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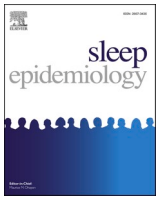

Adolescents' sleep quality is associated with day of the week, school timing and chronotype

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ABSTRACT

Late chronotypes and early school start times are associated with unhealthy sleep habits during adolescence. Here we examine the impact of the relationship between school timing and chronotype on sleep quality in 349 Argentinian high-school students (age: 17-18 y.o., 49% females) randomly assigned to attend school in the morning, afternoon or evening. Students completed the Munich Chronotype Questionnaire and ranked their sleep quality using a Likert-like scale. We found higher sleep quality on free days than on weekdays. Importantly, morning-attending students showed lower sleep quality on weekdays. Finally, the interaction between school timing and chronotype was associated with sleep quality on weekdays: later chronotypes were associated with poorer sleep quality in morning- and afternoon-attending students, but not in the evening. Altogether, our results suggest that attending school in the morning is associated with shorter sleep duration and higher social jetlag, but also with lower sleep quality during adolescence.

1. Introduction

Humans exhibit endogenously controlled 24h-cyclic variations in their physiology and behavior [1]. Chronotype is the expression of each individual's internal circadian timing under light-dark conditions [2] and it is modulated by multiple factors, such as age [3], light [4] and social cues [5]. The sleep-corrected midpoint of sleep on free days (MSFsc) is a widely used measure of chronotype which is obtained from the standardized Munich Chronotype Questionnaire (MCTQ) [2].

Adolescents wake up very early in the morning to attend school, even though chronotype becomes progressively later during adolescence [3]. Although it has been widely reported that this phenomenon leads to chronic sleep loss on weekdays [6-8] and social jetlag (SJL) [9,10], the evidence about whether and how school start time (SST) affects sleep quality is limited and inconsistent. Certain studies report earlier SSTs are associated with poorer sleep quality [11,12], while others have found associations between SSTs and sleep timings without any impact of SSTs on sleep quality [13,14].

Even though adolescence is the developmental period in which humans present later chronotypes, there exists large interindividual variability. Then, the alignment of different chronotypes to the same early school schedule (i.e. morning SST) is expected to be worse the later the chronotype is. Consistently, earlier SSTs represent a greater limitation for students with later chronotypes [9,15]. Later chronotypes have been associated with shorter sleep duration [2], higher SJL [5] and poorer sleep quality [13,16]. Interestingly, how the interaction between SST and chronotype affects sleep quality, however, remains unclear.

The aim of this study is to understand how adolescents' sleep quality is affected by the interplay between school timing and chronotype. We hypothesize that (1) sleep quality on weekdays is poorer than on free days; that (2) earlier school timing is associated with poorer sleep quality on weekdays, but not on free days; and that (3) later chronotype are associated with poorer sleep quality in the morning and, although less likely, the afternoon but not in the evening school timing.

2. Material and methods

2.1. Participants and procedure

This study was performed at a high school from the City of Buenos Aires, Argentina. A total of 349 students in their last year of secondary school (M=17.59 y.o; SD=0.37 y.o.) were included in the study.

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Students were excluded from part of the analysis when data was missing, specifically when they did not respond to all the questions necessary to calculate their chronotype (MSFsc). An important aspect of our study is that the school timing was randomly assigned to each student at the beginning of secondary school to either morning (7:45 am-12:05 pm, n=123), afternoon (12:40-5:00 pm, n=124) or evening (5:20-9:40 pm, n=102). Data collection took place in July 2019, during the regular hours of each school timing. Mean values of sleep-related variables (e.g. sleep timings) for each school timing are presented in Supp. Table 1.

2.2. Measurements

Students completed a Spanish version of the MCTQ from which the corrected midpoint of sleep on free days (MSFsc) was calculated [2]. The MSFsc is a local time: earlier values indicate early chronotypes and later values, late chronotypes. MSFsc distribution is shown in Supp. Figure 1.

We obtained self-reported sleep quality on weekdays and free days from a numerical Likert-like. Students responded to the following statements: "Indicate how well you sleep on weekdays" and "Indicate how well you sleep on free days" by choosing a value from 1 to 10, 1 indicating very bad and 10, excellent. Sleep quality distribution for week- and free days are shown in Supp. Figure 2 and 3 respectively.

For a detailed description of the evaluated measurements please see Supp. Information.

