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# INSIGHTS ON CHILDREN SLEEP PATTERNS DURING THE SECOND DECADE OF THE 21ST CENTURY: STUDIES BASED IN PORTUGUESE SCHOOL-AGE CHILDREN DATA

**Dissertation submitted to obtain the degree of Master in Psychology, in the subarea of specialty of Cognitive-Behavioral Interventions in Psychological and Health Disorders, oriented by Professor Ana Cardoso Allen Gomes and presented to the Faculty of Psychology and Educational Sciences of the University of Coimbra.**

July 2019

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## Acknoledgements

I owe my profound gratitude to Professor Ana Allen Gomes, whom I admire, for the patient guidance and support. For inspiring me and encouraging my curiosity, Professor Ana Allen Gomes determined, from the first day, my academic choices.

I am deeply and sincerely grateful to my family for their continuous and unparalleled love. I am thankful to my brother, for understanding me without words, and forever indebt to my mother for giving me the opportunities that have made me who I am. This journey would not have been possible if not for them.

# Index

# Introduction

Sleep is detrimental to multiple domains of child functioning, contributing to a healthy physical, cognitive, emotional and behavioral adjustment, as well as to a positive family dynamics and academic competence (Moore, 2012). Conversely, insufficient sleep duration, sleep disturbances and fatigue negatively affect these domains, endangering the optimal development of children (Gruber, 2013). Indeed, primary sleep-related disturbances may result in daytime symptoms and adverse health consequences in children. Moreover, sleep-related disturbances may constitute comorbid conditions that contribute to daytime symptoms. Furthermore, parents are often the most affected by children sleep difficulties, suffering from sleep deprivation, medical and emotional compromises and even inability to properly care for their child (Sheldon, Ferber, Kryger, & Gozal, 2014). Ergo, the treatment of sleep disturbances may improve not only child's adjustment, normative development and health, but also promote family welfare.

The current dissertation comprises two studies. Sleep patterns vary significantly during development (Touchette, Mongrain, Petit, Tremblay, & Montplaisir, 2008). Hence, understanding the way in which sleep is shaped during development, particularly in preschool and school-age years, is imperative. As such, we will initially conduct an epidemiological study of sleep-wake timings in Portuguese children from 4 to 11 years of age. Our aim is to document the natural sleep patterns of developing children within the preschool and school-age period in a large school probabilistic sample, with a wide age range. Having a large representative sample, this study will also allow us to obtain additional evidence to develop a better understanding of the evolution of sleep in community pediatric populations. Indeed, documenting normative sleep patterns enables the update of healthcare professionals and provides them with evidenced-based rationales for guidance and support of children with sleep disturbances. Whereas data analyzed in this study dates back to 2013, this is still the most current data we have in such a wide sample, starting from the age of 4 and going until the age of 11, a group that has not been investigated as exhaustively as other age groups. By analyzing children sleep-wake patterns, we also aim to answer to unsettling questions raised by sleep professionals and to identify gaps and targets for preventive interventions. Ultimately, the relevance of this study further relies on the fact that, by understanding the evolution of normative developmental sleep patterns, it is possible to educate not only healthcare professionals but also parents, children, teachers and education administrators about the biological and environmental factors that contribute to sleep problems, which in turn can spiral into health concerns. That is, this study may constitute an impetus to positive changes in communities, reinforcing what is known from research regarding children's sleep needs.

School-age children go through changes in circadian and homeostatic sleep systems, and a biological tendency toward phase delay develops. Thus, school-age years arise as a decisive opportunity period for learning and consolidating positive sleep practices that may prevent unhealthy habits. Such unhealthy habits, in combination with those intrinsic biological regulatory sleep mechanisms, favor a delayed timing that often results in a state of chronically restricted and ill-timed sleep (Gruber, 2013). Since the conflict between children's sleep-wake patterns and social demands arises during school-age years, sleep habits and disturbances may start to affect children functioning, as school schedules become the main *zeitgeber* of their sleep-wake rhythms (Clemente, 1997). In fact, a recent study reported that 57% of school-age children was suffering from at least one sleep problem (Khazaie, Zakiei, Komasi, & Brand, 2018).

We will then conduct a second study in order to investigate trends in sleep wake-patterns (duration, timing and disturbances) among Portuguese school-age children by comparing two time points: 1996 and 2016. The objectives of this study are to gain further knowledge regarding changes in children sleep, within a 20-year period, informing and updating clinical practitioners, and to better understand the effects of psychosocial context on sleep and its disturbances on children. Sleep patterns and disturbances in children reflect an interplay of many factors, including developmental – evaluated in the first study – and environmental influences. The second study will focus on the impact of such environmental influences, as well as on the effects of altered patterns of parent-child interactions. This study will also allow to better estimate to what extent data analyzed in the first study is outdated or not.

As abovementioned, research on sleep-wake patterns of school-age children is of paramount importance given the benefits of sleep education in this age group. Since children become more independent during school-age years (e.g., begin to engage on extracurricular activities, have increasing schoolwork demands, initiate social life), self-regulation assumes greater importance in this period. Albeit sleep is affected by environmental factors such as parental attitudes, stress and poor sleep habits, sleep patterns are susceptible to change. In other words, psychological processes directly influenced by sleep timing and duration can be modulated by improving or extending sleep.

Given the scope, impact and sequalae of childhood sleep-related disturbances, early interventions are imperative. These interventions, as well as the study of sleep, should be carried by an interdisciplinary team of professionals, as an integrative and collaborative approach to sleep problems is ideal. Hence, psychologists are indispensable in order to provide an optimal care to the pediatric population. Psychologist have a critical role not only in research and advocacy for sleep-promotion but also in the treatment of primary or comorbid sleep problems and in the treatment of other emotional disorders. Since the treatment of sleep disturbances may reduce psychological distress and vice-versa, psychologists comprehensive knowledge in the interactions between sleep and psychological functioning is of paramount. Furthermore, even on sleep disorders traditionally considered to be primarily medical (e.g., restless leg syndrome, parasomnias), psychologists play a key role on promoting positive habits or decreasing interfering behaviors, which may help in its treatment. Finally and most importantly, psychologists, particularly cognitive behavioral therapists, have an imperative role on the treatment of sleep disorders which are behavioral in origin and thus require behavioral interventions, as is the case of inadequate sleep hygiene, behavioral insomnia of childhood, nightmares, nighttime fears and delayed sleep phase syndrome (Moore, 2012).

In fact, cognitive-behavioral therapy has been shown to be effective on school-age children's sleep problems, and has been associated with improvements in sleep quality, insomnia and anxiety symptoms, such as separation anxiety (including the fear of sleeping alone; Paine & Gradisar, 2011).

# Article 1

Clara, M. I. & Gomes, A. A. (2019). An epidemiological study of sleep-wake timings in school children from 4 to 11 years old: insights on the sleep phase shift and implications for the school starting times' debate. Accepted for publication[1]. Sleep Medicine.

[1] See the acceptance letter from Sleep Medicine in Appendix 1.

An epidemiological study of sleep-wake timings in school children from 4 to 11 years old: insights on the sleep phase shift and implications for the school starting times' debate

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The questionnaire collection of the present study was supported by the Project PTDC/PSI-EDD/120003/2010, hosted at the Department of Education and Psychology of the University of Aveiro, funded by the Portuguese Foundation for Science and Technology (FCT) and FEDER/COMPETE/QREN.

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Abstract

It has been assumed that during adolescence there is a strong shift towards eveningness, while children's sleep is relatively stable. Several studies have focused on the conflict between school start-times and adolescents' circadian rhythms; however, fewer studies have been conducted on younger children. The aim of this study was to examine sleep durations, schedules and sleep phase shift in preschool and school age children. Data for sleep patterns on school and free-days was obtained by means of questionnaires (Children ChronoType Questionnaire) for 3155 Portuguese children aged 4-to-11 years old. As children grow older and school-grade level increases, we found later bedtimes and sleep onsets on both school and free-days; and later wake-times only on free-days. By contrast, wake-times were progressively earlier, imposed by school start-times. There was a progressive reduction in the amount of sleep on school-nights as grade level increased. Greater social jetlag, later midpoint of sleep and higher restriction-extension patterns were found across age groups. The displacement of bed and wake-times for later hours on free-days starts at an early age. Changing early school start-times could adjust social demands to the biological rhythm of children.


*Keywords*: Sleep schedules and durations; Sleep phase delay; pre and primary school children; pubertal transition; School start-times

An epidemiological study of sleep-wake timings in school children from 4 to 11 years old: insights on the sleep phase shift and implications for the school starting times' debate

It has been assumed that during puberty and adolescence circadian rhythms, or sleep-wake cycles, shift towards a preference for late-morning wake times and late-onset sleep times (e.g., 1, 2), with previous research suggesting this transition occurs around the ages of 12-14 years (3, 4, 5, 6, 7). Contrastingly, before adolescence or during preschool and school-age years sleep is thought to be relatively stable, and recent guidelines (e.g., 8, 9) refer to children of school-age years as a single homogenous group in terms of their sleep needs and patterns (6-13 years). However, findings suggest that circadian changes to sleep occur prior to the physical changes of puberty (10) and rapid changes in sleep behavior appear to initiate around 5-7 years of age (11). Recently, a study using actigraphy to assess school-age children's sleep concluded that sleep of children in third and fourth grades is already delayed in comparison to their younger counterparts (12). Zimmermann (13) reported that in preschool children between the ages of 2 and 4 there is already a slight shift towards eveningness. Similarly, Randler, Faßl and Kalb (14) found that a slight turn towards eveningness already occurs during toddler age, even though the greatest change happens during pre-puberty around the age of 9-10 years. Collectively, the findings suggest that changes previously assumed to occur drastically around adolescence or with the onset of puberty might nonetheless start earlier, changing gradually as children develop. Even though the delay in sleep-wake patterns and its conflict with school start-times are vastly studied on adolescents (3, 6, 15), there are fewer studies in children focused on SST. However, a displacement of wake-times during the weekend to later hours is already observed in ages as early as 4-6 years (16, 17) and the differences between sleep-wake patterns during weekdays and weekends completely disappear during holidays, indicating that school children are somewhat sleep deprived (18). Randler, Vollmer, Kalb and Itzek-Greulichc (11) reported an early breakpoint for social jetlag (SJL) at 5.17 years, suggesting the circadian rhythm shift towards eveningness that peaks in adolescence starts nevertheless in early childhood with the misalignment of sleep timing between scheduled and free-days and thus proposing that this misalignment should be considered one contributing factor to a later chronotype during adolescence, along with other factors, such as sexual hormones. Social jetlag (SJL) is already present in infants 0-6 years of age and becomes greater as age increases (13, 14). Sleep is shortened by early school start-times thus sleep deprivation is partly compensated for by longer sleep durations on free-days (17). Hence, it is possible that there is already a misalignment between intrinsic biological sleep mechanisms and early school start-times in younger children. Given the assumption that circadian rhythms shift with puberty or adolescence, most studies have focused essentially on youngsters in the years of pubertal development and adolescents. In one of the very few studies with primary school children, Arbabi, Vollmer, Dörfler and Randler (19) found an association between evening orientation/chronotype and academic achievement at the age of 10. The authors reported that an earlier chronotype was associated with earlier midpoint of sleep and less social jetlag, showing that individual circadian preferences are manifested, and, thus late chronotype can be detrimental to early school schedules in pre-adolescent children. Since the sleep habits of preschool and school-age children have not been investigated as exhaustively as other groups, current understanding of the status of sleep duration and sleep schedules among children between 4 and 11 years old is relatively limited. The first aim of this study was to characterize school-grade level and age-related differences in sleep duration, schedules, and school-versus-free-days discrepancies following the sleep variables extracted by Werner et al. (20) in the original study with Children's Chronotype Questionnaire (night sleep duration, sleep restriction-extension pattern, sleep need, bedtime, sleep onset, lights-off, sleep latency, sleep inertia, wake-time, get-up and fully alert time, social jetlag and midpoint of sleep). The second aim of this study was to investigate whether there is already a sleep-wake pattern delay on preschool and school-aged years by examining specifically sleep restriction-extension pattern, midpoint of sleep, social jetlag, wake-times and sleep onset and nigh sleep duration. We hypothesize that changes in sleep which have been assumed to occur principally with the transition to puberty are already taking place since preschool years, and therefore there is a steadily increasing mismatch between school schedules and children's circadian patterns across preschool and school-aged years. Thus, we predict that sleep onset and wake-times shall already be delayed on free-days, that sleep duration will be shorter on school-days and longer on free-days to compensate sleep deficits and that schedule discrepancies on free-days versus school-days (social jetlag) and sleep restriction-extension patterns shall already be present in younger children. Furthermore, we mainly expect these patterns to be gradually and consistently greater from 4 to 11 years as age increases.

