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Article

The influence of remote learning on sleep patterns of teenagers

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SUMMARY

A healthy sleep pattern is crucial to the overall health and wellbeing of teenagers, and poor sleep patterns can harm school performance. Due to stay-at-home orders mandated by the governor of Ohio in March 2020, students were converted to remote learning. The purpose of this study was to compare the sleep patterns of teenagers before the stay-at-home orders and during remote learning. Individual chronotypes impact peak productivity, and remote learning imposed by the COVID-19 pandemic provides a unique opportunity to study how teenagers may take advantage of their chronotype for optimal learning. Data was collected using an online survey distributed to teenagers in the Greater Cincinnati area. The survey completed by 141 participants compared teenagers' overall sleep habits and attitude towards school before and during the remote learning period. During the stay-at-home orders, teenagers participating in remote learning extended their sleep duration by 1-2 hours, resulting in 83% of surveyed teenagers receiving healthy sleep amounts and 55% reporting feeling more rested. Sleep patterns of teenagers were also altered by the stay-at-home orders, as seen by the significant shift to later bedtimes and wake times. Later wake times and bedtimes align with the self-reported night owl chronotype reported by a majority of respondents. These results can help create more effective learning periods for adolescents that optimize personal chronotype.

INTRODUCTION

The COVID-19 pandemic changed many aspects of society, including the way teenagers learn. On March 12, 2020, Governor DeWine of Ohio ordered the first statewide school closure to start on March 17, 2020. Due to the stay-at-home orders mandated by the governor of Ohio, teenagers rapidly converted to remote learning. The various remote learning styles adopted by different schools changed the learning environment and daily schedules, including required wake times, which impacted adolescent sleep schedules.

Sleep is a key component in overall health and well-being. The American Academy of Sleep Medicine recommends that teenagers should sleep 8–10 hours in a 24-hour period (1). Short sleep duration is defined as less than 8 hours of sleep (2). The Centers for Disease Control and Prevention (CDC) analysis of the 2015 National Youth Risk Behavior revealed that approximately 72% of teenagers have short sleep duration (2). Insufficient sleep duration among adolescents has potential adverse effects on adolescent cardiometabolic health (3, 4), poor mental health (5-7), increased likelihood of risky behavior (8, 9), increased risk of accidents (10), and poor academic performance (11, 12). Additionally, the CDC reports that teenagers who get less than the recommended 8-10 hours of sleep per night are at a greater risk for obesity and diabetes (2). Sleep patterns of adolescents over the last one hundred years reveals a decrease in sleep duration, approximately 1 hour less per night (13). Studies have documented that adolescents sleep later and longer than adults (14), however adolescents are losing sleep time during the week due to school, work, and other social engagements. Adolescents who have later bedtimes but wake up early in the morning for school are operating on sleep debt, and sleep debt is known to decrease performance, mood, and attention (15). During early to late adolescence, sleep duration increases on the weekends to make up for lost time on weekdays (16, 17).

An individual's preferred sleep timing and "diurnal preference" are described as chronotypes (18). Chronotypes can be categorized as either larks, who prefer an early-to-bed, early-to-rise sleep schedule, or owls, who prefer a late-to-bed, late-to-rise schedule. Studies have revealed that an individual's chronotype is tightly linked to sleep duration, whereby owl chronotypes, which include many adolescents, have shorter sleep durations on school or work days (18). Early start times of schools can inhibit the required sleep duration for the maturing adolescent. School start times have been a matter of debate in recent years not only because late chronotypes do not perform as well at school in the morning (19) but also because sleep is a key component in the overall health of the individual. Therefore, a change in school start time could be beneficial for all teenagers, and especially those individuals with the owl sleeping pattern. During the stay-at-home orders, many teenagers were able to shift their wake and bedtimes because many schools did not conduct virtual learning on the regimented synchronous schedule. Due to the removal of early school start times and adoption of asynchronous learning plans by many schools during the stay-at-home orders, the teenagers were able to have greater flexibility with their wake times and bedtimes.

