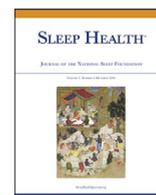


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Does iPhone night shift mitigate negative effects of smartphone use on sleep outcomes in emerging adults?

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ABSTRACT

Objectives: Apple's iPhone Night Shift feature purports to reduce short-wavelength light emissions and improve sleep. We aimed to investigate these claims by comparing emerging adults' sleep outcomes associated with smartphone use before bed with iPhone's Night Shift enabled to two comparison conditions (iPhone use with no Night Shift, no iPhone use).

Design: Participants were randomly assigned to one of three conditions specifying iPhone use during the hour preceding bedtime for seven consecutive nights: iPhone use with Night Shift enabled; iPhone use with Night Shift disabled; and no phone use.

Setting: Participants were recruited from a western undergraduate university.

Participants: A sample of 167 emerging adults (ages 18–24; 71.3% female) with iPhones participated in the study.

Measurements: Sleep outcomes (sleep latency, duration, efficiency and wake after sleep onset) were tracked using wrist-worn accelerometers.

Results: There were no significant differences in sleep outcomes across the three experimental groups. Post-hoc exploratory stratified analyses revealed a significant main effect of phone condition on sleep efficiency ($P = .014$) and WASO ($P = .013$) for participants averaging more than 6.8 hours of sleep per night, with the no phone condition demonstrating the best sleep outcomes. For those averaging less than 6.8 hours of sleep, there was no effect of phone condition on sleep outcomes.

Conclusions: Across our full study sample, there were no differences in sleep outcomes attributable to Night Shift. For individuals who regularly obtained adequate sleep, abstaining from screen use resulted in better quality sleep than did phone use with Night Shift enabled.

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Sleep is an essential health behavior that affects many important areas of human functioning and health.¹ Sleep is particularly important in emerging adults, a developmental period (typically 18–24 years of age) characterized by rapid neural development and social/occupational tasks requiring optimal cognitive performance.² Ideally, emerging adults should obtain 8–9 hours of sleep,³ though this recommendation frequently goes unmet.⁴ One contributor to suboptimal sleep behavior in emerging adults is light exposure around bedtime, especially from smartphones which emit white, short-wavelength light. Human circadian rhythms are highly dependent on light/dark cycles, with onset of darkness increasing secretion of endogenous melatonin which signals for sleep readiness in the brain.⁵ The short-wavelength light emitted from smartphones delays sleep onset, reduces nighttime sleepiness, and delays melatonin secretion and circadian rhythm such that falling asleep at an

appropriate time is more difficult on subsequent nights.^{6–9} While greater screen exposure across the day is associated with shorter sleep and poorer sleep quality,¹⁰ the timing of light exposure is particularly important, with exposure to bright light before bedtime showing more detrimental effects on sleep than earlier in the day.^{11–14}

Ninety-five percent of college students own a smartphone¹⁵ and emerging adults are the most frequent cell-phone users of any age range,¹⁶ warranting research on the effects of these devices on sleep in this population. Smartphone ownership is associated with electronic media use before sleep and later bedtimes, and smartphone and electronic media use is negatively correlated with sleep duration and sleep quality.^{17–19} Experts recommend reducing exposure to screens before bedtime in order to minimize the negative effects of screen use on sleep outcomes.^{13,14,20–23} However, screen restriction is difficult to implement for autonomous emerging adults, making the use of a blue light blocker on a device seemingly more appealing and practical.²⁴

The Apple iPhone Night Shift mode is a feature that purports to limit short-wavelength light emissions. However, there is little

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evidence to support the use of short-wavelength light blocking devices, such as filtering glasses or the Night Shift function, to improve sleep quality in healthy populations, although there may be a small benefit for people with insomnia.^{25,26} The literature is mixed regarding the effectiveness of filtering short-wavelength light on preventing melatonin suppression,^{25,27,28} and preliminary findings suggest that filtering short-wavelength light has no impact on sleep-onset latency or minutes spent in rapid-eye movement sleep (compared to not filtering short-wavelength light), as assessed through laboratory-based polysomnography.²⁹ To our knowledge, no studies have examined the effects of Night Shift on objectively assessed sleep outcomes in free living conditions, limiting our understanding of how utilizing this feature impacts an individual's sleep in their natural environment. Furthermore, no studies have employed a no-screen control group.^{25,27-29} Finally, the existing research has been conducted with either adolescents^{27,29} or older adults²⁵ and extant research has been limited by small sample sizes ($N < 20$; 25, 27, 28, 29).