# Methods

## Design

The present cross-sectional study, in which we evaluated sleep schedules and sleep duration among children 4-to-11-years of age, was part of a large-scale, school-based survey that recruited participants from both kindergarten and primary schools in Portugal. Ethical approval was provided by the General Direction of Education – Portuguese Ministry of Education.

## Procedures and participants

This investigation was conducted in Continental Portugal, which is divided into 5 educational regions (Alentejo [DREA], Algarve [DREALG], Center [DREC], Lisbon and Tagus

Valley [DREL], North [DREN]). For the purpose of the study, the expression "school clusters" will be used to refer to a group of schools in the same parish, under the same Direction, that offer all levels of education ranging from kindergarten up to 12th grade of high school ("agrupamentos de escola" in Portuguese). Based on the list of public-school clusters available at the Ministry of Education's public network for the academic year of 2012/2013, a cluster sample was planned to cover all educational regions. Participants were recruited through the "school clusters": for each educational region, a specific number of school clusters were randomly sampled, based on the calculation of the approximate proportion of school clusters (and, thus, the country's population distribution) in each region. A total of 11 school clusters were sampled randomly, and invitations were sent to their principals. In case of refusal, which happened twice, another "school cluster" was randomly selected. 84.6% (11/13) of the approached "school clusters" agreed to participate in this study. The target study population included all preschool to 6th grade students between 4 and 11 years of age from each one of these school clusters, who were invited, along with their parents, to participate in the survey. Based on the voluntary principle and the guarantee of anonymity, informed consent was obtained from the respondents, who were free to discontinue the participation in the study at any time. Questionnaires and informed consents were provided and retrieved through the children's teachers. Children between 4 and 11 years of age whose parents provided data to calculate at least one of the chronotype measures were included in the study. 11 subjects were excluded, leaving a final sample for the current study of 3155 children.

## Measures

### Portuguese version of Children's Choronotype Questionnaire (QCTC).

All children were assessed through QCTC (21), the Portuguese version of the Children's Chronotype Questionnaire (CCTQ; 20), a parent-report 27-item questionnaire, in which tutors respond to a short demographics section and questions about sleep/wake parameters for both scheduled and free days, regarding 4- to 11-year-old children. (The scale also provides three individual measures of chronotype which were not the focus of the present study). Reliability results for the QCTQ (Cronbach's α=.728; 21) were similar to those obtained through the original questionnaire, CCTQ, for the M/E scale (Cronbach's α =.81; 20). Scheduled days (SC) were defined as those when the children's sleep-wake patterns are directly influenced by individual or family activities (e.g., school, scouts or athletics) and free days (FR) as those when the children's sleep/wake patterns are "free" from any influence of individual or family activities (20). As in the original study by Werner et al. (20), sleep onset (SO) was defined as sleep latency added to time of lights-off; night sleep duration (NSD) as the difference between sleep onset in the evening and wake-up time in the morning; and sleep inertia as the difference between wake-up time and time being fully alert. Sleep need was calculated through the weighted average: ([weekday sleep duration × 5] + [weekend sleep duration × 2])/7. Midpoint of sleep was calculated (SO + NSP/2) for both school (MSC) and free-days (MSF). Corrected midpoint of sleep (MSFsc) was calculated using the formula suggested by Roenneberg et al. (22): MSF – [0.5 × (NSP on FR – Sleep Need)]. Social jetlag was calculated according to Roenneberg's (SJL_R; was operationalized as the absolute difference between MSF and MSC; 23) and Jankowski's formulas (SJLsc; 23). Sleep restriction-extension pattern was defined as the difference between sleep duration on school and free-days.

**Portuguese version of Self-rating scale for pubertal development (EAP).**

Children from the age of 9 attending 4th grade or above were assessed through EAP (24), the Portuguese version of the Self-Rating Scale for Pubertal Development (SSPD), a self-report measure of pubertal status adapted by Carskadon and Acebo (25) from the interview-based

Pubertal Development Scale (PDS; 26). EAP includes 5 items which rate physical development ~~a~~nd the results of those are combined to classify the adolescents' pubertal development, 3 of which are common to both boys and girls and 2 are specific questions by gender. This brief self-rating scale is intended for children from the age of 9 and it is a 4-point Likert Scale – except for item 5 of the female version, which is a "yes-or-no" question (if the answer is affirmative, it is asked for girls to report in which age they had the menarche) – rating an overall maturation measure (global mean) and a categorical maturation measure (total punctuation of puberty, the sum of the answers 2, 4 and 5), that can be converted in the Tanner pubertal development stage, through the algorithm developed by Peterson et al. (26).

**Statistical analysis**

All analyses were performed using version 22.0 of IBM SPSS Statistics for Windows (IBM Corpo., Armonk, NY). Results for continuous variables with normal distributions were presented as mean ± standard deviation (SD). Skewness and Kurtosis were used to judge distribution (if under 2 and 7, respectively, variables were considered close to normally distributed; 27). Initially we performed univariate analysis to explore the associations between variables. Comparisons of sleep parameters across different age and school-grade groups were conducted using one-way ANOVAS and between boys and girls using Student's t-tests. Homogeneity of variance was tested by Levene method. One-way ANOVAS were followed by Tukey post hoc tests or Games-Howell post hoc tests when homogeneity assumptions were violated. For the parameters that were not normally distributed, Kruskall-Wallis Tests were performed as non-parametric techniques instead of one-way ANOVAS and Mann-Whitney U Tests instead of t-tests. Comparisons on sleep parameters between school and free-days were conducted through Paired-Samples T-Test (or Wilcoxon Signed Rank Tests when assumptions were violated). Due to the multiple testing, Bonferroni correction was used to counteract the significance level $p$=.05. Thus, statistical significance was set at $p$<.003 in the sex, age and school-grade level analysis (.05/16 variables; Tables I, III and IV) and at $p$<.005 (.05/10) in the comparison between school and free-days (Table II). We then performed a series of multifactorial ANCOVAs / General Linear Model (GLM) entering sex and age as fixed factors and school cluster as the random factor (data of 1 school cluster was excluded because it only had 22 participants), while controlling for the school entry time of each participant (introduced as covariate), in order to determine the main effects and detect possible interactions between age and other factors on the variables of interest (i.e., sleep restriction-extension pattern, social jetlag and corrected midpoint of sleep). Considering the aims of the present work, special attention will be given to the effects of age. Partial eta squares were computed as effect size measures to appreciate the impact of each factor on the variables of interest (using Cohen criteria to interpret the values found). It was not possible to test the impact of age and pubertal stage in the same model, since these variables were largely correlated ($r$>0.7). Thus, in order to avoid multicollinearity, age was chosen for GLM analysis, as it is more discriminative for prepubertal participants in the current sample. Still, we conducted preliminary ANCOVAs to detect possible interaction effects between pubertal developmental stage, age and sex, on the variables of interest, and no significant interactions were found between the pubertal stage and age or sex, over the relevant variables (neither when considering the 9-11 years old subset of the sample, neither when considering all age groups, nor when considering a dichotomized pubertal versus non pubertal categorization).

**Sample characteristics**

Overall, the survey was answered by the children's mother (85.1%, N=2675), father (10.1%, N=319), both mother and father (1.8%, N=57) or others (3%, N=94). Tutors age was 37.25±6.30. Most tutors had completed high school education (28.3%, N=784), 26.3% (N=729) completed basic education, 23.7% (N=655) did not complete basic education, and 21.7% (N=599) had completed or were completing higher education.

The final analysis included 3155 children attending one of 11 public school clusters across five educational regions of continental Portugal (DREN [3 schools]; DREL [3 schools]; DREC [2 schools]; DREA [2 schools]; DREALG [1 school]), 51% boys (N=1601) and 49% girls (N = 1544), with ages ranging from 4 to 11 years old, 7.92±2.054. Albeit there was no gender difference in age ($t(3143)=-1.030$, $p=0.303$), there was a gender difference in pubertal stage, with slightly more girls reaching midpubertal/late pubertal stage (9-11 years old girls vs boys: 66.13% vs 18.22%, [$t(1073.331)=-16.240$, $p<.001$]).

## Results

**Overview of the sleep-wake patterns**

On school-days, children woke-up, on average, at 7:37±32m and got-up at 7:43±33m. They woke-up with the help of a relative (76.1%, N=2277), on their own (19.1%, N=571) or with an alarm clock (4.8%, N=145), and were fully awake at 7:49±34m. On school-days, bedtime was, on average, at 21:35±36m, lights-off at 21:49±38m, sleep latency 11m±9m and sleep onset 21:59±39m. Period of sleep was, on average, 9h37m±44m, MS 2:48±28m.

On free-days, children woke-up, on average, at 9:05±1h03m. Most did not return to sleep (84.4%, N=2556) and the ones who did (15.6%, N=474), returned to sleep 16m±16m after waking up. On free-days, children got-up at 9:24±1h0m3 and were fully awake at 9:24±1h06m.

