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# Sleep among Brazilian adolescents before and after the COVID-19 pandemic: repeated cross-sectional and longitudinal analyses

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## Abstract

**Background** The COVID-19 pandemic significantly disrupted adolescents' routines, including their sleep patterns, due to school closures, social isolation, and increased screen time. As routines normalized post-pandemic, understanding whether these changes persisted or reverted to pre-pandemic levels is essential.

**Objective** To compare sleep variables between the periods before and after the COVID-19 pandemic in samples of Brazilian adolescents.

**Methods** A repeated cross-sectional study with a nested cohort targeting high-school students from Southern Brazil was used. Different sleep variables were obtained from wrist-worn accelerometers and validated questionnaires. Generalized linear mixed models with Gaussian distribution and identity link function were used to compare sleep variables between the survey years.

**Results** In 2019, 674 adolescents participated (51.8% female, mean age = 16.3, SD = 1.1), and in 2022, 625 participated (56.3% female, mean age = 16.5, SD = 1.2). In the longitudinal sample, 242 out of 333 eligible participants provided complete data in 2019, and 138 out of 286 agreed to participate in 2022. Cross-sectional data indicate significant differences for social jet lag ( $\beta: -0.28, p < 0.001$ ) and self-reported sleep duration ( $\beta: -0.14, p = 0.03$ ) between 2019 and 2022. Prospective data indicate significant changes for sleep regularity ( $\beta: -4.27, p < 0.001$ ), daytime sleepiness ( $\beta: 1.05, p = 0.01$ ), catch-up sleep ( $\beta: -0.35, p = 0.04$ ) and self-reported sleep duration ( $\beta: -0.42, p < 0.001$ ). However, effect sizes were all small.

**Conclusion** Our findings suggest that adolescent sleep characteristics in Brazil post-COVID-19 are similar to pre-pandemic levels, indicating that the initial impact of the pandemic on sleep did not persist after routines normalized.

**Keywords** Sleep timing, Sleep efficiency, Sleepiness, Sleep-related behaviors, Youth, Accelerometry

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## Background

Preventive measures adopted during the COVID-19 pandemic, such as school closures and lockdowns, have led to significant behavioral changes, including sleep patterns. A systematic review with meta-analysis indicated that these pandemic-related changes influenced adolescent sleep characteristics, resulting in longer sleep durations, later bedtimes, and poorer sleep quality [1]. Other indicators like sleep regularity, behaviors, and efficiency may also impact adolescent health [2]. In this regard, studies assessing post-pandemic sleep indicators among adolescents are crucial to determine whether changes in sleep habits have continued or regressed to pre-pandemic patterns. Although the studies already published generally involve cross-sectional designs conducted in high-income countries at the start of the COVID-19 pandemic [3], it is important to examine this issue using a longitudinal design in other settings over a time frame that reflects the post-COVID-19 period. Thus, our study aims to compare sleep regularity, sleep midpoint, social jetlag, catch-up sleep, daytime sleepiness, sleep efficiency and sleep duration between periods before (2019) and after (2022) the COVID-19 pandemic in repeated cross-sectional and longitudinal samples of Brazilian adolescents.

## Methods

### Study design and participants

Data are from the Longitudinal Study of Adolescent Lifestyle (ELEVA), a repeated cross-sectional study with a nested cohort design. The study includes all three federal institutes in the mesoregion of Florianópolis, Brazil, offering programs of technical training integrated with high school. These programs are organized in four or more years, comprising the standard high school curriculum in addition to specialized technical training. More information on recruitment and methods is available on the ELEVA website (<https://eleva.ufsc.br/en/>).

Participants for the repeated cross-sectional samples in 2019 and 2022 were high school students from the first to third years. The nested cohort included students who participated in both surveys, primarily first-year students in 2019, expected to graduate by late 2022 or early 2023. Data were collected between August and December in both years. Students unable to complete all measurements due to disabilities or injuries were excluded.

Figures S1 and S2 detail participant enrollment. Out of 1,618 and 1,052 eligible students for the cross-sectional assessments in 2019 and 2022, respectively, 1,010 and 998 agreed to participate. A total of 333 participants assessed in 2019 were still enrolled in the same institutions in 2022 and were eligible for the prospective assessment. Informed consent for participation was obtained from students and their parents/guardians. The Human Research Ethics Committee approved the study.