The objective of this study was to determine if there was a difference in the sleeping patterns of teenagers when rapidly changing to a remote learning environment. There has not been a pandemic in the 21st century in which school districts had to completely change and adapt educational content delivery and essential services within days. To learn more about the impact of the rapid adaptation of the remote learning environment on the sleep patterns of teenagers, we developed a survey that asked participants a series of questions including chronotype self-identification, wake times, bedtimes, energy

levels, nap patterns, and their opinions about learning before and during the stay-at-home orders. The online survey was distributed to 141 participants enrolled at 13 high schools in the Cincinnati area, both private and public schools. Our hypothesis was that teenagers exposed to remote learning styles during the stay-at-home orders would receive more hours of sleep per night, and feel more rested than before the stay-at-home orders. As a result of the change in school start times during remote learning, more students were getting healthy sleep and achieving longer sleep durations.

RESULTS

A sleep pattern survey was created to ask high school students about their overall sleep habits, attitudes towards learning, caffeine intake, and napping habits before and during remote learning that occurred in the spring of 2020 in Ohio during the COVID-19 pandemic.

Demographic data results

The demographic data of the 141 recruited participants is organized in **Table 1**. The mean age of the teenage participants was 16.0 (range 13-18) years, and all participants were enrolled in grades 8–12. The majority of the responses (71%) were private school students, while 29% of the responses were from students enrolled at public schools. Unpaired t-tests comparing private school to public school student responses showed no significant difference ($p < 0.05$); therefore, data from both groups were combined. The race category shows that 91% of the participants in the survey identified as White, 5% identified as Black or African American, 4% identified as Asian, and 1% identified as American Indian or Alaskan Native. Nearly 97% of the respondents had at least one parent or guardian who had completed college (data not shown).

Table 1: Demographics of survey respondents.

	% respondents (n[a])
Gender	
Male	43% (60)
Female	57% (81)
Race	
American Indian or Alaskan Native	1.4% (2)
Asian	4.3% (6)
Black or African American	5.0% (7)
White	91.3% (129)
Ethnicity	
Hispanic, Latino, Spanish Origin	Yes: 4.9% (7) No: 95.1% (134)
Grade level	
8th	10% (14)
9th	22% (30)
10th	26% (36)
11th	20% (28)
12th	22% (31)
Age, years	16 ± 1.48[b]
13	6% (9)
14	9% (13)
15	21% (29)
16	25% (35)
17	18% (26)
18	21% (29)
Type of School	
Private	71% (99)
Public	29% (41)
Self-Identified Chronotype[c]	
Morning Lark	27% (35)
Night Owl	73% (95)

[a] Categories might not sum to sample total due to missing responses.
[b] Mean ± standard deviation
[c] Survey participants were asked to self-identify their chronotype with the following question, "How would YOU describe your sleep patterns?" Responses were "I am a night owl. (I go to bed later in the evening and wake up later in the morning) or "I am a morning lark. (I go to bed earlier in the evening and wake up earlier in the morning)."

Self-reported chronotype

The survey asked participants to self-identify a chronotype (**Table 2**). The majority of teenagers who participated in the study (73%) identified with the night owl chronotype. Those who self-identified as morning lark represented 27% of the respondents. Overall, the data was grouped by chronotype. Of the respondents who self-identified as the morning lark chronotype, 74% were female and 26% were male (data not shown). For the night owl chronotype, 55% of these respondents identified as female and 45% as male (data not shown).

Sleep duration and feeling rested

Prior to the stay-at-home orders, 54% of morning larks and 67% of night owls reported insufficient sleep duration, which is defined as less than 8 hours of sleep per night (**Figure 1A**). During the stay-at-home orders, both the morning lark and night owl chronotypes reported an increase in their sleep duration. Out of all the participants, 80% of the respondents received healthy sleep amounts, defined as 8 or more hours of sleep per night (1). The remaining 20% of the respondents reported insufficient sleep durations during the stay-at-home orders. There was a significant decrease in the number

Table 2: Morning lark and night owl wake and bedtimes on school days before and during the State of Ohio stay-at-home orders in Spring 2020. Participants were asked, "What time did you usually wake up on school days DURING/BEFORE the stay-at-home orders (remote learning)?" and, "What time did you usually go to bed on school nights DURING/BEFORE the stay-at-home orders (remote learning)." Possible responses for wake times were "6am-7am," "7am-8am," "8am-9am," "9am-10am," "10am-11am," "11am-noon," and "after noon," and for bedtimes were "9pm-10pm," "10pm-11pm," "11 pm-midnight," "Midnight-1am," "1am-2am," and "Other."