Most children did not take regular naps (91.5%, N=2760), and the ones who did (8.5%, N=258), napped once a week (28.2%, N=68), twice (52.3%, N=126), three times (5.8%, N=14), four (0.8%, N=2), five (5.4%, N=13), six (0.4%, N=1) or seven times a week (7.1%, N=17), on average, for 1h36m±44m a day. Bedtime was 22:14±47m, lights-off 22:27±48m, sleep latency 11m±9m and sleep onset 22:38±49m. Period of sleep on free-days was, on average, 10h27m±1h01m, and MSF 3:52±47m. Sleep need was, on average, 9h51m±40m. MSFsc was 3:34±41m.

Most sleep-wake parameters did not differ significantly between boys and girls (Table I), except wake-up, get-up and fully alert time on free-days, which were later in girls. MSF was also later in girls. Girls also exhibited a greater sleep restriction-extension pattern and social jetlag (according to Roenneberg's formula).

**Differences between school-days and free-days**

Table II shows the parents' reports of their child's sleep-wake parameters on school-days and free-days for the whole sample. Most parameters were statically different between school and free-days; timing was delayed and sleep durations were lengthened from school to free-days. For example, children in our sample go to bed and start sleeping, on average, 39 minutes later on free-days in comparison to school-days, and extend their sleep by waking up, on average, 1 hour and 28 minutes, and by getting up, on average, 1 hour and 41 minutes later on weekend mornings. Their MSF is delayed, on average, by 1 hour and 4 minutes when compared to their MSC. Night sleep duration averages about 50 minutes more on free-days than school-days. There was no statistical significance in the differences in sleep latency.

**Differences by age**

Our results (Table III) show that, on free-days, wake-times and sleep onsets are already delayed compared to school-days in children as young as 4 years of age, and that this delay increases progressively with age. Figure 1b shows that children have later sleep onsets as they get older, both on school and free-days. However, wake-times (Figure 1a) on school-days get earlier across these age groups since they are mostly dictated by school start-times. Social jetlag (Figure 1c) increases gradually as children grow older and is already present in younger children (SJL_R is 45 minutes and SJLsc 24 minutes for children at the age of 4, and go up to 1 hour and 21 minutes and 42 minutes in children at the age of 11, respectively). MSFsc (Figure 1d) too increases progressively from 4 to 8 years of age, when it reaches its maximum, and then it remains stable around ages 9-11. A sleep restriction-extension pattern (Figure 1e) is already present in children as young as 4 years of age (30 minutes), and it increases gradually as children grow older, reaching 1 hour and 16 minutes at the age of 11. Night sleep duration (Figure 1f) decreases significantly on school-days as children grow older, while on free-days they remain relatively consistent across age-groups (there are no significant differences). The effect size of age was small on sleep restriction-extension patterns, school entry times, corrected midpoint of sleep and social jetlag operationalized by Jankowski and medium on social jetlag operationalized by Roenneberg.

**Differences by school-grade level**

Sleep parameters vary greatly across school-grade level (Table IV). As shown above with age, wake-times (Figure 2a) and sleep onsets (Figure 2b) are already delayed in children attending kindergarten (k) on free-days compared to school-days. On school-days, wake-times are increasingly earlier across school-grade level, most probably dictated by school entry (Figure

2e) due to earlier school start-times since on free-days wake-times are increasingly later. Sleep onsets are progressively later as school-grade level goes up on both school and free-days. SJL_R is already 47 minutes in kindergarten and it increases until 6th grade, reaching, at the latter school-age level, 1 hour and 22 minutes (Figure 2c). SJLsc increases from 26 minutes in kindergarteners to 44 minutes in 6th graders. MSFsc also increases from kindergarten through 6th grade, although at a lower rate (Figure 2d). Kindergarteners already present a sleep restriction-extension pattern of 31 minutes, and this pattern increases as school-grade level goes up, reaching a maximum of 1 hour and 16 minutes at 5th grade (Figure 2f). As expectable, there is a pronounced overlap of results by school-grade level and results by years of age. On school-days, night sleep duration (Figure 2g) decreases gradually as school-grade level increases, whereas on free-days, although there is a decreasing tendency, they remain middling constant. The effect size of school-grade level was small on sleep restriction-extension patterns, midpoint of sleep corrected and social jetlag operationalized by Jankowski and medium on social jetlag operationalized by Roenneberg and school entry times.

**Multifactorial analyses – main effects and interaction effects**

The interactions effects (Table V) between age and sex and between age and school cluster were not significant for sleep restriction-extension pattern, social jetlag as operationalized by Jankowski or corrected midpoint of sleep. For social jetlag operationalized by Roenneberg significant interaction effects were found between sex and age. Therefore, in this case we further analyzed the main effect of age for boys and girls separately. Post hoc analysis showed this interaction does not invalidate the main effects, as the general tendency for social jetlag operationalized by Roenneberg across age, a middling linear increase, is the same for boys and girls. However, girls exhibited a more pronounced increase of social jetlag between the ages of 10 and 11 than boys.

There were statistically significant main effects of age, school entry time and school cluster on sleep restriction-extension patterns and midpoint of sleep and statistically significant main effects of age, sex and school entry times on social jetlag operationalized by Jankowski. There were statistically main effects for age, sex, school cluster and school entry times on social jetlag operationalized by Roenneberg. The effect size of age and school cluster was large for each one of the variables of interest, while the effect size of school entry time was small for every variable.

These analyses confirm our results are not moderated by age-sex or age-school cluster interactions.

## Discussion

The present large-scale school-based study on the sleep habits of Portuguese children suggests that the delay of the sleep-wake pattern in relation to school schedules is already apparent in preschool children, and that it increases gradually year after year, from preschool to the 6th grade. Albeit without studying preschool children, Spruyt and colleagues (29) also observed this tendency. Hence, our results suggest that changes assumed to occur with the onset of puberty or during adolescence start much earlier and change gradually as children develop. Research on middle and high school teens found a delayed sleep-wake time by an average of 1-3h from school to free-days as a function of age (3, 6, 15) which has been interpreted as a result of puberty (22, 29, 30). Our findings indicate that similar patterns, albeit softly, already occur in preschool children as follows: 39 min later for sleep onset, 1h 28 min later for wake-up time and 50 min longer for sleep period on free-days than on school-days. According to Touchette et al.

(16), this may occur due to the fact that the endogenous circadian period in children is already longer than 24 hours.

Younger children in our sample already exhibit statistically significant sleep restriction-extension patterns and a behavioral sleep rebound on free-days, as well as social jetlag, suggesting that their late sleep-wake patterns lead to the accumulation of sleep debt during the week, for which they try to compensate on free-days by extending their sleep duration. On free-days, all children sleep more than they do on school-days, including the younger ones, and there is a progressive and significant reduction in the amount of sleep time on school-days as school-grade level and age increased. These phenomena, consistently found in adolescents (e.g., 31), suggest a gradual delay in sleep-wake patterns of children in preschool and school-age years. Our findings are in line with the ones presented by Gruber (12), indicating that free-days versus school-days discrepancies start at a much younger age than what is assumed. The reduction in the amount of sleep time occurs due to a progressive delay in sleep onset as age and school-grade level increase, while wake-times demanded by school start-times remain constant or even advanced. Although the sleep restriction-extension pattern and social jetlag increased as children grew older, they already seem to be a reason for concern in younger children, especially because previous studies (12, 32) found that, whilst the majority of children spend the recommended amount of hours in bed, only a small percentage obtain the recommended amount of sleep following the National Sleep Foundation recommendations (33). This is a cause for concern since sleep deprivation during the first years of life may result in long-lasting consequences (34), as sleep is considered crucial for learning and academic function in children given its role in brain maturation (35). Insufficient sleep duration in children has social, academic, health and behavioral consequences (36), may result in excessive daytime sleepiness (37), it interferes with the memorization process (29, 38, 39) and increases the risk of cognitive impairments (41). Prolonged sleep deprivation can result in serious physical symptoms, such as increased heart rate and blood pressure (41), insulin resistance and changes in hormones which may lead to obesity (16, 42, 43) and is associated with poorer overall health and body's natural defense mechanisms (44). Furthermore, social jetlag has also been recognized as detrimental for psychological (46), physiological (46) and cognitive functioning (47, 48) and health (49).

During the past decade, the growing amount of scientific evidence demonstrating that an adequate sleep duration and timing is crucial for the teens' health, well-being and academic performance, as well as the encouragement of the American Academy of Pediatrics and The American Medical Association for later school start-times that allow students to get sufficient sleep and align school schedules to their biological sleep rhythms, have led to the delay of school start-times in some middle and high schools (50). Studies show teens in schools with later start-times have less daytime sleepiness, fatigue and sleep restriction, exhibit ~~a~~ better behavior, attention and concentration during class (51, 52, 53, 54, 55) and show improved sleep quality (56). Furthermore, previous studies indicate not only that early school start-times for both middle and high school students are associated with diverse and serious adverse sleep, health, safety, and education consequences, but also that delaying them may mitigate the impact of negative consequences (57, 58, 59). Our results suggest it is possible that early school start-times likewise contribute to insufficient sleep duration and circadian misalignment in younger children, albeit to a much lesser degree than their older peers. Despite not being the focus of our analysis, our findings dispute the predominant supposition that sleep-wake habits are unaltered across the school age period, as several previous studies (e.g., 12) have shown. Even though night sleep duration's means were within the recommended sleep range, particularly amongst preschool children they were closer to the lower limit. A great percentage of Portuguese school-children sleep less than the recommended number of hours on school-days due to late bedtimes, thus accumulating a sleep debt for which they try to compensate by sleeping longer on free-days.

Though there is an obvious overlap of children's sleep-wake patterns across age and school-grade level, school entry varies importantly across school cycles in Portugal. Hence, an analysis by school-grade level was performed in order to underline the circadian misalignment of school start-times and children's biological sleep rhythms. Our results suggest that the advance of school start-times across school-grade level, from preschool to the 2$^{nd}$ study cycle, in the Portuguese school system is clearly inappropriate, as it follows an inverse tendency from the sleep-wake schedules exhibited by our participants. In other words, there seems to be an increasing divergence between school schedule's progression and sleep-wake patterns exhibited by children in our sample. Delaying school start-times could adjust social demands to the biological rhythm of children. Albeit school-age children's schedules are largely influenced by their tutor's schedules and Portugal has one of the longest working schedules amongst European countries, which might explain the late schedules at bedtimes in this study, tutors' schedules are not the only factor contributing to their sleep-wake patterns' delay since the delay is progressive from 4 to 11 years of age. Furthermore, though it may seem Portuguese children already have later school start-times than many children in other countries, it is important to take into account that Portugal follows Greenwich Mean Time, even though Portugal's time zone is slightly to the west of the Prime Meridian. A large portion of continental Portugal is on -1 Time Zone during winter. This means that there is a mismatch (of approximately 37 minutes in "winter time", plus one more hour mismatch in summer) between clock time and solar time. Thus, for instance, when Portuguese preschool children start kindergarten at 9:30 clock time, they are entering at

8:53 solar time (winter hour). And when 5th and 6th grade students (10-11 years old) start classes at 8:30, they are in reality starting at 7:53 solar time (winter).