The current study aims to overcome these limitations by examining the effects of Night Shift on sleep outcomes in a large cohort of emerging adults in a naturalistic setting employing objective sleep assessment methods. Findings from this study have the potential to inform clinical interventions aimed to increase sleep quality in emerging adults, a population at increased risk for poor sleep and heavy screen use. Specifically, our study aimed to examine actigraphy-based sleep outcomes in emerging adults randomized to one of three experimental conditions: using iPhone before bed with Night Shift enabled, using iPhone before bed with Night Shift disabled, and not using iPhone before bed. We hypothesized that emerging adults who abstained from smartphone use before bed would have the best sleep outcomes, followed by those who used phones with the Night Shift feature enabled; we hypothesized that those using phones with the Night Shift feature disabled would have the poorest sleep outcomes.

Participants and methods

Participants

The study sample included emerging adults ages 18-24 who owned an iPhone and used it daily. Participants were recruited with flyers distributed on local college campuses as well as through a university website where students signed up to participate in research studies. Participants were not included if they self-reported that they had a primary sleep disorder diagnosis (eg, insomnia, narcolepsy, sleep apnea), irregular sleep schedules (eg, shift work, bedtimes varying more than four hours across the week), or regularly obtained less than six hours of sleep.

Procedure

The institutional review board of the senior author's institution approved all study procedures. An initial screening for eligibility was conducted by phone, text or email. Eligible participants were asked to download the Moment application on their iPhone (a free application used to track phone usage), were scheduled to attend an initial orientation visit, and were instructed to obtain eight hours of sleep for each of the three nights preceding their orientation visit in order to establish a standardized baseline sleep pattern across participants. Upon arrival to the first lab visit, informed consent was obtained from each participant. After obtaining participant self-reported confirmation that they had obtained eight hours of sleep per night over the prior three days, participants were asked to choose a consistent bedtime between 9:00 p.m. and 12:00 a.m. (in alignment with their normal bedtime) and to agree to spend at least 8 hours in bed following their chosen bedtime. Participants were informed of their

experimental condition, instructed on how to adhere to the experimental protocol, and informed regarding how study staff would determine protocol adherence at their second lab visit. Participants were adorned with a wrist-worn accelerometer (Actigraph GT3X+) worn on their non-dominant wrist, and were instructed to wear the accelerometer at all times except when the participating in high-impact sports or water-based activities (eg, bathing, swimming).

Following the orientation visit, participants completed their experimental condition (outlined below) while wearing the accelerometer and using the Moment application to track smartphone use. Following the experimental week, participants completed the second lab visit, which consisted of returning the accelerometer, visually examining iPhone use on the Moment app to ensure experimental condition adherence, and providing compensation. See Fig. 1 for CONSORT flow diagram.

Experimental manipulation

Participants were randomly assigned to one of the following experimental conditions: 1) 60 minutes of iPhone use directly before bed with Night Shift enabled, 2) 60 minutes of iPhone use directly before bed with Night Shift disabled, or 3) no iPhone use for 60 minutes before bed. All experimental manipulations lasted seven consecutive nights. Research staff demonstrated how to adjust phone brightness and participants who used iPhones prior to bed were instructed to turn their phones to the lowest brightness setting to standardize brightness across phones. For participants in the Night Shift-enabled condition, research staff also demonstrated how to adjust the Night Shift mode to the warmest setting and instructed participants to keep Night Shift on this setting across the experimental week to reduce variability in the amount of blue light filtration. Those in the Night Shift-disabled condition were shown how to disable Night Shift and were instructed to keep Night Shift disabled across the experimental week. All participants were instructed not to use any other light-emitting electronic devices (eg, televisions, computers) during the 60 minutes preceding bedtime, to spend the hour preceding bedtime in their bedrooms to avoid unintended electronic device use, and to not use any light-emitting devices following bedtime. iPhone use was monitored using a free application (ie, "Moment") installed on the iPhone by each participant. All participants texted study staff each morning with their bedtime, wake time, and number of minutes that they engaged in screen time usage during the 4 hours before bedtime (excluding the one hour spent engaging in the experimental manipulation). All participants were also instructed not to consume caffeinated beverages after 2:00 p.m.