	Wake time		
	Morning larks[a]	Night owls	
Before	5:50-6:50 AM[b]	6:04-7:04 AM	n.s.[c, d]
During	7:34-8:34 AM	9:08–10:08 AM	p=0.001
	p=0.001	p=0.001	
	Bedtime		
	Morning larks	Night owls	
Before	9:53-10:53 PM	10:53-11:53 PM	p=0.001
During	10:50-11:50 PM	11:50 PM-12:50 AM	p=0.001
	p=0.001	p=0.001	

[a] Chronotype was self-identified by participant.
[b] Wake times and bedtimes are reported as a mean range. Potential answers were in one hour increments.
[c] n.s. = not significant ($p > 0.05$)
[d] Statistical tests compared times between morning larks and night owls as well as before and during stay-at-home orders using a one-way ANOVA with a post-hoc Tukey HSD analysis.

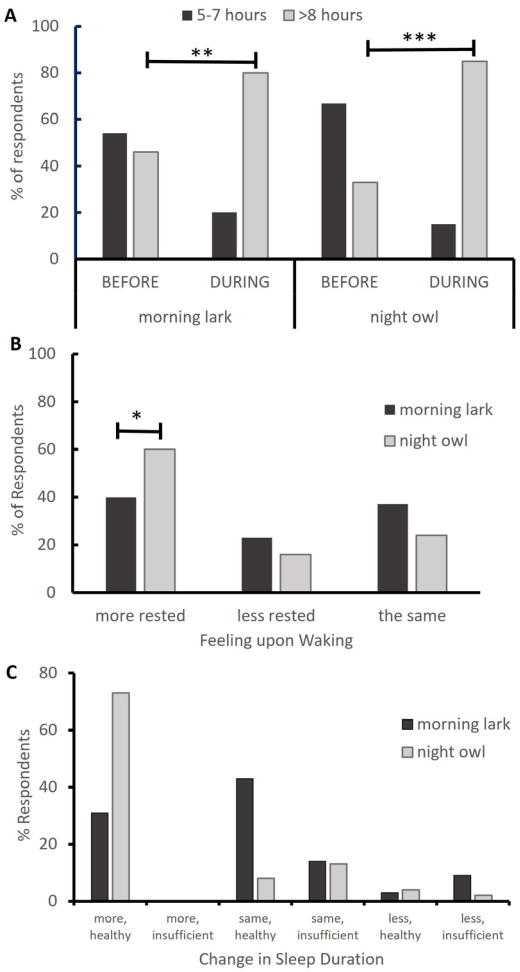

Figure 1: (A) Teenagers participating in the survey were asked the question, "On average, how many hours of sleep did you get on school nights DURING the stay-at-home orders and BEFORE the stay-at-home orders?" Possible responses were "5-7 hours", "8-9 hours", "9-10 hours", "more than 10 hours", and "other." To examine the difference between chronotypes, the proportion of morning larks and night owls who reported healthy sleep (>8 hours per night) and insufficient sleep (< 8 hours per night) were calculated and analyzed with a Z-test for proportions. Significantly more morning larks (p = 0.003) and night owls (p < 0.00001) received healthy sleep during the stay-at-home orders compared to before the stay-at-home orders. Significantly fewer morning larks (p = 0.003) and night owls (p < 0.00001) had restricted sleep during the stay-at-home orders compared to before the stay-at-home orders. **(B)** Teenagers participating in the survey were asked the question, "During the stay-at-home orders, how do you feel upon waking up in comparison to before stay-at-home orders? Possible responses were "I have felt more rested," I have felt less rested," and "I feel the same." To examine the difference between chronotypes, the proportion of morning larks and night owls who reported feeling more rested, less rested or the same during the stay-at-home orders were calculated and analyzed with a Z-test for proportions. Significantly more night owls (p = 0.042) reported feeling more rested compared to morning larks. **(C)** Change in sleep duration on school nights for each chronotype was calculated using the average hours of sleep before and during the stay-at-home order that each respondent reported. Teenage respondents were grouped based on if they received more sleep, the same amount of sleep or less during the stay-at-home orders and whether or not the change in direction was towards a healthy duration (>8 h) or insufficient amounts (<8 h).

of morning larks (p = 0.002) and night owls (p < 0.00001) reporting insufficient sleep duration during the stay-at-home orders. During the stay-at-home orders, 80% of morning larks and 85% of night owls received healthy sleep (**Figure 1A**) which reflects a significant increase in healthy sleep for morning larks (p = 0.002) and for night owls (p < 0.00001).