A gender difference in sleep-wake patterns was also observed. In line with our results, previous studies (3, 6, 12, 60) found a tendency for girls to wake up later and sleep longer on free-days, suggesting later chronotypes in the analyzed age range. A possible explanation for these results is the early changes in homeostasis and chronotype for preadolescent girls.

Contrary to what was expected, interaction effects between pubertal development stage and age and between pubertal development stage and sex were not found on the variables of interest. This may be due to the fact that our sample largely consists of prepubertal children and not exactly adolescents, including children until the age of 11. Therefore, there is a limited range of represented pubertal development stages (early pubertal and midpubertal stages are represented, but there is an insufficient number of cases for the late pubertal analysis and none for postpubertal stage).

As to the effect of school “cluster”, albeit it was not the focus of the present work, it seems to deserve further research given its magnitude and statistical significance. It is important to notice that since no significant interaction was found between age and school cluster, one may conclude that the main effects by age are applicable to the variety of school clusters considered.

Our results should be considered in light of some limitations. First, the study was cross-sectional, which restricts the possibility to draw longitudinal inferences. Second, subjective measures were used, and parent-report surveys are exposed to social desirability bias and inadvertent error. Besides, parents can only report the sleep period, as they aren’t able to know how much of that time in bed is spent sleeping. Studies found that sleep periods are longer in parental reports than actigraphy records (61). Nonetheless, survey designs are considered the best method to collected information from large groups and to determine community trends (62). The major strengths of the present study are the large and representative sample size that includes children from all regions of continental Portugal and the amplitude of age groups covered. As potential implications of the present study, we believe there is a need for families, educational authorities and health professionals to be alert to children's circadian biology, since they need to receive an adequate quantity and quality of sleep in order to achieve peak daily performance. Hence, society should promote adequate sleep habits and practices among developing children and adapt school organization to meet their sleep-wake cycle.

## Conclusion

Our results show that the displacement of sleep-wake patterns to later hours is already apparent in preschool children and that it increases gradually with age, from preschool to the 6$^{th}$ grade. Albeit there is a progressive delay in sleep onset across school-grade level and age groups, wake-times on school-days advance as age and school-grade level increase due to an advance in school start-times to earlier hours. Thus, there is an increasing divergence between sleep-wake patterns exhibited by children in our sample and school schedules progression. The changes of school starting times in Portugal, from kindergarten (9:30) to 5-6th school grades of basic education (8:30), seem in clear contradiction with the progression in sleep-wake patterns from 4 to 11 years old.

**Acknowledgments**

We are deeply grateful to Dr. Diana Couto (University of Aveiro) for her precious help with data collection. We are also grateful to the Faculty of Psychology and Educational Sciences of the University of Coimbra, where currently Dr. Inês Clara is conducting her master degree and research work, under the supervision of Ana Allen Gomes, presently coordinating the related research project True Times – PTDC/PSI-ESP/32581/2017 and CENTRO-01-0145-FEDER-032581, hosted at the FPCEUC.

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Tables

Table 1

Differences in sleep variables between boys and girls

| Sleep variable | | Sex | | *t*-test | *p* |
|---|---|---|---|---|---|
| | | Boys | Girls | | |
| Wake-time | SC | 7:38am±32m | 7:36am±32m | *t*(3094)=1.574 | .116 |
| | FR | 8:59am±1h03m | 9:12am±1h02m | *t*(3109)=-5,839 | <.001* |
| Get-up | SC | 7:44am±33m | 7:43am±33m | *t*(3093)=1,195 | .232 |
| | FR | 9:17am±1h03m | 9:32am±1h02m | *t*(2839)=-6.550 | <.001* |
| Fully alert | SC | 7:50am±35m | 7:49am±33m | *t*(3003)=.609 | .543 |
| | FR | 9:15am±1h06m | 9:33am±1h05m | *t*(2794)=-7,108 | <.001* |
| Sleep inertia | SC | 11m±17m | 13m±14m | *Z*=-3.398 | .001* |
| | FR | 16m±29m | 20m±32m | *Z*=-3.545 | <.001* |
| Bedtime | SC | 9:36pm±36m | 9:35pm±36m | *t*(3094)=1.034 | .301 |
| | FR | 10:14pm±46m | 10:14pm±46m | *t*(3059)=-.234 | .815 |
| Lights-off | SC | 9:49pm±37m | 9:49pm±39m | *t*(3007)=.114 | .909 |
| | FR | 10:27pm±47m | 10:28pm±48m | *t*(2941)=-.688 | .491 |
| Sleep latency | SC | 11m±9m | 11m±9m | *Z*=-.897 | .370 |
| | FR | 11m±9m | 11m±10m | *Z*=-.639 | .523 |
| Sleep onset | SC | 10:00pm±38m | 9:59pm±39m | *t*(2858)=.673 | .501 |
| | FR | 10:38pm±48m | 10:39pm±50m | *t*(2808)=-.532 | .595 |
| Night sleep duration | SC | 9h38m±43m | 9h37m±45m | *t*(2797.407)=.548 | .584 |
| | FR | 10h21m±1h01m | 10h33m±1h01m | *t*(2793)=-5.171 | <.001* |
| MS (MSF and MSC) | SC | 2:49am±28m | 2:47am±28m | *t*(2828)=1,431 | .153 |
| | FR | 3:48am±46m | 3:56am±47m | *t*(2793)=-4,004 | <.001* |
| Sleep need | | 9h50m±39m | 9h53m±40m | *t*(2710)=-1,816 | .069 |
| Sleep restriction-extension pattern | | 43m±1h03m | 55m±1h05m | *t*(2710)=-5.103 | <.001* |
| MSFsc | | 3:33am±41m | 3:36am±42m | *t*(2710)=-1.588 | .112 |
| SJL_R | | 59m±38m | 1h08m±40m | *t*(2675.297)=-5.583 | <.001* |
| SJLsc | | 34m±30m | 37m±32m | *t*(2490)=-2.712 | .007 |
| School entry | | 8:49am±47m | 8:51am±51m | **t**(3055)=-1.162 | .245 |

Table 2

Sleep variables on school-days and free-days

| Sleep variable | SC | FR | Paired *t*-Test | *p* |
|---|---|---|---|---|
| Wake-time | 7:37am±32m | 9:05am±1h03m | *t*=.255 | <.001* |
| Get-up | 7:43 am±33m | 9:24am±1h03m | *t*=.226 | <.001* |
| Fully alert | 7:50 am±34m | 9:24am±1h06m | *t*=.272 | <.001* |
| Sleep inertia | 12m±16m | 18m±30m | *Z*= -9.871 | <.001* |
| Bedtime | 9:35 pm±36m | 10:14pm ± 47m | *t*=.695 | <.001* |
| Lights-off | 9:49 pm±38 | 10:27pm±48m | *t*=.683 | <.001* |
| Sleep latency | 11m±9m | 11m±9m | *Z*=-.281 | .779 |
| Sleep onset | 9:59 pm±39m | 10:38pm±49m | *t*=.691 | <.001* |
| Night sleep duration | 9h37m±44m | 10h27m±1h01m | *t*=.288 | <.001* |
| MS (MSC and MSF) | 2:48±28m | 3:52 ± 47m | *t*=.540 | <.001* |

Table 3

Sleep variables across age

| Sleep variable | Age | | | | | |
|---|---|---|---|---|---|---|
| | **SC** | | | **FR** | | |
| | ***F*** | ***P*** | ***$\eta^2$*** | ***F*** | ***p*** | ***$\eta^2$*** |
| Wake-time | $F(7, 3097)=37.306$ | <.001* | .078 | $F(7, 3111)=8.887$ | <.001* | .020 |
| Get-up | $F(7, 3097)=40.332$ | <.001* | .084 | $F(7, 2842)=8.042$ | <.001* | .019 |
| Fully alert | $F(7, 3006)=38.401$ | <.001* | .082 | $F(7, 2796)=8.480$ | <.001* | .021 |
| Sleep inertia | $\chi^2(7)= 6.286$ | .507 | | $\chi^2(7)= 17.035$ | .017* | .017 |
| Bedtime | $F(7, 3098)=19.197$ | <.001* | .039 | $F(7, 3062)=27.743$ | <.001* | .060 |
| Lights-off | $F(7, 3011)=19.197$ | <.001* | .043 | $F(7, 2944)=29.401$ | <.001* | .065 |
| Sleep latency | $\chi^2(7)= 11.881$ | .105 | | $\chi^2(7)=9.045$ | .249 | |
| Sleep onset | $F(7, 2860)=19.739$ | <.001* | .046 | $F(7, 2810)=27.723$ | <.001* | .065 |
| Night sleep duration | $F(7, 2830)=69.414$ | <.001* | .147 | $F(7, 2794)=1.571$ | .139 | .004 |
| MS (MSF and MSC) | $F(7, 2830)=2.521$ | .014 | .006 | $F(7, 2794)=21.363$ | <.001* | .051 |
| | ***F*** | | ***p*** | | ***$\eta^2$*** | |
| Sleep need | $F(7, 2710)=42.827$ | | <.001* | | .100 | |
| Sleep restriction-extension pattern | $F(7, 2710)=20.153$ | | <.001* | | .049 | |
| MSFsc | $F(7, 2710)=10.027$ | | <.001* | | .025 | |
| SJL_R | $F(7, 2710)=29.884$ | | <.001* | | .072 | |
| SJLsc | $F(7, 2490)=10.625$ | | <.001* | | .029 | |
| School entry | $F(7, 3058)=22.414$ | | <.001* | | .049 | |