Measures

Sleep outcomes

Sleep outcomes were measured using Actigraph GT3X+ wrist-worn accelerometers. Participants wore the accelerometers for the duration of their participation in the study (except when engaging in high impact sports or water activities). Wrist-worn actigraphy devices have been shown to identify polysomnography epochs with 91% accuracy and have been deemed a valid measure of sleep.³⁰ The accelerometers were initialized with zero crossing at 15-second epoch intervals with the ActiLife software.

Experimental condition adherence

Participants downloaded the free "Moment" application to their iPhone. When kept open on the iPhone, this application tracks the total minutes spent on the phone per day and provides a 24-hour

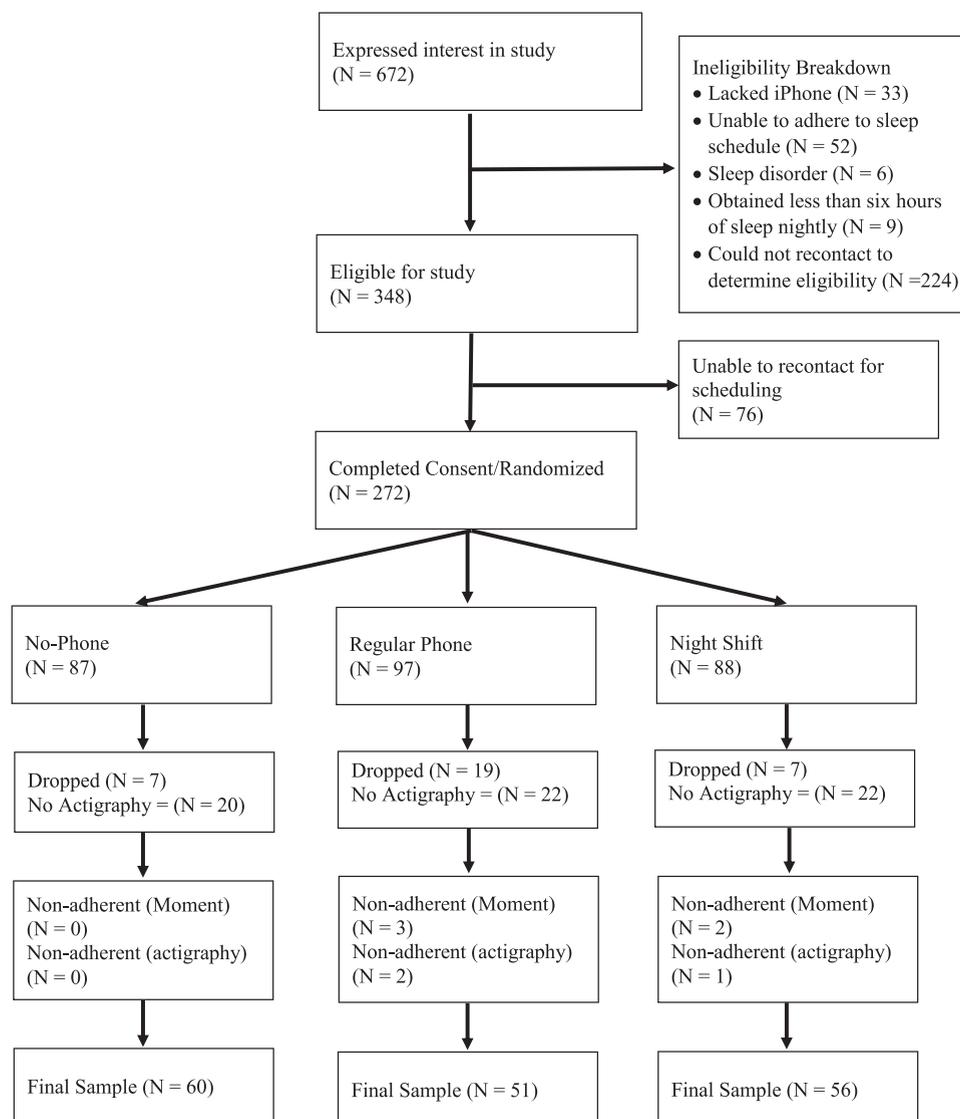


Fig. 1. CONSORT diagram.

display of each instance the user opens his/her phone, how long the phone was used in each instance, and if the user "force-quits" the app (when closed, it cannot track usage). The "Moment" application was used throughout the duration of the study to both ensure participant adherence to study protocol and to calculate total screen time on each given day. If the participant had more than two days that were deemed non-adherent (ie, the participant either 1) had more than a 15 minutes discrepancy between recorded phone use and assigned phone use, based on experimental condition or 2) used the phone for more than 5 minutes after bedtime, their data was excluded from final analysis. Additionally, participants were excluded if their average bedtime (as assessed through actigraphy) varied more than 60 minutes from their originally set bedtime.

