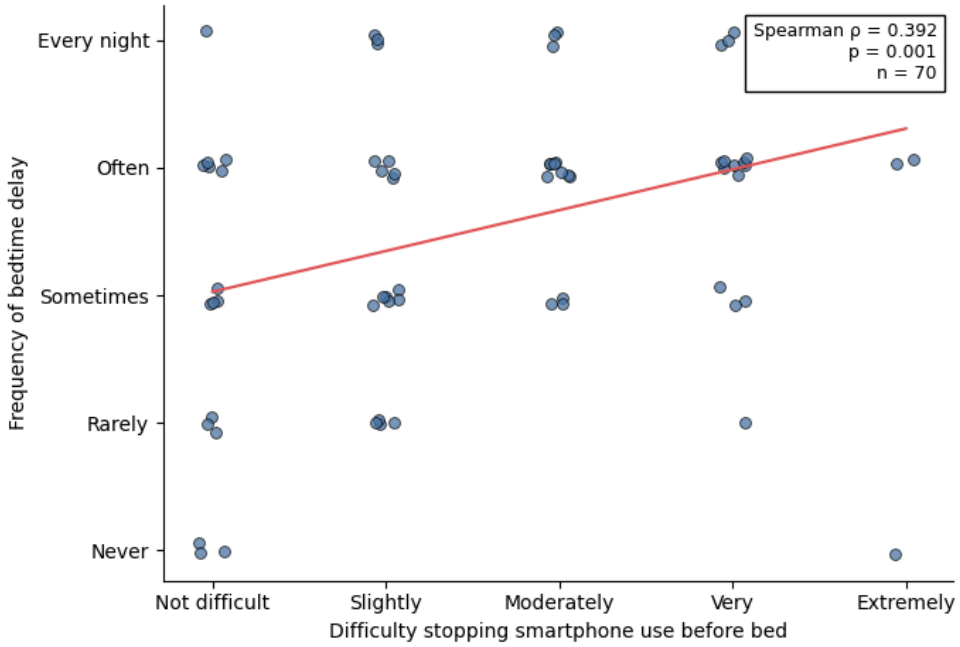


Figure 12: Association between difficulty stopping smartphone use before bed and frequency of smartphone-related bedtime delay among participants.

Associations Between Sleep Quality, Self-Reported Next-Day Symptoms, and Reported Metabolic Conditions

In order to analyse the relationship between self-reported sleep quality and next-day outcomes, Spearman correlations were calculated. Participants who never and always used a blue-light reduction feature reported very similar next-day outcomes. Among the survey participants, 21 (30.0%) reported never using a blue-light reduction feature, while 20 (28.6%) reported always using one. Sugary-food cravings were almost identical (M = 2.81 vs. 2.80). Always-users reported slightly higher high-calorie cravings (2.55 vs. 2.43) and mental fog (2.85 vs. 2.76), while unusual tiredness was slightly lower among always-users (2.85 vs. 3.05). The differences between the groups were small and none of the outcomes differed significantly (all $p > 0.05$), as shown in figure 10.

Figure 11 shows that participants with frequent nighttime smartphone use reported higher scores across all measured next-day outcomes compared with lower-frequency users. The higher-frequency nighttime smartphone-use group consisted of 57 participants who reported using their smartphones often or every night, while the lower-frequency group consisted of 13 participants who reported using them sometimes, rarely, or never. Frequent users reported greater sugary-food cravings (M = 2.75 vs. 2.15) (U = 257.5, p = 0.077). This difference was not statistically significant. These participants also reported high-calorie cravings (M = 2.58 vs. 1.85) (U = 237.0, p = 0.038), unusual tiredness (M = 3.05 vs. 2.46) (U = 246.0, p = 0.045), and mental fog (M = 2.79 vs. 2.15) (U = 240.5, p = 0.041). The largest difference was observed for high-calorie cravings, with a mean difference of approximately 0.73 points.

Better sleep quality was potentially associated with less frequent sugary-food cravings ($\rho = -0.15$), unusual tiredness ($\rho = -0.12$), and mental fog ($\rho = -0.07$), as seen in figure 13. However, a very small and insignificant correlation was seen for high-calorie food cravings ($\rho = 0.06$) and reported day time energy ($\rho = -0.07$). In order to analyse the relationship between frequency of blue-light reduction feature use and next-day sugary-food cravings, the correlation with blue-light exposure was examined. A slight positive correlation was found ($\rho = 0.076$, $p = 0.546$, $n = 66$).