Table 4

Sleep variables across school-grade level

| Sleep variable | School-grade level | | | | | |
|---|---|---|---|---|---|---|
| | **SC** | | | **FR** | | |
| | ***F*** | ***P*** | $\boldsymbol{\eta^2}$ | ***F*** | ***p*** | $\boldsymbol{\eta^2}$ |
| Wake-up | $F(6, 3091)=54.622$ | <.001* | .096 | $F(6, 3104)=11.276$ | <.001* | .021 |
| Get-up | $F(6, 3090)=60.711$ | <.001* | .105 | $F(6, 2836)=9.448$ | <.001* | .020 |
| Fully alert | $F(6, 3001)=55.169$ | <001* | .099 | $F(6, 2792)=10.278$ | <.001* | .022 |
| Sleep inertia | $\chi^2(6)=7.790$ | .254 | | $\chi^2(6)=19.068$ | .004 | |
| Bedtime | $F(6, 3091)=25.076$ | <.001* | .046 | $F(6, 3057)=36.464$ | <.001* | .067 |
| Lights-off | $F(6, 3005)=25.420$ | <.001* | .048 | $F(6, 2940)=38.165$ | <.001* | .072 |
| Sleep latency | $\chi^2(6)=14.429$ | .025 | | $\chi^2(6)=11.330$ | . 079 | |
| Sleep onset | $F(6, 2855)=25.025$ | <.001* | .050 | $F(6, 2806)=34.944$ | <.001* | .070 |
| Night sleep duration | $F(6, 2826)=94.438$ | <.001* | .167 | $F(6, 2790)=2.462$ | .022 | .005 |
| MS (MSF and MSC) | $F(6, 2826)=4.915$ | <.001* | .010 | $F(6, 2790)=26.477$ | <.001* | .054 |
| | ***F*** | | ***p*** | | $\boldsymbol{\eta^2}$ | |
| Sleep need | $F(6, 2707)=59.363$ | | <.001* | | .116 | |
| Sleep restriction-extension pattern | $F(6, 2707)=25.494$ | | <.001* | | .053 | |
| MSFsc | $F(6, 2707)=12.251$ | | <.001* | | .026 | |
| SJL_R | $F(6, 2707)=38.133$ | | <.001* | | .078 | |
| SJLsc | $F(6, 2487)=12.744$ | | <.001* | | .030 | |
| School entry | $F(6, 3057)=35.961$ | | <.001* | | .066 | |

Table 5

Main effects and interaction effects

| Sleep variable | Factor | $F$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| Sleep restriction-extension pattern | Age | $F(7, 84.194)=7.391$ | <.001* | .381 |
| | Sex | $F(1, 2535)=.965$ | .326 | .000 |
| | School cluster | $F(9, 73.185)=6.130$ | <.001* | .430 |
| | School entry (covariate) | $F(1, 2535)=51.023$ | <.001* | .020 |
| | Age*sex | $F(7, 2535)=1.180$ | .311 | .003 |
| | Age*school cluster | $F(60, 2535)=1.287$ | .070 | .030 |
| SJL_R | Age | $F(7, 89.223)=17.382$ | <.001* | .577 |
| | Sex | $F(1, 2535)=26.415$ | <.001* | .010 |
| | School cluster | $F(9, 75.827)=5.203$ | <.001* | .382 |
| | School entry (covariate) | $F(1, 2535)=31.989$ | <.001* | .012 |
| | Age*sex | $F(7, 2535)=2.392$ | .019* | .007 |
| | Age*school cluster | $F(60, 2535)=1.082$ | .312 | .025 |
| SJLsc | Age | $F(7, 90.799=8.047$ | <.001* | .383 |
| | Sex | $F(1, 2323)=8.218$ | .004* | .004 |
| | School cluster | $F(9, 76.832)=1.402$ | .202 | .141 |
| | School entry (covariate) | $F(1, 2323)=19.731$ | <.001* | .008 |
| | Age*sex | $F(7, 2323)1.473$ | .172 | .004 |
| | Age*school cluster | $F(60, 2323)=1.035$ | .402 | .026 |
| MSFsc | Age | $F(7, 84.194)=7.391$ | <.001* | .381 |
| | Sex | $F(1, 2535)=.965$ | .326 | .000 |
| | School cluster | $F(9, 73.185)=6.130$ | <.001* | .430 |
| | School entry (covariate) | $F(1, 2535)=51.023$ | <.001* | .020 |
| | Age*sex | $F(7, 2535)=1.180$ | .311 | .003 |
| | Age*school cluster | $F(60, 2535)=1.287$ | .070 | .030 |

Differences in sleep variables by age:

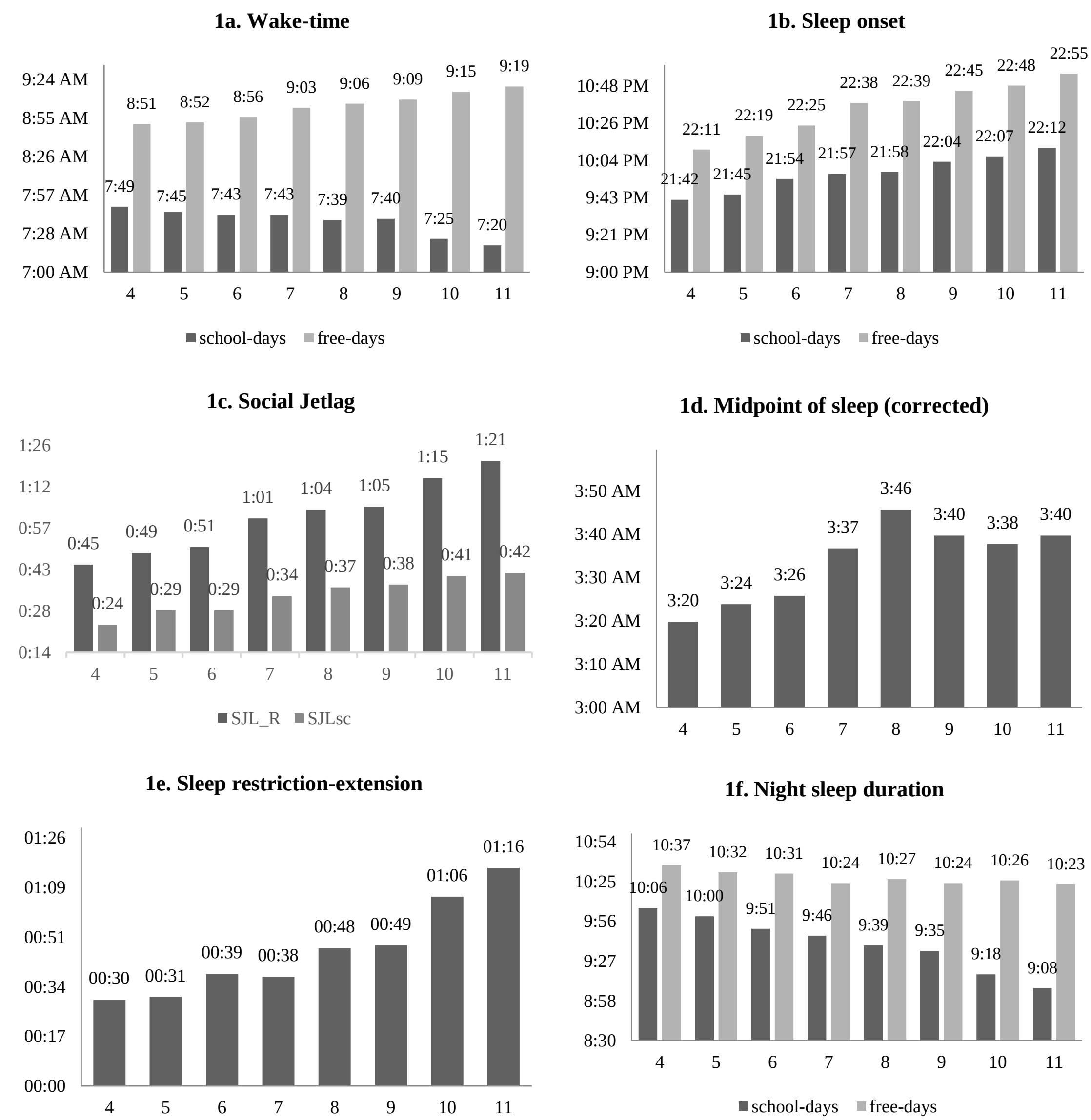


*Figure 1*. Figure 1a shows wake-time progression by age [on SC, post hoc: 4>8, 9, 10, 11; 5, 6, 7>10, 11; 4>8, 9>10, 11; 10, 11<4, 5, 6, 7, 8, 9; on FR: 4<8, 9, 10, 11; 5, 6<9, 10, 11; 10>4, 5, 6; 11>4, 5, 6, 7]. Figure 1b shows sleep onset progression by age [on SC, post hoc: 4<6, 7, 8, 9, 10, 11; 5<7, 8, 9, 10, 11; 4<6<9, 10, 11; 4, 5<7<10, 11; 4, 5<8<11; 4, 5, 6<9; 10>4, 5, 6, 7; 11>4, 5, 6, 7, 8; on FR, post hoc: 4<6, 7, 8, 9, 10, 11; 5<7, 8, 9, 10, 11; 4<6<7, 8, 9, 10, 11; 4, 5, 6<7,

8<11; 9, 10, >4, 5, 6; 11>4, 5, 6, 7, 8]. Figure 1c shows social jetlag operationalized according to Roenneberg's (23; SJL_R – darker graph), and to Jankowski's (24; SJLsc – lighter graph) formulas [SJL_R post hoc: 4, 5, 6<7, 8, 9<10, 11 and SJLsc post hoc:4<7, 8, 9, 10, 11; 5<9, 10, 11; 6<8, 9, 10, 11; 7<11]. Figure 1d shows the progression of midpoint of sleep operationalized as Roenneberg et al. (23) by age [post hoc: 4, 5, 6<7, 8, 9, 10, 11]. Figure 1e shows sleep restriction-extension pattern's [post hoc: 4, 5<8, 9<10, 11; 10, 11>4, 5, 6, 7, 8, 9] and Figure 1f shows night sleep duration's progression by age [on SC, post hoc: 4>6, 7, 8, 9, 10, 11; 5>7, 8, 9, 10, 11; 4>6>8, 9, 10, 11; 4, 5>7>9, 10, 11; 4, 5, 6>8>10, 11; 4, 5, 6, 7>9>10, 11; 4, 5, 6, 7, 8, 9>10>11; 11<4, 5, 6, 7, 8, 9, 10; on FR there are no significant differences].