### Variables and measurement instruments

We utilized the Peds B-SATED theoretical framework proposed by Meltzer, Williamson, and Mindell [2] to assess adolescent sleep health. This framework includes several dimensions, including sleep-related behaviors, satisfaction/quality, alertness/sleepiness, sleep timing, sleep efficiency and continuity, and sleep duration. The set of variables was assessed through self-reported instruments and actigraphy.

Actigraphy data were collected using Triaxial Actigraph GT3x+ and wGT3x+ accelerometers (ActiGraph Corporation, Pensacola, Florida, USA). Accelerometers were distributed and collected during in-person data collection, which occurred in three stages. In the first visit, the research team introduced the study and distributed informed consent forms to be signed by parents or legal guardians. During the second visit, participants completed the questionnaire, and their weight and height were measured. At the end of this visit, accelerometers were provided with verbal instructions for use. After seven consecutive days of wear, the research team returned to the schools to collect the devices. No additional contact was made with the participants during the measurement period. Participants wore the device on their non-dominant wrist for seven consecutive days. This protocol was tested in a pilot study and showed good adherence [4]. Data were considered valid if participants wore the device for at least 16 h per day on a minimum of three weekdays and one weekend day. Raw accelerometer data, collected at 30 Hz and calibrated to local gravity, were processed into Euclidean norm minus one (ENMO) using 5-second epochs. Non-wear time within each 24-hour interval was identified and imputed based on average values across valid days to normalize all days to 24 h. Sleep parameters were derived using a heuristic algorithm that analyzed changes in the Z-angle to differentiate sleep from other inactive periods, determining the longest sustained period of inactivity with the fewest interruptions as a proxy measure for time in bed. Data processing utilized the GGIR package version 2.9.1 in R software, version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria).

Accelerometer-determined variables were the Sleep Regularity Index (which measures the consistency of sleep and wake times, ranging from 0 to 100 with higher values indicating greater regularity), social jetlag (the difference in the midpoint of sleep between weekends and weekdays), and catch-up sleep (the difference in sleep duration between weekends and weekdays). Sleep timing was determined using accelerometers to calculate the midpoint of sleep, defined as the halfway point between sleep onset and wake time. Sleep efficiency was evaluated by calculating the percentage of time spent asleep relative to the total time in bed with the accelerometer.

Sleep duration was assessed using both self-reports and accelerometer measurements. Participants' sleep durations were also compared to the recommended 8 to 10 h based on self-reports [5, 6]. Alertness/sleepiness was self-reported using the Pediatric Daytime Sleepiness Scale (scores range from 0 to 32, with higher scores indicating greater daytime sleepiness) [7]. Unfortunately, this study did not assess sleep satisfaction due to space limitations in the larger survey.

In addition to sleep-related measures, adolescents self-reported their sex, age, and their school shift (whether they studied in the morning or afternoon). They also provided data on household items (e.g., TVs, computers, refrigerators, stoves), access to treated water, street paving, and parental education to calculate a socioeconomic status (SES) score. Each factor was weighted differently, such as cars being weighted more than refrigerators. The SES score, ranging from 0 to 100, was computed according to guidelines from the Brazilian Association of Research Companies, with 100 indicating the highest SES level [8].

#### Data analysis

Sample characteristics for each survey wave (2019 and 2022) are presented separately for both the repeated cross-sectional and nested cohort samples. Nominal variables are shown as absolute and relative frequencies, while continuous variables are reported as means and standard deviations (SD). Sociodemographic differences between the survey waves were evaluated using Pearson's Chi-squared test for categorical variables and the Wilcoxon rank sum test for continuous variables.

We employed generalized linear mixed models with a Gaussian distribution and identity link function to compare sleep variables between the survey years for cross-sectional and prospective samples. For the variable assessing sleep duration recommendation adherence, we used a binomial distribution with a logit link function. The hierarchical structure of the data was addressed by estimating a random intercept for participants nested

within schools for cross-sectional data and adding an additional random intercept for measurements nested within participants for prospective data. The outcomes were regressed against a factor variable identifying the survey wave (2022 versus 2019). The coefficient of the survey wave variable was exponentiated and expressed as odds ratios, with "Does not meet the recommendation" as the reference category. All models were adjusted for sex, age, socioeconomic status (SES), and school shift. Effect sizes were evaluated using Cohen's *d* and classified as small ( $d = 0.2$ ), medium ( $d = 0.5$ ), and large ( $d \geq 0.8$ ) [9].