Data analysis

Sleep accelerometry cleaning and scoring

Wrist-worn accelerometry data was initialized and downloaded in 60-second epoch intervals within ActiLife5. Total time in bed was established by using sleep diary text message reports of bedtimes and wake times to mark in-bed and out-of-bed times. Data was

excluded if no movement was noted throughout the night. Using the Sadeh sleep algorithm,³¹ we generated a sleep report that included the following outcomes: sleep onset latency, sleep duration, sleep efficiency, and WASO. These generated variables served as the primary outcomes of our study.

Compliance with statistical assumptions

An *a priori* power analyses using G*Power³² revealed that a one-way analyses of variance (ANOVA) with three groups required a sample of 177 individuals to allow for .95 power and a .05 alpha to detect a medium effect size of .30, suggesting that our sample size is adequate to evaluate study hypotheses. We confirmed that the standardized residuals of each primary outcome were normally distributed and homogeneous. Twenty-three participants did not have full Moment data (on one or more days the Moment application did not track screen usage), precluding assessment of study adherence for these participants. Analyses were run both including and excluding these participants, and no significant differences in study findings were noted. Therefore, we assumed adherence for these 23 participants and retained them in our final analyses.

Analyses for hypotheses

We ran four one-way between-groups analyses of variance (ANOVAs) to determine the impact of experimental condition (no-phone, phone use with Night Shift enabled, phone use with Night Shift disabled) on sleep onset latency, sleep efficiency, total sleep time, and WASO. In instances of a significant main effect of experimental condition, Tukey post-hoc analyses were used to examine group differences in the sleep outcome being examined. To determine whether covariates were to be included in the ANOVAs, we regressed a number of theoretical covariates on each of our primary outcomes, including age, income, and averaged minutes of screen use in the four hours before bed. We also conducted a between-subjects t-test to examine whether our primary outcomes differed by participant sex. No theorized covariates emerged as significant predictors of our primary outcomes (all p 's > .10) and none were included in the final ANOVAs.

While we experimentally controlled for participant bedtime, we did observe variability in median sleep duration over the experimental period. Given that consistently restricted sleep can influence sleep characteristics,³³ we conducted exploratory stratified analyses to determine if our primary outcomes differed by total sleep duration across the week. We used a median split of averaged total sleep time to dichotomize the population, using this dichotomized variable to re-run all study analyses as two-group analyses.

Results

Sample characteristics

Our final study sample consisted of 167 emerging adults (M age = 20.86, SD = 2.13; 71.3% female; see Table 1 for sample characteristics at baseline). No significant demographic differences existed between those who completed the study and those who did not. Across the seven nights of the experimental manipulation, actigraphy revealed that participants across conditions obtained a median of 6.82 (0.54) hours of total sleep time (range 4.85–8.02), had a sleep onset latency of 11.84 (6.93) minutes (range 0.43–44.57), were awake for 66.46 (28.61) minutes during the night (7.29–158.11), and had a sleep efficiency of 83.68% (6.27; range 62.29%–97.99%).

Sleep outcomes

We conducted a series of one-way between groups ANOVAs to explore the impact of experimental condition on primary sleep

Table 1
Sample characteristics at baseline

	Percent or mean \pm SD
Female (%)	71.3
Race/ethnicity (%)	
White, non-Hispanic	74.9
Black, non-Hispanic	1.2
Hispanic	10.8
Asian	10.8
Multiracial	2.4
Age (years)	20.86 \pm 2.13
Mean family income (%)	
60K or less	35.9
>60K and <=125K	37.3
>125K	26.8
Living situation (%)	
Parents	6.6
Roommates	70.1
Spouse	18.0
Other	5.4

Sample features at time of randomization. Categorical variables are listed in percentages, while normally distributed variables are listed as mean \pm SD.