Differences in sleep schedule variables by school-grade level:

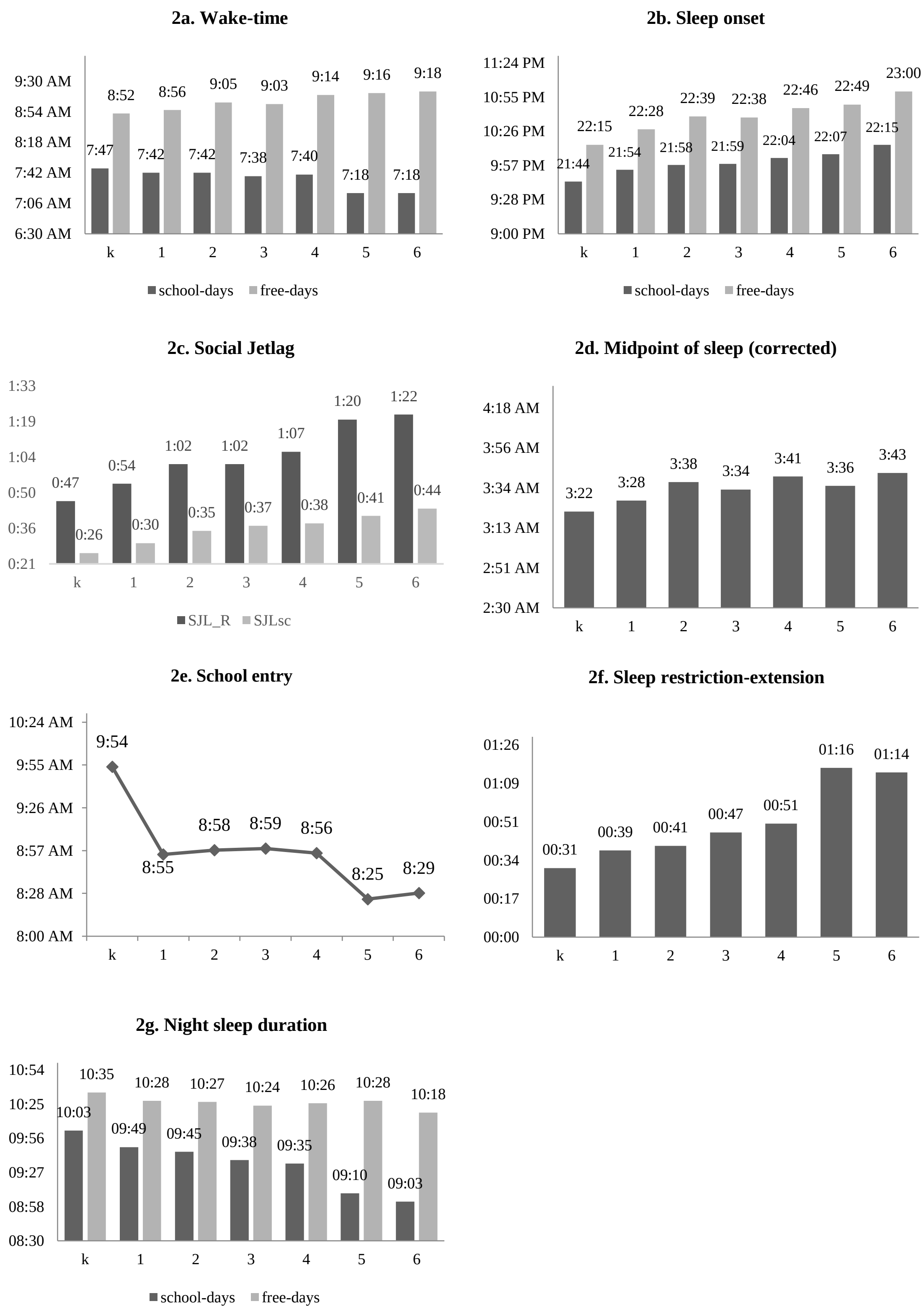

*Figure 2*. Differences in sleep schedule variables by school-grade level. Figure 2a shows wake-times' progression by school-grade level [on school-days, post hoc: k>3rd, 4th, 5th, 6th; 1st, 2nd>5th, 6th; k>3rd, 4th>5th, 6th; 5th, 6th<k, 1st, 2nd, 3rd, 4th; on free-days, post hoc: k<2nd, 3rd, 4th, 5th, 6th; 1st<4th, 5th, 6th; k<3rd<4th, 5th, 6th; 4th>k, 1st, 3rd; 5th>k, 1st, 3rd; 6th>k, 1st]. Figure 2b shows sleep onset [on SC, post hoc: k<1st<4th, 5th, 6th; k<2nd<5th, 6th; k<3rd<6th; k, 1st<4th<6th; 5th>k, 1st, 2nd; 6th>k, 1st, 2nd, 3rd, 4th; on FR: k<1st<2nd, 3rd, 4th, 5th, 6th; k, 1st<2nd, 3rd<5th, 6th; k, 1st<4th<6th; 5th>k, 1st, 2nd, 3rd; 6th>k, 1st, 2nd, 3rd, 4th]. Figure 2c shows social jetlag operationalized by Roenneberg's (23; SJL_R) and Jankowski's formulas (24; SJLsc) [SJL_R post hoc: k, 1st<2nd, 3rd, 4th, 5th, 6th; k, 1st<2nd, 3rd, 4th<5th, 6th; 5th, 6th>k, 1st, 2nd, 3rd, 4th; SJLsc post hoc: k<2nd, 3rd, 4th, 5th, 6th; 1st<3rd, 4th, 5th, 6th; 2nd<6th]. Figure 2d shows corrected midpoint of sleep, operationalized by Roenneberg (23) [post hoc: k<2nd, 3rd, 4th, 5th, 6th; 1st<2nd, 4th, 6th; k, 1st<2nd, 4th, 6th]. Figure 2e shows school entry times' progression by school-grade level [post hoc: 5th, 6th<k, 1st, 2nd, 3rd, 4th]. Figure 2f shows sleep restriction-extension pattern's [on SC, post hoc: k>4th, 6th; on FR there are no significant differences] and Figure 2g shows night sleep duration's progression by school-grade level [on SC, post hoc: k>1st>3rd, 4th, 5th, 6th; k>2nd>4th, 5th, 6th; k, 1st>3rd>5th, 6th; k, 1st, 2nd>4th>5th, 6th; 5th, 6th<k, 1st, 2nd, 3rd, 4th; on FR: k>6th].

A poster based on this paper was presented on the 30th Conference of the International Society for Chronobiology (see Appendix 2).

# Article 2

[Proposed authorship]: Clara, M. I., Clemente, V., Abrantes, J., Azevedo, M. H. & Gomes, A. A. (2019). Trends in sleep-wake patterns of primary school children: a comparison between 1996 and 2016.

# Trends in sleep-wake patterns of primary school-age children: a comparison between 1996 and 2016

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Abstract

**Objective**: In spite of the inconsistent evidence, it is often assumed that sleep duration has declined over recent decades and that sleep schedules have delayed as society modernizes. We aimed to investigate sleep-wake patterns differences of primary school-age children between 1996 and 2016. **Methods**: Data from two different studies using the same questionnaire (Children's sleep-wake patterns questionnaire) was combined for 666 Portuguese children attending 3rd and 4th grades of basic education. **Results**: There were no statistically significant differences between the two time points regarding average sleep duration. However, the number of children sleeping the recommended number of hours decreased since 1996. Wake-times on free-days as children got older became earlier on 2016. Difficulties on settling to sleep alone and returning back to sleep, as well as fearing the dark and needing lights on or parents' presence in order to fall asleep increased in 2016 when compared to 1996. **Conclusion**: Sleep timing and duration did not change on average between the two times points, albeit more children were sleeping less in 2016 when compared to 1996. Sleep onset-related disturbances increased from 1996 to 2016, most likely due to changes in parental practices that prevent children from learning to fall asleep independently.

*Keywords*: children; sleep timing; sleep duration; sleep-wake behaviors; sleep disturbances.

Trends in sleep-wake patterns of primary school-children: a comparison between 1996 and 2016

Despite conflicting evidence, it is widely presumed that sleep deprivation has increased in recent years, with some authors suggesting it has reached epidemic levels (e.g., Roenneberg, 2013). While some studies report a decreasing trend in sleep duration of children and adolescents (Iglowstein, Jenni, Molinari, & Largo, 2003; Matricciani et al., 2017; Matricciani, Olds, & Petkov, 2012; Twenge, Krizan, & Hisler, 2017), literature is inconsistent, with recent studies noting rather a slight increase in average sleep time in adults (Pérez, Gershuny, Foster, & De Vos, 2018) and adolescents (teens 15 years and older; Leech, 2016). An empirical review by Matricciani, Olds, and Petkov (2012) reported that total sleep duration of children and adolescents has declined by an average of 0.75 per night over the last century and by 14 minutes per night since 1970. However, Youngstedt et al. (2016) argue that these data might be explained by decreased children physical activity levels (e.g., walking/cycling to school and playing outdoors have been largely replaced by car rides and sedentary indoor activities), denying a decline in sleep duration over the past 50 years. De Ruiter, Olmedo-Requena, Sánchez-Cruz and Jiménez-Moleón (2016) found a decrease of 20 minutes in sleep duration in children aged 2-14 years old over the last two decades, a downward trend slightly higher than the reported by Matricciani et al. (2012). On the other hand, Basner and Dinges (2018) reported an increase in sleep duration in high school students over 15 years only during weekends and holidays.

Furthermore, research conducted over the past decades reports that many children and adolescents do not meet recommended sleep guidelines (Bowers & Moyer, 2017), notwithstanding its association with significant health consequences. The National Sleep Foundation (NSF; Hirshkowitz et al., 2015) recommends 9-11 hours for school age children (6-13 years of age) in order to maintain alertness and perform well during the day. However, it has been estimated that 15%–75% of school-aged children are not getting sufficient sleep (Li et al., 2013). Besides early school start-times, developments in technology have been advocated as factors that might underlie disturbances in sleep patterns or duration. According to Akacem and colleagues (2016), during early childhood, chronic exposure to light during the evening hours and late bedtimes may interact to facilitate the development of a late sleep phenotype. Exposure to artificial light near bedtime, particularly light emitted from electronic screens, has been associated with prolonged sleep onset and shorter sleep duration and in children and adolescents (Cain & Gradisar, 2010; Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016). Twenge, Krizan and Hisler (2017) examined changes in sleep duration of U.S. adolescents between 2009 and 2015 and found an increase in short sleep duration after 2011-2013, arguing that increased media screen time may be involved in insufficient sleep among adolescents, whilst other activities linked to short sleep duration, such as homework time and TV watching, were stable or decreased over this time period, making it unlikely they caused the increase in shorter sleep duration. Nevertheless, the literature has produced contrary findings, as Leech (2016) found no evidence that growth of screen time occurred at the expense of sleep duration, noting rather an increase of the average sleep duration in Canadians aged 15 years and older between 1998 and 2010, a period of rapid advances in computer technology, video gaming and electronic social media.

A recent study reported that 57% of school-age children was suffering from at least one sleep problem (Khazaie, Zakiei, Komasi, & Brand, 2018). The conflict between children's sleep-wake patterns and social demands arises during school-age years. Thus, sleep habits and disturbances may start to affect children's functioning, as school schedules become the main *zeitgeber* of their sleep-wake rhythms (Clemente, 1997). Sleep-related difficulties often reported among children include problems falling asleep, waking up during the night, parasomnias, bruxism and symptoms relate to sleep-disordered breathing (Sheldon, Ferber, Kryger, & Gozal 2014) and may cause disruptions in emotional, cognitive, behavioral and academic domains (Fallone, Acebo, Seifer, & Carskadon, 2005; Sadeh, Gruer, & Raviv, 2002) and family dynamics (Meltzer & Mindell, 2007). Sleep problems during childhood are related to emotional problems later in life, such as depression (Gregory, Rijsdjik Lay, Dahl, & Eley, 2009).