We conducted interaction analyses to explore potential sociodemographic moderators (i.e., sex, age, SES) of the survey differences (2022 vs. 2019). Analyses were performed in R (version 4.4.0). To facilitate interpretation, marginal predictions of averages and proportions were presented for Gaussian and binomial distributions, respectively. These predictions were made at average age and SES and were weighted proportionally according to levels of sex and school shift. The analyses were performed in R (version 4.4.0) using the "glmmTMB", "lme4" and "ggeffects" packages.

#### Results

A total of 2,008 adolescents took part in the repeated cross-sectional surveys, with 1,299 providing complete data on the variables of interest. In 2019, 674 adolescents participated, and in 2022, 625 adolescents participated. Approximately half of the participants were female in both years (2019: 51.8%, 2022: 56.3%,  $p = 0.10$ ), with similar mean ages (2019: 16.3,  $SD = 1.1$ ; 2022: 16.5,  $SD = 1.2$ ,  $p = 0.08$ ) and SES levels (2019: 39.2,  $SD = 9.8$ ; 2022: 39.1,  $SD = 10.2$ ,  $p = 0.94$ ). In the longitudinal sample, 242 out of 333 eligible participants provided complete data in 2019, and in 2022, 138 out of 286 agreed to participate. Analyses showed no significant differences between dropouts and participants in 2022 regarding sex and SES score, though dropouts were slightly older. Detailed descriptive characteristics are in Table 1. No significant differences were observed in 2019 sleep variables between

**Table 1** Descriptive characteristics of the participants

Characteristic	Cross-sectional		p-value	Longitudinal		p-value
	2019, N = 674	2022, N = 625		2019, N = 242	Dropouts, N = 104	
Sex			0.10			0.99
Male	325 (48.2%)	273 (43.7%)		107 (44.2%)	46 (44.2%)	
Female	349 (51.8%)	352 (56.3%)		135 (55.8%)	56 (55.8%)	
Age (years) (Mean (SD))	16.3 (1.1)	16.5 (1.2)	0.08	15.5 (0.8)	15.8 (0.9)	< 0.001
SES (Mean (SD))	39.2 (9.8)	39.1 (10.2)	0.94	38.6 (9.5)	38.4 (9.1)	0.88
School shift			0.18			0.48
Morning	323 (47.9%)	323 (51.7%)		111 (45.9%)	45 (43.3%)	
Afternoon	351 (52.1%)	302 (48.3%)		131 (54.1%)	59 (56.7%)	

Data are presented as n (%) or n (SD). Pearson's Chi-squared test and Wilcoxon rank sum test were used to test statistical significance

SES Socioeconomic status, SD Standard Deviation

adolescents who remained in the study in 2022 and those lost to follow-up (see Supplementary Table S3).

Overall, minimal changes were observed in most sleep variables. In the repeated cross-sectional sample, there was a significant decrease in social jetlag in 2022 compared to 2019 ( $\beta$ :  $-0.28$ ,  $p < 0.001$ ) and a significant decrease in reported sleep duration in 2022 ( $\beta$ :  $-0.14$ ,  $p = 0.03$ ). However, the effect sizes were small (Cohen's  $d = 0.14$  and  $0.15$ , respectively).

In the longitudinal sample, there was a significant increase in sleep irregularity ( $\beta$ :  $-4.27$ ,  $p < 0.001$ ) and in daytime sleepiness ( $\beta$ :  $1.05$ ,  $p = 0.01$ ), and a significant decrease in catch-up sleep ( $\beta$ :  $-0.35$ ,  $p = 0.04$ ) and in reported sleep duration ( $\beta$ :  $-0.42$ ,  $p < 0.001$ ) from 2019 to 2022. The effect sizes for these changes were small (Cohen's  $d = 0.31$ ,  $0.19$ ,  $0.17$ , and  $0.32$ , respectively) (see Table 2).

The interaction analysis results are detailed in the supplementary material. In the cross-sectional sample, interactions were found between survey year (2019 vs. 2022) and sex for sleep regularity, survey year and age for daytime sleepiness, and survey year and school shift for sleep midpoint. In the prospective sample, interactions occurred between survey year and socioeconomic status (SES) for sleep duration (questionnaire), and between survey year and school shift for sleep midpoint, catch-up sleep, and sleep duration (both accelerometry and questionnaire) (Tables S1 and S2).