The change in sleep duration for each respondent was evaluated to determine if there were students who were receiving healthy sleep before the stay-at-home orders that switched to receiving insufficient sleep. Overall, 5% of the total respondents reported a change from healthy sleep duration before the stay-at-home orders to insufficient sleep during the stay-at-home orders (**Figure 1B**). A larger proportion of morning larks, 9%, changed from healthy sleep duration to insufficient sleep compared to night owls, 2%. The majority of night owls, 73%, changed to longer sleep durations that were healthy amounts (>8 h), and the majority of morning larks, 43%, reported that their sleep duration remained the same and were healthy amounts (**Figure 1B**). In addition to receiving more hours of sleep per night, 60% of the respondents who self-reported as night owls also reported that they felt more rested during the stay-at-home orders (**Figure 1C**).

Wake times and bedtimes based on self-identified chronotype for school days

Before the stay-at-home orders, self-identified morning larks reported a mean wake time range of 5:50-6:50 AM on school days (**Table 2**). Self-identified night owls reported a mean wake time range of 6:04-7:04 AM on school days (**Table 2**). During the stay-at-home orders, there was a significant shift to later wake times (**Figure 2A, B**). The mean wake-up range for morning larks was 7:34-8:34 AM, which is 84 minutes later in the morning compared to the reported wake times before the stay-at-home orders (p = 0.001). The mean wake-up range for night owls during the stay-at-home orders on school days was 9:08-10:08 AM, which is 124 minutes later in the morning than before the stay-at-home orders (p = 0.001). Morning larks reported a mean bedtime range on school days of 9:53-10:53 PM (**Table 2**). Night owls reported a mean bedtime range on school days of 10:53-11:53 PM

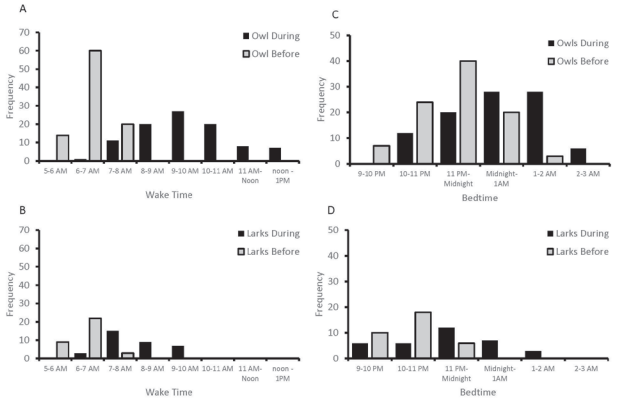

Figure 2: Distribution of self-reported wake times and bedtimes on school days for different self-identified chronotype groups. Distribution of (A) night owl and (B) morning lark wake times on school days before and during stay-at-home orders are shown on the left. Distribution of (C) night owl and (D) morning lark bedtimes on school days before and during stay-at-home orders are shown on the right.

(**Table 2**). During the stay-at-home orders, morning larks and night owls had a significant difference in their bedtimes, reporting going to bed later in the evening (**Figure 2C, D**). The morning larks reported a mean bedtime range of 10:50-11:50 PM, one hour later compared to their bedtimes before the stay-at-home orders (p = 0.001) (**Table 2**). Night owls reported a mean bedtime range of 11:50 PM-12:50 AM, one hour later compared to their bedtimes before the stay-at-home orders (p = 0.001) (**Table 2**). Both morning larks and night owls reported later wake times and bedtimes on school days during the stay-at-home orders.