Finally, as shown in figure 14 the relationship between sleep quality, self-reported sleep quality scores were compared between participants with and without a metabolic condition. Participants with a metabolic condition generally reported lower sleep quality, with a median score of 3, while participants without a metabolic condition had scores more concentrated between 3 and 4. The Mann–Whitney U test showed U = 558.0 and p = 0.065 (n = 65).

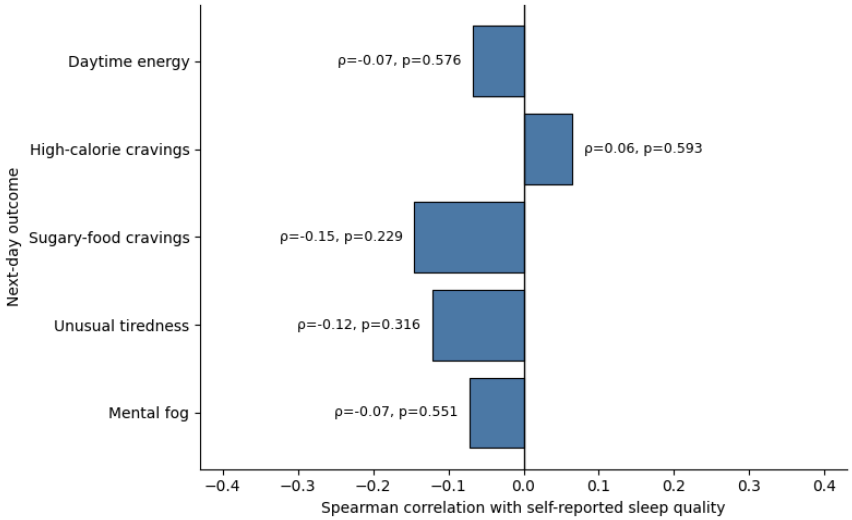


Figure 13: Correlations between self-reported sleep quality and next-day outcomes among survey participants

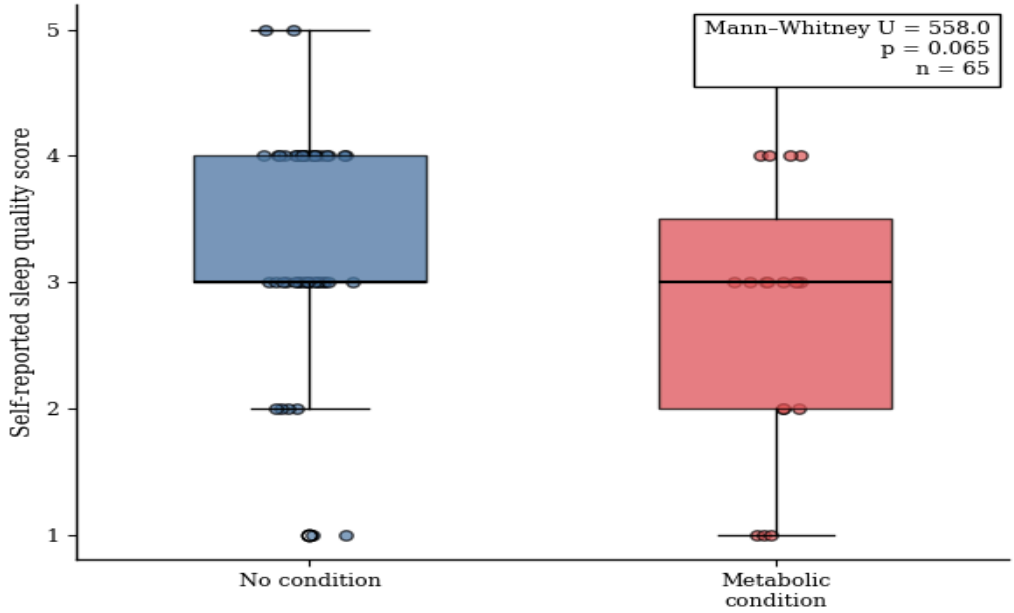


Figure 14: Comparison of self-reported sleep quality between participants with and without a reported metabolic condition

DISCUSSION

Current literature:

Overall, the literature suggests that blue light may contribute to sleep and metabolic disruption, but it is not the only factor involved. The effect of blue-light exposure on sleep quality and metabolic outcomes in adolescents and young adults remains unclear compared with other forms of sleep disruption. This study was conducted to compare the association of smartphone-emitted blue light with sleep quality and metabolic-related outcomes against other forms of sleep disruption in adolescents and young adults.