2.3. Statistical analysis

The analysis was divided into two steps. First, we performed an Aligned Rank Transformation to study whether school timing, type of day (week or free day) and their interaction affect sleep quality. Pair-wise comparisons between groups were performed using Mann-Whitney *U*. Significance threshold was set in $p<0.05$. Second, we adjusted an ordinal regression model to test the effect of chronotype and school timing on sleep quality on weekdays. Then, we calculate the MSFsc odd ratios (OR_{MSFsc}) for each school timing (for more details see Supp. Information). Differences in the MSFsc effect on students' sleep quality between school timings were derived from the coefficients of the model (Supp. Table 3). All statistical analyses were performed using the R system for statistical computing (version 3.6.1; R Core Team, 2019).

2.4. Ethical approval

The study was approved by the institutional Ethical Committee of the Universidad Nacional de Quilmes (Verdict #4/2017) and conducted according to ethical recommendations for human chronobiological research [17], based on the Argentinian national regulations [18]. A written informed consent was obtained from the head of the school, while parents' written consent was not required. Students gave their oral and active consent to participate.

3. Results

3.1. Sleep quality depends on both school timing and type of day

We found that sleep quality is affected by school timing ($F=6.36$, $df=2$, $p=0.0019$), type of day ($F=695.35$, $df=1$, $p<0.0001$) and their interaction ($F=17.73$, $df=2$, $p<0.0001$). Sleep quality was poorer on weekdays than on free days and morning-attending students presented poorer sleep quality on weekdays than their peers (Fig. 1).

3.2. Sleep quality on weekdays depends on both chronotype and school timing

Although we observed an effect of school timing on self-reported sleep quality on weekdays, it remains unclear how chronotype is associated with sleep quality on each school timing. Table 1 shows the

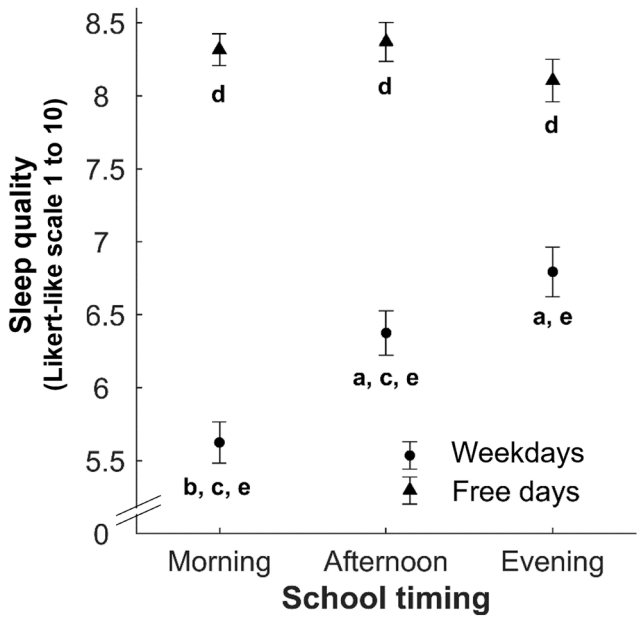

Fig. 1. Differences in Sleep quality are associated with school timing and type of day. Sleep quality is better on free days than on weekdays for all school timings (morning: $p<0.0001$, ES=0.730; afternoon: $p<0.0001$, ES=0.566; evening: $p<0.0001$, ES=0.370). Importantly, sleep quality on free days did not significantly differ between school timings, but morning-attending students reported poorer sleep quality on weekdays than students from the other two school timings ($p=0.025$, ES=0.192 compared with afternoon and $p<0.0001$, ES=0.295 compared with evening). Data are Mean ± SEM. Lowercase letters indicate significant differences between groups ($p<0.05$): a-compared with morning; b-compared with afternoon; c-compared with evening; d-compared with weekdays; e-compared with free days ($p<0.05$, Bonferroni corrected). ES: effect size. n = 349.

Table 1
MSFsc odd ratios for poorer sleep quality on weekdays on each school timing.