Wake times and bedtimes based on self-identified chronotype for non-school days

The quarantine also shifted the non-school day sleep habits between the morning larks and night owls (**Figure 3**). Although there was a significant difference between the morning lark and night owl sleep habits (p = 0.001), there was no significant difference between morning lark sleep behavior before and during the stay-at-home orders on non-school days. The mean wake time range on non-school days before stay-at-home orders was 8:00-9:00 AM for morning larks and during the stay-at-home orders it was 8:26-9:26 AM (**Table 3**). The night owl chronotype had a significant difference between mean wake time range before the stay-at-home orders in comparison to during the stay-at-home orders. Before the stay-at-home orders, night owls had a mean wake up time range of 9:23-10:23 AM on non-school days, while during stay-at-home orders it shifted to 10:03-11:03 AM (p = 0.001) (**Table 3**).

Morning larks had a calculated mean bedtime range of 11:21 PM-12:21 AM both before and during the stay-at-home orders on non-school days. However, the night owls had a significant shift in their bedtimes before and during the stay-at-home orders on non-school nights. Those who self-reported as night owls had a mean bedtime range of 11:57 PM-12:57 AM on non-school days before the stay-at-home orders and this shifted to a significantly later mean bedtime range of 12:32-1:32 AM (p = 0.006) during the stay-at-home orders (**Table 3**). Morning larks maintained their earlier-to-rise, earlier-to-bed sleep patterns on non-school nights during the stay-at-home orders whereas night owls woke up later in the morning and stayed up later at night on non-school days.

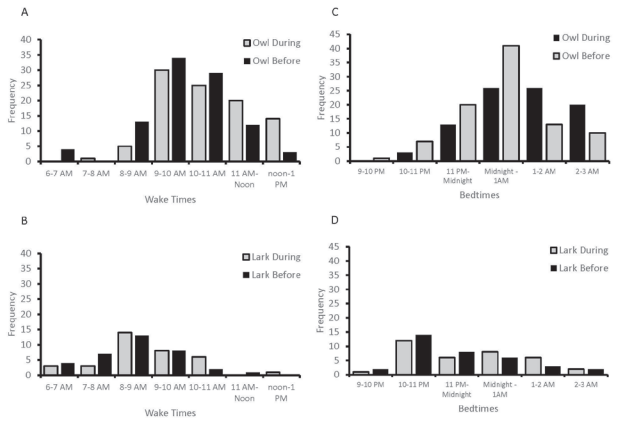

Figure 3: Distribution of self-reported wake times and bedtimes on non-school days for different self-identified chronotype groups. Distribution of (A) night owl and (B) morning lark wake time on non-school days before and during stay-at-home orders are shown on the left. Distribution of night owl (C) and morning lark (D) wake time on non-school days before and during stay-at-home order are shown on the right.

Weekend oversleep and bedtime delay

We further evaluated differences between the sleep patterns of the students separated by self-reported chronotype by calculating weekend oversleep and weekend bedtime delays. Weekend bedtime delays reflect the difference in bedtimes on the weekend in comparison to school nights. Comparison of weekend bedtime delays between morning larks and night owls, before and during the stay-at-home orders, revealed mean weekend bedtime delays with no significant difference between groups (**Table 4**). Weekend oversleep is the difference in sleeping later in the morning on non-school days compared to school days. Night owls had a mean 132 minute oversleep on weekends before the stay-at-home orders, almost 2 times more than the 63 minute weekend oversleep of morning larks (**Table 4**). This weekend oversleep is a significant difference between the chronotypes (p = 0.001). During the stay-at-home orders, night owls had a mean weekend oversleep of 23 minutes, which is a significant decrease compared to before the stay-at-home orders (p = 0.001). Additionally, the night owls' mean weekend oversleep of 23 minutes is not significantly different compared to the morning larks' 21 minute average weekend oversleep (p = 0.899).