Survey results vs Literature

No statistically significant association was observed between blue-light reduction feature use and self-reported sleep quality ($\rho = 0.176$, $p = 0.144$). Moreover, the comparison based on screen brightness and filter use was not statistically significant ($U = 55$, $p = 0.290$). The survey did not directly quantify blue-light exposure, so these findings cannot establish whether blue light independently contributes to sleep disturbances. This allowed the conclusion that other aspects of nighttime smartphone use such as bedtime delay and cognitive engagement to also be relevant.

The findings of this study indicated that bedtime smartphone use is very common among adolescents and young adults. 81.4% of the participants used their smartphones before bed often or every night. Daily smartphone and sleep quality did not differ significantly across the age groups included in the survey. Frequent nighttime smartphone users reported greater food cravings and next-day symptoms, and participants reporting metabolic conditions showed more frequent nighttime smartphone use and also tended to report poorer sleep quality.

The survey findings were consistent with current studies as described in the literature review. Both show an association between nighttime smartphone use and poorer sleep quality. In the survey, bedtime smartphone use was associated with poorer sleep quality across subgroups ($\rho = -0.284$, $p = 0.017$). This was also observed by Brosnan et al. (2024), who found that screen use after going to bed was associated with delayed sleep onset and shorter total sleep time. Another important finding was that smartphone overuse was associated with increased symptoms of depression and anxiety, which may contribute to sleep disruption in both duration and quality (Demirci et al. 2015).

The data found no direct relationship of blue-light reduction and smartphone brightness features with sleep quality. The participants who never used a blue-light reduction feature had a mean sleep quality score of 3.10 compared with 3.35 among participants who always used one. Although this suggests a tendency toward better sleep quality among frequent blue light filter users, the relationship was small ($\rho = 0.176$, $p = 0.144$) and not statistically significant. The two groups reported very similar levels of

sugary-food cravings, high-calorie cravings, unusual tiredness, and mental fog. Participants with higher nighttime higher screen brightness and less frequent use of blue-light reduction features had poorer median sleep quality (3.0 vs. 4.0), but the difference was not statistically significant ($U = 55$, $p = 0.290$). These results suggest that blue light reduction alone may not fully explain the relationship between nighttime smartphone use and poorer sleep. When narrowing down smartphone use to blue light exposure, Randjelović et al. (2023) found that reducing smartphone blue-light exposure significantly decreased PSQI scores, indicating improved subjective sleep quality. These results are consistent with Huthsteiner (2022) who found that unfiltered blue-light exposure reduced melatonin levels, worsened sleep quality, increased sleep fragmentation, and lowered the cortisol awakening response in adults. But in adolescents, there were little to no significant effects. This could indicate that adolescents have a different response, the sample size was too low, or how blue-light exposure was measured. The present survey used self-reported blue-light-filter use and screen brightness, not specific wavelengths. In contrast, Huthsteiner (2022) directly exposed participants to unfiltered smartphone light at 448 nm, filtered light at 613 nm, or a printed book for 1.5 hours before bedtime. Therefore, the findings from these experimental studies cannot be directly compared with the self-reported measures used in the present survey.

The survey also shows that smartphone use may disrupt sleep through other behavioral factors, not only blue-light reduction. In the survey, 60% of participants reported that smartphone use delayed their bedtime often or every night. One of the clearest and most statistically significant relationships was difficulty stopping smartphone use before bed, which was also positively associated with more frequent bedtime delay ($\rho = 0.392$, $p = 0.001$). This suggests that smartphones may disrupt sleep not only through light exposure, but also by keeping the participants engaged through social media, gaming, streaming apps and messaging. This can activate dopamine-related reward pathways, and contributes to delayed bedtime (Echevarria et al., 2023) and is consistent with Brosnan et al. (2024), who found that screen use after going to bed was associated with delayed sleep onset and shorter total sleep time.