Table 2
Actigraph-estimated sleep parameters across experimental condition

	Condition	Mean (SD)	Condition effect
Sleep onset latency (min)	No phone	11.45 (7.25)	$P = .85$
	Regular phone	11.91 (6.19)	
	Night shift	12.18 (7.31)	
Sleep efficiency (%)	No phone	83.80 (6.59)	$P = .86$
	Regular phone	83.92 (6.67)	
	Night shift	83.31 (5.59)	
Total sleep time (min)	No phone	400.79 (35.28)	$P = .59$
	Regular phone	404.80 (34.00)	
	Night shift	406.93 (28.57)	
WASO (min)	No phone	65.67 (30.26)	$P = .81$
	Regular phone	75.18 (30.17)	
	Night Shift	68.47 (25.57)	

WASO, wake after sleep onset.

outcomes. We did not observe a significant impact of experimental condition on sleep onset latency ($F(2, 164) = .16, P = .85, \eta^2 = .002$), sleep efficiency ($F(2, 164) = .15, P = .86, \eta^2 = .002$), total sleep time ($F(2, 164) = .53, P = .59, \eta^2 = .006$), or WASO ($F(2, 164) = .21, P = .81, \eta^2 = .003$). See Table 2 for experimental group means across primary sleep outcomes.

Because we noted significant variability in total sleep duration, we then conducted exploratory two-group stratified analyses for individuals who fell above and below the median for total sleep time (6.82 hours). One-way between-group ANOVAs were used to examine the impact of experimental condition on primary sleep outcomes in each subgroup. For those who fell below the median cutoff for average total sleep time, we failed to observe a significant impact of experimental condition on sleep onset latency (p 's > 0.4).

For those who fell above the sleep-duration median cutoff, we observed similar non-significant condition effects on sleep onset latency ($P = .72$) and total sleep time ($P = .43$). However, we did observe a significant main effect of condition on sleep efficiency ($F(2,$

Table 3
Actigraph-estimated sleep parameters across experimental condition stratified by median total sleep time

Participants below median ($N = 83$)			
	Condition	Mean (SD)	Condition effect
Sleep onset latency (min)	No phone	13.38 (8.61)	$P = .53$
	Regular phone	13.08 (6.33)	
	Night shift	15.34 (8.14)	
Sleep efficiency (%)	No phone	79.16 (4.47)	$P = .89$
	Regular phone	79.87 (6.42)	
	Night shift	79.28 (5.56)	
Total sleep time (min)	No phone	375.24 (30.04)	$P = .45$
	Regular phone	380.96 (26.46)	
	Night shift	384.43 (24.65)	
WASO (%)	No phone	85.21 (27.87)	$P = .94$
	Regular phone	82.61 (29.95)	
	Night shift	84.65 (27.55)	
Participants above median ($N = 82$)			
	Condition	Mean (SD)	Condition Effect
Sleep onset latency	No phone	9.38 (4.77)	$P = .72$
	Regular phone	10.60 (5.88)	
	Night shift	9.83 (5.60)	
Sleep efficiency	No phone	88.78 (3.13)	$P = .01$
	Regular phone	88.49 (3.02)	
	Night shift	86.57 (2.94)	
Total sleep time (min)	No phone	428.11 (12.68)	$P = .43$
	Regular phone	431.62 (17.42)	
	Night shift	426.16 (15.71)	
WASO	No phone	44.79 (14.95)	$P = .01$
	Regular phone	45.57 (14.38)	
	Night shift	55.31 (14.49)	

WASO, wake after sleep onset.

Table 4
Tukey post-hoc analyses—experimental group comparisons sleep efficiency (%)

Condition (I)	Condition (J)	Mean difference (I-J)	Standard error	Sig
No phone	Regular phone	0.29	0.84	<i>P</i> = .94
	Night shift	2.21	0.80	<i>P</i> = .02
Regular phone	No phone	-0.29	0.84	<i>P</i> = .94
	Night shift	1.92	0.84	<i>P</i> = .06
Night shift	No phone	-2.21	0.80	<i>P</i> = .02
	Regular phone	-1.92	0.84	<i>P</i> = .06
Wake after sleep onset (minutes)				
Condition (I)	Condition (J)	Mean difference (I-J)	Standard error	Sig
No phone	Regular phone	-0.78	4.04	<i>P</i> = .98
	Night shift	-10.52	3.84	<i>P</i> = .02
Regular phone	No phone	0.78	4.04	<i>P</i> = .98
	Night shift	-9.74	4.04	<i>P</i> = .047
Night shift	No phone	10.52	3.84	<i>P</i> = .02
	Regular phone	9.74	4.04	<i>P</i> = .047