### Discussion

This study aimed to compare sleep variables before and after the COVID-19 pandemic in a sample of Brazilian adolescents. In our study, cross-sectional data indicate that individuals had more consistent sleep schedules across weekdays and weekends in 2022 than in 2019, and individuals self-reported sleeping slightly shorter on average. The prospective data suggest that individuals had more sleep irregularity across the week, fewer instances of compensating for lost sleep on weekends or days off, which could suggest either more consistent sleep during the week or less overall sleep need, and that individuals were experiencing more fatigue and sleepiness during the day, possibly due to poorer sleep quality or insufficient sleep duration. However, the small effect sizes associated with these differences suggest that while there are statistically significant differences between time points, they are relatively modest and may not be considered meaningful or clinically important, unless they become a trend. Despite of that, more than 50% of the adolescents reported insufficient sleep duration in both years. This persistent pattern of sleep deprivation remains clinically relevant, given its association with a range of negative outcomes across psychological/

**Table 2** Changes in sleep variables for the repeated Cross-Sectional and longitudinal samples (2019 vs. 2022)

Variables	Repeated cross-sectional sample				Longitudinal sample							
	Coefficient	95% CI	p-value	2019	2022	Cohen's d	Coefficient	95% CI	p-value	2019	2022	Cohen's d
Sleep Regularity Index [0-100]	-0.49	-1.84, 0.86	0.48	55.2	54.7	0.05	-4.27	-6.55, -2.00	<0.001	55.9	51.6	0.31
Sleep midpoint (hours)	-0.04	-0.15, 0.07	0.51	4:00 AM	4:00 AM	0.08	0.08	-0.11, 0.27	0.41	3:48 AM	3:54 AM	0.00
Social jetlag (hours)	-0.28	-0.43, -0.14	<0.001	1.64	1.36	0.14	0.29	-0.59, 0.01	0.06	1.68	1.39	0.13
Catch-up sleep (hours)	0.16	-0.02, 0.33	0.08	0.87	1.03	0.11	-0.35	-0.69, -0.01	0.04	1.07	0.71	0.17
Daytime sleepiness (0-32)	0.28	-0.77, 0.22	0.28	18.7	18.4	0.02	1.05	0.38, 1.73	0.01	17.8	18.9	0.18
Sleep efficiency (%)	0.00	0.00, 0.01	0.36	87.0	87.0	0.00	0.004	0.00, 0.01	0.13	87.0	88.0	0.00
Sleep duration (accelerometry) (hours/day)	0.05	-0.04, 0.14	0.28	7.48	7.53	0.00	-0.09	-0.24, 0.05	0.21	7.50	7.41	0.12
Sleep duration (Questionnaire) (hours per day)	-0.14	-0.27, -0.01	0.03	8.04	7.90	0.15	-0.42	-0.62, -0.22	<0.001	8.11	7.70	0.32
Meeting sleep duration recommendation*	1.08*	0.86, 1.36	0.50	44%	46%	0.15	0.96*	0.57, 1.61	0.87	44%	43%	0.32

Marginal predictions of averages and proportions were presented for Gaussian and binomial distributions, made at average age and SES, and weighted by sex and school shift

Bolded values denote statistical significance ( $p < 0.05$ )

CI confidence interval

\*Sleep duration recommendation for this age group is 8 to 10 h per day. The reference category was "Does not meet the recommendation". Expressed as odds ratio and the proportions are for those who meet the recommendation

social, cognitive/academic, and physical health domains, reported in a number of studies [2].

Some changes in adolescents' sleep patterns during the pandemic were documented, such as longer sleep durations, later bedtimes, and poorer sleep quality [1]. However, our results indicate that once adolescents returned to their routines and school, their sleep behaviors also returned to values like those before the pandemic. These findings are in line with international evidence on adolescent sleep duration before and after the COVID-19 pandemic. A prospective study with 28,307 Canadian adolescents showed that sleep duration increased during the early stages of the pandemic but later declined, returning to pre-pandemic levels by 2022 [10]. This is not necessarily a positive outcome, given that some sleep behaviors are not adequate, such as the fact that only about half of adolescents are meeting the recommended sleep duration of 8 to 10 hours per night. This underscores the need to promote sleep health within this group.