Smartphone use was not the only factor associated with sleep disruption and delayed bed time among participants. Stress or anxiety was the most commonly reported sleep disruptor ($n = 45$), followed by room temperature ($n = 41$) and smartphone use ($n = 40$). Interestingly, participants in the smartphone use group reported poor mean sleep quality scores ($M = 3.05$). However, the survey indicates that multiple psychological, and environmental factors, like room temperature, may contribute to sleep disruption indicating that this may not be due to smartphone use alone. This could be explained by the fact that non-photic sleep disruptions result in high cortisol levels leading to elevated fasted glucose levels the following morning (Dinneen et al., 1993; Leproult et al., 2014). Circadian misalignment in shift workers reduced insulin sensitivity even when sleep duration was similar between groups (Leproult et al. 2014). This is consistent with the present survey, which showed that sleep disruption was not limited to blue-light exposure, as stress, anxiety and room temperature were reported as sleep disruptors more frequently than smartphone use. However, the survey did not directly measure circadian misalignment or insulin sensitivity, so the findings cannot be directly compared. These findings support the possibility that blue light is not the only pathway connecting sleep disruption with metabolic outcomes.

Improved self-reported sleep quality showed small negative correlations with sugary-food cravings ($\rho = -0.15$, $p = 0.229$), unusual tiredness ($\rho = -0.12$, $p = 0.316$), mental fog ($\rho = -0.07$, $p = 0.551$), and daytime energy ($\rho = -0.07$, $p = 0.576$). High-calorie cravings showed a very small positive correlation with sleep quality ($\rho = 0.06$, $p = 0.593$). These relationships were not statistically significant, which shows that sleep quality alone was not strongly associated with these next-day outcomes among the participants. A clearer pattern was seen when next-day outcomes were compared according to nighttime smartphone-use frequency instead of sleep quality. Frequent nighttime smartphone users reported greater sugary-food cravings, high-calorie cravings, unusual tiredness, and mental fog than lower-frequency users. There were statistically significant differences seen for high-calorie cravings, unusual tiredness, and mental fog.

These findings indicate that frequent nighttime smartphone use was associated with greater self-reported high-calorie food cravings, unusual tiredness, and mental fog in this sample. Some of the previous research has linked sleep disruption to hormonal pathways involved in appetite regulation hormones such as leptin and ghrelin (Klok et al., 2007), these mechanisms were not directly assessed in the present survey. Hence, the observed symptoms cannot be interpreted as evidence of altered hormone levels, glucose regulation, or insulin sensitivity.

Furthermore, participants who reported having a metabolic condition also tended to report poorer sleep quality than those without a reported metabolic condition. The metabolic-condition group had a median sleep-quality score of 3, whereas participants without a reported condition had scores more prevalent between 3 and 4 but this was not statistically significant ($U = 558.0$, $p = 0.065$, $n = 65$). In addition, participants reporting a metabolic condition also showed more frequent nighttime smartphone use. All participants in this group used their smartphones during the hour before sleep either often or every night: 84.2% reporting use every night. In contrast, only 53.3% of participants without a reported condition used their smartphones every night ($U = 577.5$, $p = 0.011$). Taking these observations together, the greater frequency of nighttime smartphone use and poorer sleep among participants with reported metabolic or endocrine conditions shows that these factors may overlap within the sample. This is also consistent with Mark and Janssen (2008) who found that adolescents with greater daily screen time had a higher likelihood of metabolic syndrome, with those reporting five or more hours of daily screen time having over three times the risk compared with those reporting one hour or less.

In the literature review, experimental studies provided more evidence of metabolic changes associated with nighttime light exposure. However, the present survey did not directly measure metabolic biomarkers, so there is no quantitative evidence to directly compare these findings.

However, these results do not establish that nighttime smartphone use, blue-light reduction features or poorer sleep caused the reported metabolic outcomes. The survey was cross-sectional and was solely based on self-reported measures. Direct metabolic biomarkers such as fasting glucose, insulin, HOMA-IR, and OGTT, were not measured.