79) = 4.48, *P* = .014, $\eta^2 = .10$; Table 3) for individuals who averaged 6.82 hours or more of nightly sleep across the week. Tukey post-hoc analyses revealed that participants in the no-phone condition had significantly better sleep efficiency compared to the Night Shift condition (*P* = .018); all other comparisons of sleep efficiency across experimental conditions were non-significant (Table 4). We also observed a significant main effect of condition for participants who fell above the sleep-duration median cutoff on WASO estimates (*F* (2, 79) = 4.55, *P* = .013, $\eta^2 = .10$; Table 3). Tukey post-hoc analyses revealed that those in the no-phone condition had significantly lower WASO estimates than those in the Night Shift condition (*P* = .021). Interestingly, we also observed that those who were in the iPhone without Night Shift condition had significantly improved WASO estimates compared to the Night Shift Condition (*P* = .047). No significant differences were noted between the No-Phone and the iPhone without Night Shift phone condition (Table 4).

Discussion

Due to the deleterious effects of light emitting device use on sleep, approaches to mitigate these effects (ie, short-wavelength light filters) have high appeal, particularly for emerging adults who generally have short sleep duration and frequently use smartphones at bedtime. We aimed to test whether the Night Shift feature on the iPhone, a feature purported to filter short-wavelength light to optimize sleep, improved objectively measured sleep outcomes. To do so, we compared sleep outcomes across three groups: using one's phone before bed with the Night Shift enabled, using one's phone before bed with Night Shift disabled, and not using one's phone before bed.

Contrary to our original hypotheses, we did not detect differences in sleep outcomes across the three experimental groups. Our three study groups demonstrated comparable means for total sleep time, time taken to fall asleep, amount of time spent awake after falling asleep, and sleep efficiency regardless of their group assignment. Our study findings paired with the previous literature does not support short-wavelength light filters (such as Night Shift) as sleep improving interventions, whether measured by sleep characteristics (eg, sleep duration, sleep-onset latency; 29), melatonin onset,^{25,27,28} or minutes spent in rapid-eye movement sleep.²⁹

Interestingly, despite having instructed all study participants to spend at least eight hours in bed with the intention to sleep, we observed that the total average sleep duration for this population was 6.82 hours during our sleep modification window. Furthermore, we found that the average sleep efficiency within our sample was less than 85%, which would qualify the majority of this young adult population as having "poor" sleep efficiency.³⁴ While poorer sleep efficiency is not uncommon in emerging adults,³⁵ the lower sleep efficiency observed in this sample may have been due, in part, to

study participants being assigned to sleep eight hours in bed, which may have exceeded their habitual sleep duration. Given that both acute and prolonged bouts of insufficient sleep can alter the sleep architecture and quality of sleep on subsequent nights,^{33,36} we suspect that the lack of group differences may be driven by the fact that our study population was, in general, sleep deprived.

Because chronic sleep debt may attenuate the effects of light exposure on sleep outcomes (eg, sleep-onset latency), we stratified our sample to explore whether those who fell above or below the sleep duration median demonstrated the hypothesized effects on our primary sleep outcomes. Not surprisingly, those who were obtaining less than the sleep duration median continued to have no differences in their sleep outcomes across experimental groups. This suggests that, for individuals who are chronically sleep deprived, phone exposure prior to bed (with or without Night Shift enabled) does not significantly worsen sleep outcomes. This lack of group effect is likely due to increased homeostatic pressure to sleep³⁴ that decreases the impact of extraneous factors on sleep.

Interestingly, those who fell above the population median for average sleep duration across the experimental week did demonstrate differences in sleep outcomes across experimental groups, with those in the no-phone condition having significantly greater sleep quality (ie, more efficient sleep and less time spent awake during sleeping hours) than those using their phone in the Night Shift condition. Notably, Night Shift use did not produce superior sleep outcomes relative to the iPhone without Night Shift, suggesting that even for (relatively) well-rested emerging adults, Night Shift does not confer advantage in relevant sleep outcomes for those who use iPhones before bed. We unexpectedly observed that those using Night Shift had more night wakings than those using their phone without Night Shift, suggesting that future studies examining the role of Night Shift on sleep quality may be warranted. Taken together, these findings suggest that as emerging adults approach recommended sleep duration, phone use prior to bed may negatively impact the overall quality of sleep, even with Night Shift enabled. Similar trends were recently observed in an adolescent population, where restricting phone use one hour before bed resulted in longer sleep duration than when allowed free access to phones before bed³⁷; however, this study did not explore mechanisms that drove these differences, such as short-wavelength light exposure.