The aim of this paper is to investigate changes in sleep wake-patterns (duration, timing and disturbances) among Portuguese school-age children by comparing two time marks: 1996, prior to the emergence of social media and technology device use, and 2016. Changes in sleep timing will be explored by analyzing bedtime, wake-time, social jetlag and midpoint of sleep differences between the two time points. In order to investigate whether children are getting enough sleep, night sleep duration, sleep need and sleep restriction-extension pattern will be analyzed. To examine sleep-wake behaviors and difficulties differences between 1996 and 2016, we will analyze bedtime-related disturbances (e.g., having trouble falling asleep without parents presence, a comforting habit or lights on), nighttime disturbances (night wakings, difficulty going back to sleep, bruxism, and parasomnias, including sleepwalking, night terrors, somniloquy and enuresis), daytime disturbances (daytime sleepiness, irritability and fatigue), as well as aspects related to child's health.

## Methods

### Participants

The sample for the current study included 666 children attending 3rd and 4th grades of basic education, 421 from study a (215 girls, 8.99±.776) and 245 from study b (129 girls, 8.99±.760). Table 1 summarizes sample characteristics for each study. There were no statistically significant differences in sex [$t(664)=.394$, $p=.694$] or age [$t(664)=.006$, $p=.995$] between the two studies. There were, however, statistically significant differences on school grade level between the two studies [$t(664)=-2.114$, $p=.035$], as the 2016 sample included more 4$^{th}$ graders.

## Measures

### Children's sleep-wake patterns questionnaire (PSVC).

Children were assessed by PSVC (*Questionário sobre o Padrão de Sono-Vigília de Crianças em idade escolar*; Clemente, Silva, Ferreira, César, & Azevedo, 1997), a Portuguese scale regarding school-age children habits, behaviors and sleep disturbances that has well established validity and stability. Previous studies (Carvalho Bos et al., 2009; Ferreira et al., 2000) provide a more detailed description of PSVC and study *a* methodology, as this questionnaire was developed to assess sleep and waking behavior for that epidemiologic survey. In this parent-report questionnaire, tutors of school-age children are asked to respond to 33 items, most of which following a 4-point Liker-type format, concerning children's sleep habits over the last six months. In addition to a short demographics, it includes 5 groups of questions: on group 1, regarding bedtime, tutors are inquired about children's bedtime on weekdays (school-days, SC) and weekends (free-days, FR), motive for bedtime and bedtime or sleep-onset-related behaviors and/or disturbances. Group 2 contemplates night sleep duration on school and free-days and nighttime phenomena (e.g., night wakings, parasomnias). Group 3 explores wake-times on school and free-days and motive for waking, while group 4 explores the waking state. Group 5 evaluates other aspects of sleep-related difficulties.

Sleep need was calculated for the current study through the weighted average: ([Night sleep duration [NSD] on SC × 5] + [NSD on FR × 2])/7. Midpoint of sleep was calculated by approximation using bedtime, as sleep onset was not explored (bedtime + NSD/2), for both SC

(MSC) and FR (MSF). Corrected midpoint of sleep (MSFsc) was calculated using the formula suggested by Roenneberg et al. (2004): MSF – [0.5 × (NSD on FR – sleep need)]. Social jet lag (SJL) was operationalized according to Roenneberg's (SJL_R; 204) and Jankowki's (SJLsc; 2017) formulas. Sleep restriction-extension pattern was defined as the difference between NSD on SC and FR.

The prevalence of sleep disturbances was defined as the totality of "*very often*" and "*always*" answers. For all items, including inverted items (i) – *settling to sleep alone*, *willingness to go to bed* and *going back to sleep alone after night wakings* – there is a directly proportional relation between mean and sleep disturbances.

The six previously established factors for PSVC (Carvalho Bos et al., 2009; Ferreira et al., 2000) were considered. Factor 1, *parents help to sleep* (including items settling to sleep alone, needing parents to fall asleep and falling asleep in parents' bed), reflected the need of parents' intervention in promoting child's sleep onset. Factor 2, *parasomnias*, included four items (night terrors, somniloquy, nightmares and sleepwalking). Factor 3 was termed *sleeping difficulties* and included the items seeking professional help to sleep, existence of sleep problems and needing sleep medication. Factor 4, *afraid of dark*, included two items (needing lights on to fall asleep and afraid of sleeping in the dark). Factor 5, *sleep limit setting*, was composed by bedtime resistance and unwillingness to go to bed items. Finally, Factor 6 included three items regarding *daytime sleep consequences* (sleepiness, fatigue and irritability). Cronbach's alpha coefficient ($\alpha$) in the current sample was .74 for Factor 1 and .84 for Factor 4. Albeit Chronbach's $\alpha$ was <.7 for the other factors, for including a small number of items, mean inter-item correlation values were considered optimal if ranging from .2 to .4, as suggested by Briggs and Cheeks (1986). We found an inter-item correlation of .23 for Factor 2, .29 for Factor 3, .12

for Factor 5 and .29 for Factor 6. Thus, all factors showed appropriate internal consistency except for Factor 5, with Factors 1 and 4 exhibiting greater reliability.

Parental consent was obtained on both studies from where data was drawn. Study *a* was reviewed and approved by the Regional Director of Education, and study *b* was accepted by the Portuguese Ministry of Education (permission corresponding to the MIME-DGE reference number 0516600001), as well as school administrators. Albeit children participating in study a were also assessed by the Portuguese version of The Rutter Teacher's Questionnaire (Azevedo, Barreto, Faria, & Robalo, 1986) and children participating in study *b* were also assessed by the Portuguese versions of School-Age Temperament Inventory (SATI; Lima, Lemos & Guerra) and Children's Choronotype Questionnaire (QCTC; Couto et al., 2011), these are beyond the scope of our study.

**Procedures**

This study investigates changes of school-age children sleep wake-patterns between 1996 (study *a*) and 2016 (study *b*). To this end, we selected and combined two samples from two different studies with Portuguese school-age children attending 3rd and 4th grades of basic education (primary school), which have used the same parental questionnaire. Study *a* was conducted in 1996 (Clemente, 1997) and it included 988 children attending the first cycle of basic education from 10 primary schools in a parish of the city of Coimbra (Central Portugal). It aimed to study sleep habits and estimate the association between sleep behaviors and psychopathology and between sleep behaviors and school performance. The sample from the study *b* was collected on two "school clusters" of Center Portugal in 2016 and it involved 376 children attending first and second cycles of basic education (Abrantes, 2016). The aims of this study were to examine the relation between dimensions of temperament and chronotype measures, as well as between dimensions of temperament and sleep patterns in children. Only comparable data, hence, only children attending 3rd and 4th school-grade levels of basic education from both samples were included in the present study (data from 421 participants was drawn from study *a* and for 245 participants from study *b*).

**Statistical analysis**

Analysis were performed using 22.0 version of IBM SPSS Statistics for Windows (IBM Corpo., Armonk, NY). Variables with normal distributions were presented as mean (M) ± standard deviation (SD). Variables were considered close to normally distributed if Skewness and Kurtosis were under 2 and 7, respectively (Kim, 2013). Homogeneity of variance was tested by Levene method. Comparisons of continuous sleep variables between 1996 and 2016 were initially conducted using Student *t*-tests and afterwards we used ANCOVAS controlling for age and sex (inserted as covariates). Chi-square tests were performed to compare categorical variables for the overall sample, boys and girls. Then, for the sleep disturbances that showed statistically significant differences between the two time marks in the overall sample, direct logistic regressions were performed to assess the impact of year, age and sex on the likelihood that the children would have a sleep disturbance. For *willingness to go to sleep*, besides year, age and sex, MSFsc was included in the model in order to rule out the influence related to chronotype. Finally, categorical variables were aggregated following previously established factors for this questionnaire (Carvalho Bos et al., 2009; Ferreira et al., 2000), and ANCOVAS with age and sex as covariates were performed. A $p$-value <.05 was considered statistically significant.

# Results

## Sample characteristics

In 2016, most children's bedtime was determined by the family routine (43.21%), as opposed to 1996, where the majority of children went to bed in order to get enough hours of sleep for the following day activities (52.91%). The percentage of children who went to bed when sleepy declined from 16.99% in 1996 to 6.58% in 2016. Table 2 compares motive for bedtime in 1996 and 2016.

The majority of children was woken by their parents or family both in 1996 (75.12%) and 2016 (77.05%). The percentage of children who woke-up with an alarm increased from 4.11% in 1996 to 11.07% in 2016. Conversely, the percentage of children who woke-up by themselves decreased from 19.32% in 1996 to 10.66% in 2016. Table 3 compares motive for wake-time in 1996 and 2016.

Appendix 1 includes sleep patterns for study *a* (1996) and Appendix 2 includes sleep patterns for study *b* (2016).

## Sleep timing and duration

Figure 1 shows sleep parameters means for 1996 and 2016 and Table 4 comprises the detailed comparison results. In 2016, children woke-up, on average, 13 minutes earlier on school days [$t(657.468)=4.115$, $p<.001$] and 38 minutes earlier on free-days [$t(654)=7.833$, $p<.001$] than they did in 1996. Children's bedtime was also earlier in 2016 than 1996 both on school [$t(660)=5.292$, $p<.001$] and free-days [$t(658)=9.975$, $p<.001$], 14 minutes on school-days and 33 minutes on free-days. MSC was, on average, 15 minutes earlier on 2016 when compared to 1996 [$t(618.513)=5.740$, $p<.001$], and MSF was 24 minutes earlier [$t(548.027)=9.855$, $p<.001$].

Accordingly, MSFsc, a marker for chronotype, is also 35 minutes earlier in children from the 2016 sample when compared to the 1996 sample [$t(638)=9.838$, $p<.001$].

Although there was an decrease of 22 minutes of SJL_R [$t(568.860)=6.572$, $p<.001$] and of 28 minutes of SJLsc [$t(127)=4.055$, $p<.001$] from 1996 to 2016, there were no statistically significant differences between the two studies in the sleep restriction-extension pattern. There were also no statistically significant mean differences in night sleep duration or sleep need between the two time points.

After that, on ANCOVAs by year controlling for age and sex, there were no main effects for year, sex or age and no interaction effects of year*sex, year*age nor age*sex for bedtime and midpoint of sleep both on school and free-days, nor for social jetlag or corrected midpoint of sleep. There was an interaction effect of year and age on wake-time on free-days [$F(1, 655)=6.001$, $p=.015$]. In 1996, wake-times on free-days were gradually later as children grew older, while in 2016 the opposite can be observed, that is, wake-times on free-days became gradually earlier as children get older. There were interaction effects of age and sex on wake-time on school-days [$F(1, 659)=7.194$, $p=.008$]. In 1996, girls wake-times on school-days were gradually later as they got older, while in 2016 girls wake-times on school-days were gradually earlier as they grew older. On school-days, the wake-times of boys were gradually earlier as they get older in 1996 and 2016.