In this survey, smartphone use, bedtime delay, stress or anxiety, and other forms of sleep disruption showed clearer patterns than blue light. This differs from some of the literature, which showed stronger effects of blue-light exposure. However, the survey is consistent with studies that found limited blue-light-specific effects in adolescents. An inference that delayed sleep itself may lead to metabolic issues and next day outcomes, and not the direct cause of that sleep disruption can be drawn from the survey. This supports the literature showing that blue light can affect sleep and metabolic regulation, and supports some of the papers that show that sleep disruption can also occur through non-photic pathways.

The association between sleep quality and self-reported metabolic-related outcomes in adolescents and young adults appears to involve multiple forms of sleep disruption, which can be behavioral or environmental, rather than blue-light exposure alone. The behavioral mechanisms and effects of smartphone use can outweigh, or be more strongly associated with the effects of smartphone-emitted blue light, as there is a shift from a physical stimulus to a cognitive one, which can have a more significant effect on metabolic health. This shift to cognitive excitement triggers internal stress responses, which raises nighttime cortisol and adrenaline levels that can contribute insulin resistance while the body should be resting (Rao et al. 2015). The findings of this study suggest that this metabolic deregulation may be more strongly associated by the sleep loss itself, caused by the other factors that may stimulate brain activity, rather than blue light which sets a baseline curve for a delayed sleep.

Overall, the survey findings suggest that nighttime smartphone use and behavioral factors may be related to poorer self-reported sleep quality and next-day symptoms. However, because blue-light exposure was not directly measured, the contributions of light exposure and behavioral factors could not be determined. The literature provides evidence of physiological mechanisms, but these cannot be directly established from the present survey.

Limitations:

The survey did not collect participants' weight or body composition, which could influence metabolic outcomes. The sample size is also small, containing only 70 participants. There was an absence of age-specific analyses where one group was compared directly to another which limited the interpretation of potential differences in smartphone use, sleep patterns, and metabolic health indicators between adolescents and young adults could not be independently assessed. In addition, blue-light exposure was not directly quantified, the observed associations cannot be attributed specifically to blue light. There were more female than male participants (an uneven gender distribution). Parental controls may have affected smartphone use, which may occur among younger participants. The survey was conducted during summer vacation, when sleep schedules and smartphone-use habits may differ from those during the school year. The study relied on self-reported data, which may be affected by recall or reporting bias. The survey did not directly measure glucose, insulin, HOMA-IR, or OGTT responses. This limits conclusions about metabolic changes. Some subgroup comparisons, particularly those involving screen brightness and blue-light filter use and self-reported metabolic or endocrine conditions, included relatively small numbers of participants, limiting statistical power and the interpretation of these findings. The study could

not make a direct comparison between blue-light exposure and other forms of sleep disruption because concrete measures were not collected for each type of disruption. The cross-sectional study shows associations, but cannot establish causation.

CONCLUSION

This paper aimed to study the association between sleep quality and night-time exposure to smartphone-emitted blue light, as opposed to other forms of sleep disruption, with measures of self-reported metabolic symptoms in young adults and adolescents. Overall, the literature and survey linked nighttime smartphone use with poorer sleep quality and self reported metabolic-related outcomes while the survey also identified associations with self-reported metabolic-related symptoms.. The literature showed that blue light can disrupt the circadian rhythm, glucose regulation, and insulin sensitivity, but the survey found weaker effects that were specific to blue light reduction. Other forms of sleep disruption (stress and anxiety, room temperature, physical discomfort, and bedtime delay) were also associated with poorer sleep. Frequent nighttime smartphone use was also linked with greater food cravings, tiredness, and mental fog, and the survey found that nighttime smartphone users also reported slightly more metabolic conditions. The findings suggest that blue light may contribute to sleep and metabolic disruption, but it is one of several factors affecting these outcomes. Instead of working alone, blue light sets a delay that becomes much worse when paired with late-night mental stimulation that is a part of smartphone use. Future research should directly measure blue-light exposure, melatonin, glucose, and insulin sensitivity, while also looking at specific measures of nonphotic sleep disruption, to better determine the specific metabolic effects of nighttime smartphone-emitted blue light in adolescents.

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