It is notable that the findings from this naturalistic study are similar to those reported in more highly controlled laboratory studies.^{28,29} While naturalistic studies are limited in their ability to experimentally control for extraneous factors that may increase the variability in sleep outcomes, they enhance the ability to generalize study findings outside of laboratory settings. Our study findings suggest that for emerging adults who are given the opportunity to sleep in their own bed and given freedom to interact with their phone how they prefer, phone use prior to bed may negatively impact sleep, even with Night Shift enabled. Characteristics of smartphone use before bedtime other than light exposure may play a role in sleep quality and duration. For example, smartphone use increases a variety of other alertness-inducing processes including social cognition, attention, and executive neural functions. Several studies have reported that psychological arousal resulting from electronic device use can increase sleep onset latency.^{18,38} Our findings suggest that additional research examining psychological arousal as a potential mechanism for smartphone-related sleep problems is warranted.³⁹

Our findings have several implications for sleep improvement interventions. First, our study provides evidence that abstaining from phone use within the hour before bedtime produces superior sleep outcomes relative to smartphone use, with short-wavelength light being associated with poorer sleep outcomes for individuals attaining adequate sleep duration. Second, our findings imply that young adulthood is a challenging time period to implement sleep change

and smartphone use interventions. Even when instructed to sleep 8 hours per night, our participants' mean sleep duration was under 7 hours and only 62.4% of our initially randomized sample completed the experimental protocol, speaking to the challenges of altering sleep and phone use during emerging adulthood even when using prescriptions and monetary incentives, a finding which has also been documented in adolescent samples.³⁷

Our study was among the first to examine how iPhone Night Shift impacted sleep in a large sample of emerging adults – a population at risk for shorter sleep duration and increased screen use – and was the first to use a no-screen control condition in examining the impact of Night Shift on sleep outcomes. We also employed a flexibly rigorous study design which extended previous laboratory research and allowed for better representation of individual sleep patterns and environments. Our naturalistic, week-long study design also enhanced generalizability and allowed us to evaluate habitual sleep patterns, rather than observing sleep outcomes following limited nights spent in a sleep laboratory. Additionally, our use of wrist-worn accelerometers as an objective measure of sleep strengthened the assessment of our primary outcomes.

A free-living study of sleep behavior is accompanied by several limitations, including limited ability to track important variables including adherence to phone use instructions prior to bed, avoiding other light-emitting devices prior to and after bedtime, and keeping phone settings consistent throughout the week. While the Moment application provided useful information that helped inform adherence to study instructions, we were unable to determine adherence for approximately 14% of our study population due to malfunctions in the Moment application. While our approach to tracking adherence was theoretically more objective than relying on often unreliable self-report of phone use⁴⁰ or other applications that only provided a daily total of screen use, additional methods to assess and track phone use are needed. While we set Night Shift features on the participant's phone with them in person and instructed them to leave these settings on during the duration of the study, we were unable to determine whether the Night Shift features remained on/off as instructed. Furthermore, despite setting bedtimes and wake times with the participant to allow for eight hours of sleep, nearly all of our study sample obtained less than eight hours of sleep, restricting our overall range of sleep duration and potentially limiting our ability to detect differences across experimental groups. While we did allow participants to self-select their bedtimes to enhance the alignment of the assigned sleep schedule with individual circadian rhythms, we did not explicitly assess or control for individual chronotype. Additionally, we were not able to control for ambient light exposure preceding sleep onset, size of iPhone or the distance of the iPhone from the participant's face, or what specific activities participants engaged in on their phones during the experimental manipulation window. This, paired with enrolling a largely Caucasian sample, limits the generalizability of this study.

Conclusions

These study findings suggest that not using a smartphone was superior to use of phone with Night Shift for emerging adults obtaining adequate sleep; those who were consistently receiving less sleep showed no differences in sleep outcomes, regardless of phone or Night Shift use before bed. We conclude that aspects of phone use beyond short-wavelength light must be contraindicative to sleep, such as engagement in stimulating activities (eg, social networking, texting) that increases physiological arousal that makes sleep difficult. Future research that examines these unique contributions of phone use on sleep outcomes is critical.

Human subjects protection

The methods described in this paper were approved by the Human Subjects Committee at Brigham Young University and are in keeping with the Ethical Principles and Standards of the American Psychological Association.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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