Napping and consumption of caffeinated beverages

The survey contained questions that asked participants about their napping habits before and during the stay-at-

Table 3: Morning lark and night owl wake and bedtimes on non-school days before and during the State of Ohio stay-at-home orders in Spring 2020. Participants were asked, "What time did you usually wake up on non-school days DURING/BEFORE the stay-at-home orders (remote learning)?" and, "What time did you usually go to bed on non-school nights DURING the stay-at-home orders (remote learning)." Possible responses for wake times were "6am-7am," "7am-8am," "8am-9am," "9am-10am," "10am-11am," "11am-noon," and "after noon," and for bedtimes were "9pm-10pm," "10pm-11pm," "11 pm-midnight," "Midnight-1am," "1am-2am," "2am-3am," and

	Wake time		
	Morning lark[a]	Night owl	
Before	8:00-9:00 AM[b]	9:23-10:23 AM	p=0.001[c]
During	8:26-9:26 AM	10:03–11:03 AM	p=0.001
	n.s.[d]	p=0.001	
	Bedtime		
	Morning lark	Night owl	
Before	11:21 PM-12:21 AM	11:57 PM-12:57 AM	p=0.044
During	11:21 PM-12:21 AM	12:32-1:32 AM	*p=0.001
	n.s.	p=0.006	

[a] Chronotype was self-identified by participant.
[b] Wake times and bedtimes are reported as a mean range. Potential answers were in one hour increments.
[c] Statistical tests compared times between morning larks and night owls as well as before and during stay-at-home orders using a one-way ANOVA with a post-hoc Tukey HSD analysis.
[d] n.s. = not significant (p > 0.05)

Table 4: Sleep variables of morning larks and night owls before and during the State of Ohio stay-at-home orders in Spring 2020.

	Weekend oversleep[a]		
	Morning lark	Night owl	
Before	63 ± 13 min	132 ± 9 min	p=0.001[b]
During	21 ± 12 min n.s.	23 ± 9 min p=0.001	n.s.[c]
	Weekend bedtime delay[d]		
	Morning lark	Night owl	
Before	67 ± 10 min	67 ± 7 min	n.s.
During	31 ± 9 min n.s.	60 ± 18 min n.s.	n.s.

[a] Weekend oversleep was calculated by subtracting the weekend total sleep/night from the weekday total sleep/night and calculating the mean and standard deviation of the difference.
[b] Statistical tests compared times between morning larks and night owls as well as before and during stay-at-home orders using a one-way ANOVA with a post-hoc Tukey HSD analysis.
[c] n.s. = not significant (p>0.05)
[d] Weekend bedtime delay was calculated by subtracting the weekend bedtime from the weekday bedtime and calculating the mean and standard deviation of the difference.

home orders. No significant differences were found in napping habits before and during stay-at-home orders as well as between night owls and morning larks (**Table 5**). Most teenagers who participated in the survey responded that they never took a nap either before (65%) or during (66%) the stay-at-home orders. Caffeinated beverage consumption between night owls and morning larks during the stay-at-home orders was also reported by participants (**Table 5**). Similar percentages of night owls (41%) and morning larks (43%) reported never drinking caffeinated beverages. There were insignificant differences in those reporting they consumed the same number of caffeinated beverages, more drinks per day, and fewer drinks per day.

DISCUSSION

Receiving adequate hours of sleep per night is essential to the health and well-being of adolescents. The recommended hours of sleep per night is 8–9 hours, but before COVID-19 quarantines, 54% of morning larks and 67% of night owls who participated in this local sleep survey reported insufficient sleep duration (less than 8 hours of sleep per night). This is consistent with the 2015 National Youth Risk Behavior Survey data showing that the majority of teenagers (72%) reported less than 8 hours of sleep per night (2). Lack of sleep is damaging to one's overall health (20, 21) and can contribute to mental health issues such as anxiety and depression (5-7). During the stay-at-home orders, the sleep duration of a significant number of participants (80% of self-reported morning larks and 85% of self-reported night owls) reported healthy sleep durations of the recommended 8 or more hours of sleep per night. A majority of night owls changed their sleep durations to healthy sleep durations; however, the majority of morning larks, who were obtaining healthy sleep durations before the stay-at-home orders, did not change their sleep durations. Teenagers that receive healthy sleep durations have an overall improvement in their mental and physical health.