Our interaction analysis suggests some group differences, especially regarding the school shift, where studying in the morning or afternoon had a moderating effect on some sleep variables. The school shift differentiation is more common in low- and middle-income countries, such as Brazil, and a previous study has identified that the school shift can affect sleep timing, duration and regulation, where adolescents who study in the afternoon shift have later bed time and wake up later, and those who study in the morning have shorter sleep duration, but higher sleep efficiency [11].

The study's findings suggest that school health policies should prioritize promoting healthy sleep behaviors among adolescents by implementing flexible start times, sleep health education, and addressing environmental factors like high academic demands and screen use. Although pandemic-related disruptions normalized over time, consistent routines remain crucial for maintaining sleep health. Additionally, policies should ensure equitable access to sleep-supportive environments, as students from lower socioeconomic backgrounds may face unique challenges. School-based interventions should be designed to support diverse student needs and prevent long-term negative sleep outcomes.

It is important to acknowledge several limitations in this study. For example, the sample may only partially represent some adolescents in Brazil and device-based measures are limited by their inability to accurately distinguish between sleep and quiet wakefulness and their susceptibility to inaccuracies due to movement artifacts. Another limitation is that our study did not include a direct measure of subjective sleep satisfaction or quality. While our approach was informed by the Peds B-SATED theoretical framework, which includes six dimensions

of sleep health, we were only able to include five: sleep-related behaviors, alertness/sleepiness, sleep timing, sleep efficiency and continuity, and sleep duration. The exclusion of the satisfaction/quality dimension may limit the comprehensiveness of our sleep health assessment, particularly given the importance of perceived sleep quality in relation to mental health. This study benefits from several strengths such as the use of cross-sectional and longitudinal designs to answer the same research question, the inclusion of many accelerometer-measured sleep variables beyond sleep duration, and the inclusion of adolescents from a middle-income country (Brazil), contributing to the literature overrepresented by papers from high-income countries. Finally, data collection encompassed pre-COVID-19 (2019) and post-reopening phases, providing a robust timeframe for examining longer-term behavioral changes among high school students in response to the pandemic.

## Conclusions

Our results indicate that the sleep characteristics of adolescents in Brazil after the COVID-19 pandemic are similar to those observed before the pandemic. This suggests that, although the pandemic initially impacted adolescents' sleep due to school closures, these changes did not persist once their routines returned to normal. However, this does not imply that adolescents' sleep is adequate, as approximately half of them still do not meet sleep duration recommendations. These findings have important public health implications, as inadequate sleep among adolescents is linked to various physical and mental health issues, such as obesity, mood disorders, and academic difficulties. Future interventions should focus on promoting healthier sleep habits, including sufficient sleep duration, regular sleep and wake times, and encouraging earlier bedtimes. Such measures could contribute to improving adolescents' overall health and preventing long-term health issues, reinforcing the need for public policies aimed at youth well-being.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12887-025-05904-1>.

Supplementary Material 1.

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Not applicable.

## Clinical trial number

Not applicable.

## Authors' contributions

G.P.M. - Formal Analysis, Visualization, Writing – Original Draft. R.C. - Writing – Review & Editing. M.V.V.L. - Conceptualization, Data Curation, Investigation, Methodology, Project Administration, Software, Writing – Review & Editing. B.N.O. - Investigation, Writing – Review & Editing. B.G.G.C. - Conceptualization,

Investigation, Methodology, Project Administration, Writing – Review & Editing. J.P.C. - Writing – Review & Editing. K.S.S. - Conceptualization, Funding Acquisition, Methodology, Project Administration, Supervision, Writing – Review & Editing.

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#### Data availability

The data that support the findings of this study are available upon reasonable request from the corresponding author. The data are survey data collected for the purposes of this study and are not publicly available due to privacy or ethical restrictions.

#### Declarations

##### Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments. The project was approved by the Human Research Ethics Committee of the Federal University of Santa Catarina under protocol number 3,168,745. Informed consent was obtained from all individual participants included in the study. For participants who were minors (under the age of 18), consent was obtained from their parents or legal guardians. Additionally, assent was sought from the minors themselves after providing them with age-appropriate information about the study. Participants were informed about the study's objectives, procedures, potential risks, and benefits, and they were given the opportunity to ask questions. Consent and assent were given voluntarily, and participants and their guardians were informed of their right to withdraw from the study at any time without any consequences.

##### Consent for publication

Not applicable.

##### Competing interests

The authors declare no competing interests.

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