	MSFsc OR	95% CI
Morning*	1.377	[1.048 - 1.807]
Afternoon**,c	1.409	[1.132 - 1.751]
Evening b	1.012	[0.789 - 1.296]

The odds of students' sleep quality on weekdays being 1-point lower (poorer sleep quality) for each 1h-later chronotype are 1.38 in the morning and 1.41 in the afternoon (Table 1). That is, it is 38% more probable that a morning-attending student with an MSFsc of 06:00 presents a 1-point-lower sleep quality than a student with a 1h earlier chronotype (MSFsc=05:00). For evening-attending students, sleep quality and chronotype were not associated: students with earlier and later chronotypes present similar sleep quality. Significance level

* $p<0.05$,

** $p<0.01$. Lowercase letters indicate significant ($p<0.05$) differences in MSFsc odd ratios (i.e. MSFsc effect on sleep quality) between school timings (See Supplementary Figure 3 for a detailed explanation of these comparisons and OR): a-compared with morning; b-compared with afternoon; c-compared with evening. MSFsc = corrected midpoint of sleep on free days. OR = odd ratio. CI = confidence Interval. n = 334.

OR_{MSFsc} for each school timing, explaining adolescents' sleep quality derived from an ordinal logistic regression model (see Supp. Table 2 and 3 for the ANOVA and the Summary of the model respectively). Our results show that later chronotypes present higher odds of experiencing poorer sleep quality than earlier chronotypes. Altogether, our results suggest that adolescents' sleep quality is modulated by the relationship between the school timing and chronotype: when compared with their peers with earlier chronotypes, students with later chronotypes present poorer sleep quality in the morning and in the afternoon, but this

difference between chronotypes is not observed in the evening.

4. Discussion

Here we studied whether and how adolescents' subjective sleep quality is affected by the type of day (week- or free days), school timing and chronotype.

First, we showed that sleep quality is better on free days than on weekdays independently of school timing, which was expected considering that school can function as a stressing agent [19], Second, we observed comparable sleep quality on free days among school timings, probably because students have more flexibility to choose their sleep timings. Importantly, the interaction between school timing and type of day showed that the difference between sleep quality on week- and free days is larger for morning-attending students, probably due to the constraint that an early SST implies for adolescents' late chronotypes [6, 10]. Morning-attending students present poorer sleep quality on weekdays than other students. While some studies also reported poorer sleep quality related to earlier SST [11,12], others found no association [13, 14]. Importantly, these previous studies compared closer in time SSTs (only morning SSTs), which could make the effect undetectable.

Previous studies have already found a correlation between chronotype and sleep quality in college [16] and high-school students [13]. Nevertheless, whether and how this relationship is modulated by SST was unknown. Here, we show that adolescents' sleep quality on weekdays varies according to the interaction between school timing and chronotype. Particularly, our results indicate that later chronotypes are associated with poorer sleep quality on weekdays for both morning- and afternoon-attending students, but not in the evening. This result was not completely unexpected because Argentinian adolescents' present extremely late chronotypes compared with their peers from other countries [8,10], which might explain why late chronotypes are associated with poorer sleep quality on weekdays not only in the morning but also even in the afternoon. Importantly, these results are in line with previous results of our group reporting impacts on sleep duration and social jetlag, suggesting that not only morning but also afternoon school timings can be challenging for Argentinian students [10].

This study has several strengths. First, our data was obtained from a unique and almost ideal natural setup for studying how SST affects sleep-related variables across the widest possible range of times: a high school with three different school timings, including evening. Second, students were randomly assigned to one of those timings in their first year of school, making it highly unlikely that any school-timing-selection biases affected our results.

Our research also presents some limitations. First, all variables are self-reported. Second, even though sleep quality is heterogeneously evaluated in literature (e.g. standardized questionnaires, several proxies derived from actimetry, etc.), our approach is not commonly used. Consistently, the use of a wider-used tool (e.g. the Pittsburgh Sleep Quality Index) might enhance robustness and facilitate comparison with existing literature. Third, the interaction between school start time and solar clock [20] or other non-controlled factors might be affecting our results.

Sleep quality disturbances are widely extended in the adolescent population and have a strong negative impact on their mental health and well-being [21]. Several previous studies showed that the interplay between school timing and chronotype modulates adolescents' sleep duration, social jetlag, and performance. This study evidences that sleep quality is negatively associated with chronotype, not only in morning- but also in afternoon-attending students. Finally, our results underline the importance of conducting local studies where both researchers, school authorities and education policymakers work together to better understand how SST impacts on students' sleep and to think, design and implement future educational public policies to improve adolescents' performance and wellbeing.

CRediT authorship contribution statement

Guadalupe Rodríguez Ferrante: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Andrea Paula Goldin:** Methodology, Investigation, Funding acquisition, Conceptualization. **María Juliana Leone:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sleepe.2024.100092.

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