In alignment with previous studies (14, 18), the majority (73%) of teenagers in our study responded that they were night owls. The data showed a significant shift to later mean

Table 5: Napping habits of respondents before and during the stay at home orders and number of caffeinated drinks respondents reported consuming each day during the stay-at-home orders. To evaluate napping habits, participants were asked, "How many times did you take a nap during the week DURING stay-at-home orders?" Possible responses were "Every day," "5-6 times a week," "3-4 times a week," "1-2 times a week," and "Never." To evaluate how many caffeinated beverages were consumed each day, participants were asked, "In comparison to in school learning, how often do you consume caffeinated beverages DURING the stay-at-home orders?" Possible responses were "I drink the same number of caffeinated beverages as during the regular school year," "I drink more caffeinated beverages as during the regular school year," "I drink less caffeinated beverages as during the regular school year," and, "I did not/do not consume caffeinated beverages."

	Night Owls		Morning Larks	
Naps per week	Before	During	Before	During
Never	63%	66%	83%	66%
1-2 times	21%	19%	8.5%	23%
3-4 times	8%	12%	8.5%	8%
5-6 times	6%	0	0	0
Everyday	1%	3%	0	3%

Number of caffeinated[a] drinks per day during stay-at-home orders	Night Owls	Morning Larks
Never	41%	43%
Same number	27%	20%
More drinks	15%	17%
Fewer drinks	17%	17%

[a] Caffeinated drinks were defined in the question as coffee, tea, soda, or energy drinks.

wake times and bedtimes on both school days and non-school days during the remote learning period. This shift could potentially result in a positive correlation in student health because it may fit the students' self-identified chronotype better, especially the night owls who exhibit later wake and bed times. Studies have shown that night owls are less physically active and sleep less on weekdays (18). These habits tend to increase the stress response leading to higher cortisol levels and higher resting heart rates which are risk factors for sleep apnea, obesity, type 2 diabetes, mental disorders, and metabolic syndrome (22). Since students were able to receive more healthy sleep during the stay-at-home orders because they were able to sleep longer and later during the school week due to the later and more flexible school start times of remote learning, their risk factors for these health problems may decrease.

Much research has focused on sleep duration; however, sleep timing behavior (wake up times and bedtimes), may also influence health as detailed in a study that found that children who went to bed late reported poorer diet quality than children who went to bed early (20). When comparing the survey responses in our study based on self-identified chronotype, morning larks and night owls had a nonsignificant difference in their wake-up times before the stay-at-home orders because of the regimented school start times (**Table 3**). High school start times of the reported school districts ranged from 7:45 AM to 8:15 AM which directly influenced the wake times of teenagers during the school week. Of note, none of the schools that respondents attend follow the recommendation of both the American Academy of Sleep Medicine and the American Academy of Pediatrics that high schools begin no earlier than 8:30 AM to ensure students receive an adequate

amount of sleep (23). During the stay-at-home orders, participants in this study did have the flexibility to sleep past 8:30 AM due to the asynchronous learning of the remote learning environments, and their mean wake-up time ranges were later in the morning and distributed over a wider range of wake times. In this study, morning larks and night owls both had a significant difference between their bedtimes before and during the stay-at-home orders. The bedtime data showed a significant shift in school day sleep patterns to resemble non-school day sleep patterns during the stay-at-home orders. The non-school day sleep pattern might reflect their chronotype preference since students have greater flexibility for wake up time and bedtime on non-school days. This shift to non-school day sleep patterns could have a positive impact on school performance since school performance is influenced by chronotype. Students who are morning-types have better grades in school than evening-type chronotypes (24). Early chronotypes outperform late chronotypes in the morning, but the reverse is true in the afternoon: later chronotypes outperform early chronotypes (19). Flexible learning schedules similar to those that the students experienced during the stay-at-home orders may allow teenagers to optimize their learning time to their chronotype.

Another parameter to consider is weekend oversleep, defined as sleeping late on weekends. Sleep lost during the week due to societal demands such as early school start times or socialization late at night is made up by sleeping late on weekends. Depending on chronotype and social situation, the misalignment between social and biological clocks can lead to social jetlag (25). All but the very earliest sleep chronotypes accumulate sleep debt during the school week (26). Since school times do not correspond to adolescent night owl preference, night owls experience the most severe social jet lag (26). Additionally, studies of weekend delay of bedtime have demonstrated that students with lower grades reported greater weekend delays of sleeping (15). The decrease in weekend oversleep and bedtime delay that was seen in our study of teenagers during the stay-at-home orders should lead to a decrease in their social jetlag, thereby improving daytime functioning. Although it may be difficult to separate the effects of sleep duration from sleep timing behavior, these findings suggest that wake up time and bedtime may be an important factor to consider for health and educational outcomes.

Although there was almost 30% participation from public school students, the survey was limited in its range of participants. Mainly Caucasian, private school students in the Greater Cincinnati area participated in the survey. Participants were recruited by word-of-mouth during the governor's stay-at-home orders making it more difficult to obtain a wide variety of participants. Obtaining parental permission was also a limitation in the study because it was an extra required step for participants and could have been a deterrent in participation. Despite our provided definitions of synchronous and asynchronous learning, teenagers did not appear to understand the nuances of these definitions.

The different self-identified chronotypes, night owl and morning lark, have different sleep patterns that are optimal for their overall health (7, 20-21). Having one standard school start time can be harmful to the night owl chronotype who functions best on a later-to-rise schedule. The results of this study are important because it can help school leaders make more informed decisions about school start times, especially as schools consider future remote learning plans. Schools could consider having remote learning start later in the morning or during the afternoon, or they could have two different sessions and teenagers select which would be most advantageous to their sleep schedule.

The majority of the survey participants felt more rested and were obtaining healthy sleep amounts during the stay-at-home orders. There was no significant change in napping patterns or consumption of caffeinated beverages. During the pandemic, there were many confounding factors such as family dynamic, food insecurity, and access to remote learning technology that could influence their sleeping behavior. The COVID-19 pandemic has been a time of trauma with an increase in socioemotional and economic stress upon families. Proper amounts of sleep are important for youth to cope with stress in normal times but even more important during this time of additional stress. Despite concerns about the quality of education that teenagers are receiving during remote learning, perhaps the less rigorous school schedule that allowed extra sleep was potentially helpful for improving the mental and physical well-being of our youth during this time of trauma. This study can allow educators to understand the importance of maintaining in-school learning but also to adjust school time to allow for the optimal activity of all chronotypes and mental well-being of all youth.

MATERIALS AND METHODS

Creation of Survey and Participant Recruitment

A sleep pattern survey was created to collect data about the student's sleep duration, wake and bedtimes and napping habits before and during remote learning. This survey included 34 general questions designed to evaluate the student's overall sleep habits, as well as their attitude towards learning. Ethics approval for the survey and its administration was provided by Summit Country Day School's Institutional Review Board.

This survey was completed by 141 students during June 2020 following documentation of parent/guardian permission. Participant recruitment was through word-of-mouth requests by the authors and were to mostly private school students because of their connections. Distribution of the survey occurred through an emailed link to the SurveyMonkey version of the survey. Participants gave minor consent and data was collected anonymously during the month of June 2020. No compensation was provided for participation. Participants resided in the Greater Cincinnati Area in Ohio and were enrolled in grades 8–12 at either a public or private high school.

Data Collection and Analysis

Sleep duration is the amount of sleeping time in a 24-hour period reported by the respondent. Participants were asked "On average, how many hours of sleep did you get on school nights BEFORE (DURING) the stay-at-home orders?" and self-reported 5-7 hours, 8-9 hours, 9-10 hours, or more than 10 hours.

Bedtime is defined as the student reported start of the last sleeping period of the day (when you turn the lights off) and wake time is defined as the student reported end of the first sleeping period of the day (when you get up in the morning). The self-reported wake times and bedtimes are based on student selection of survey question responses listed as one-

hour increments.

The data from the online sleep pattern survey was exported from SurveyMonkey as a CSV file and imported into Microsoft Excel for analysis. Means and proportions were used to summarize the survey responses for continuous and categorical differences, respectively. Differences between the proportions were analyzed using a Z-score test for two population proportions. Mean wake up time ranges and mean bedtime ranges were calculated using the first hour of the selected time range. Wake time and bedtime were converted to a 24-hour, circular number for mean calculations. A one-way analysis of variance (ANOVA) with Tukey HSD post-hoc test compared the mean wake times and bedtimes between the night owl and morning lark groups. An unpaired t-test was used to compare demographic data and mean sleep duration, wake times and bedtimes for private school and public school data. No significant differences ($p < 0.05$) were found between the private school and public school groups; therefore, data from both private and public school students were combined.

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