**Classifying sleep durations according to standard sleep recommendations**

The percentage of children sleeping the recommended number of hours (9-11h) by the National Sleep Foundation (Hirshkowitz et al., 2015) on school-days has declined from 87.05% in 1996 to 80.87% in 2016. Accordingly, the percentage of children sleeping less than the recommended number of hours (7-9 hours, which may be appropriate; Hirshkowitz et al., 2015) on school-days increased from 10.07% in 1996 to 18.26% in 2016. However, mean sleep need did not differ between the two time points [$t$(562.041)=.705, $p$=.481]. The percentage of children sleeping the recommended number of hours on free-days decreased from 83.17% in 1996 to 69.26% in 2016. The percentage of children sleeping less than the recommended number of hours (7-9h, may be appropriate) increased from 2.40% to 10.39%; on the other hand, the percentage of children sleeping more than the recommended amount (11-12h, which may be appropriate) also increased from 12.26% to 17.32% on free-days. Table 5 summarizes the percentage of children sleeping according to National Sleep Foundation's recommendation parameters on school and free-days.

**Sleep disturbances**

Appendix 6 includes a detailed comparison of sleep disturbances in 1996 and 2016 for girls, boys and the overall sample.

**Bedtime disturbances.**

In order to fall asleep, more children needed a comforting object [$\chi^2$ (3, n= 660) = 17.484, $p$=.001, $phi$=.163], light [$\chi^2$ (3, n= 663)= 25.077, $p$<.001, $phi$=.194] and parents presence in the bedroom [$\chi^2$ (3, n= 661) = 15.050, $p$=.002, $phi$=.151] in 2016 when compared to 1996. In 2016, more children were willing to go to bed [$\chi^2$ (3, n= 663)=112.447, $p$<.001, $phi$=.412] and less children fell asleep in their own bed [$\chi^2$ (3, n= 662)=11.114, $p$=.011, $phi$=.130] than they were in 1996. Figure 2 shows sleep-onset and bedtime disturbances' prevalence of in 1996 and 2016. The association between year and willingness to go to bed was medium, while the associations between year and falling asleep in their own bed, needing light, comforting objects and parents' presence were small.

In 2016, boys had more trouble falling asleep in their own beds [$\chi^2$ (3, n= 319)=8.020, *p*=.046, *phi*=.159] and had a greater need of parents presence in order to fall asleep [$\chi^2$ (3, n=319)=21.332, *p*<.001, phi=259] that they did in 1996. In 2016, more girls needed a comforting object to fall asleep [$\chi^2$ (3, n= 341)= 13.539, *p*=.004, *phi*=.199] and more girls were resistance to go to bed [$\chi^2$ (3, n=340)= 9.375, *p*=.025, *phi*=.166] when compared to 1996. The prevalence of needing light to fall asleep was higher in 2016 when compared to 1996 for both girls [$\chi^2$ (3, n=343)= 13.125, *p*=.004, *phi*=.196] and boys [$\chi^2$ (3, n=320)=13.008, *p*=.005, *phi*=.202], while willingness to go to sleep decreased from 1996 to 2016 for girls [$\chi^2$ (3, n=342)= 76.259, *p*<.001, *phi*=.472] and boys [$\chi^2$ (3, n=321)=38.159, *p*<.001, *phi*=.345]. Appendix 3 displays details regarding bedtime-related disturbances.

**Nighttime disturbances.**

In 2016, more children had nightmares [$\chi$2 (3, n= 662)=10.658, *p*=.014, *phi*=.127] and feared the dark [$\chi$2 (3, n= 659)=40.749, *p*<.001, *phi*=.249] when compared to 1996. Once awake, children in 2016 had more difficulties going back to sleep [$\chi$2 (3, n= 658)=535.735, *p*<.001, *phi*=.902]. The association between year and difficulty going back to sleep was large and the associations between year and nightmares and year and fear of the dark were small.

Fear of the dark increased between 1996 and 2016 for both girls [$\chi^2$ (3, n=342)= 24.217, *p*<.001, *phi*=.266] and boys [$\chi^2$ (3, n=317)= 17.996, *p*<.001, *phi*=.238]. On the other hand, the ability to go back to sleep after a night wakening decreased between the two time points for both girls [$\chi^2$ (3, n=341)=281.756, *p*<.001, *phi*=.909] and boys [$\chi^2$ (3, n=317)=254.816, *p*<.001, *phi*=897].

Figure 3 shows the prevalence of snoring and parasomnias on both time marks. Somniloquy was the most prevalent parasomnia both in 1996 (14,60%) and 2016 (13,93).

Enuresis was the less prevalent parasomnia in 2016 (0.82%), while sleepwalking was the less prevalent parasomnia in 2018 (1.44%).

**Daytime disturbances.**

During the day, children in 2016 exhibited more irritability [$\chi^2$ (3, n= 662)=24.592, *p*<.001, *phi*=.193] than children in 1996. Figure 4 shows the prevalence of daytime disturbances related to sleep in 1996 and 2016.

Irritability increased from 1996 to 2016 for both girls [$\chi^2$ (3, n=342)=22.093, *p*<.001, *phi*=.254] and boys [$\chi^2$ (3, n=320)=10.085, *p*=.018, *phi*=.178].

**Child health.**

There were no statistically significant differences between the two time points regarding the remaining variables. In 1996, 5.73% of parents reported their children to have sleep problems, 4.53% children consulted a professional for these problems and 1.19% took medication for sleep-related problems. In 2016, no children of our sample took sleep-related medicine, albeit 5.35% of parents considered their child to have a sleep problem and 3.69% of children were reported to consult a health professional for sleep-related problems (see more details on Appendix 5).

**Predictors of sleep disturbances.**

Previously analyzed sleep disturbances that showed statistically significant differences in the overall sample (needing lights on, needing comforting objects and needing parents' presence to fall asleep, falling asleep alone in its own bed, fearing the dark, going back to sleep during the night, irritability and nightmares) were further explored with a regression model containing three independent variables (year, age and sex). For needing light to fall asleep, the full model containing all predictors was statistically significant, $\chi^2$ (3, n=666)=12.328, *p*=.006, indicating that the model was able to distinguish between children that needed light to fall asleep and the ones who did not. The model as a whole explained between 1.8% (Cox and Snell R square) and 2.8% (Nagelkerke R squared) of the variance in this sleep disturbance, and correctly classified 78.3% of cases. As shown in Appendix 7, only year made a statistically significant contribution to the model, being the strongest predictor of needing light in order to fall asleep and recording an odds ratio of 1.789. That is, 2016 children were nearly 2 times (1.7 times) more likely to need light to fall asleep than 1996 children.

Regarding needing a comforting object to fall asleep [$\chi^2$ (3, n=660)=11.536, *p*=.009], the model explained between 1.7% and 3.2% of the variance, correctly classifying 86.4% of cases. Only age was statistically significant. The odds ratio of 0.665 indicates that for every additional year of age, children were *less* likely to need something special to fall asleep, controlling for other factors in the model. Putting it in an interpretable way, for every additional year of age, children were (1/0.665=) 1.5 times *less* likely to need a comforting object to fall asleep, controlling for other factors in the model.

As for needing parents presence in the room [$\chi^2$ (3, n=661)=8.373, *p*=.039], the model explained between 1.3% and 2.7% of the variance, correctly classifying 90.3% of cases. Only year made a statistically significant contribution to the model, recording an odds ratio of 2.105. This indicated that in 2016, children were approximately two times more likely to report needing parents' presence in the room that children in 1996.

The model for falling asleep alone [$\chi^2$ (3, n=662)=11.923, *p*=.008] explained 1.8% and 3.4% of variance, and correctly classified 87.3% of cases. Year and age made statistically significant contributions to the model, with year being the strongest predictor of children's ability to fall asleep alone in its own bed and recording an odds ratio of 1.881. Thus, 2016 children were about twice likely to have difficulties to fall asleep alone, compared to 1996 ones. The odds ratio of .708 for age indicates that older children were *less* likely to have trouble falling asleep by their own in their beds, controlling for other factors in the model.

The full model for fear of the dark [$\chi^2$ (3, n=659)=11.214, $p$=.011] explained between 1.7% and 2.9% of the variance and correctly classified 83.6% of cases. Only year made a statistically significant contribution to the model, recording an odds ratio of 1.858. Again, 2016 children had nearly twice more fear from darkness than 1996 children.

As for going back to sleep after waking up during the night [$\chi^2$ (3, n=658)=551.692, $p$<.001], the model explained between 56.8% and 78.3% of the variance and correctly classified 93.6% of cases. Only year made a statistically contribution to the model. The OR value of 0.005 indicates that 2016 children were much *less* likely to going back to sleep alone than their 1996 counterparts.

The full model containing all predictors was not statistically significant for irritability [$\chi^2$ (3, n=662)=7.054, $p$=.070] or nightmares [$\chi^2$ (3, n=662)=2.125, $p$=.547].

Regarding willingness to go to bed, the model [$\chi^2$ (4, n=640)=54.840, $p$<.001] included four predictors (year, age, sex and MSFsc) and explained between 8.2% and 11.0% of the variance and correctly classified 64.8% of cases. Only year made a statistically significant contribution to the model, recording an OR of 3.709 – meaning that not being willing to go to bed was almost 4 times *more* likely to occur in 1996 children than in 2016 children.

**Multivariate analysis by sleep disturbances factors.**

Table 6 displays descriptive statistics for each one of the six factors. Only *Afraid of the dark* factor showed statistical significance, with a main effect of year [$F(1, 655)=5.171$, $p=.023$, $\eta^2=.008$] and no interaction effects of year*age, year*sex or age*sex.

## Discussion

Despite the assumption that sleep has declined with technology's advances and busy modern-lifestyles, twenty years later, mean sleep durations of Portuguese primary school children in our sample did not change on overall. In a closer look, we noticed that in 2016 more children were sleeping below the recommended hours on school nights, and above the recommended hours on weekends, suggesting that the similarity of average sleep duration in both time points might be due to a compensation, on weekend nights, of the sleep restriction that occurs during school nights in 2016 children. Accordingly, the percentage of children who woke by themselves decreased from 1996 (19.32%) to 2016 (10.66%), and the percentage of children woke by the alarm increased from 1996 (4.11%) to 2016 (11.07%), which suggests children's sleep is being interrupted on school-days. Hence, children do not seem to be getting enough sleep. However, there were no significant differences in sleep restriction-extension patterns between both samples either, which reinforces the first impression that there were no considerable changes in sleep durations.

The main motive for bedtime in 2016 was family routine, followed by "has to sleep enough for the following day activities", while sleepiness was only a motive for bedtime in 6.58% of children this year (in contrast to 16.99% in 1996). This suggests children's preferred sleep timing is not being considered as much as social demands.  Albeit sleep timing appears to have advanced since the 90s, as school-age children in 2016 present earlier wake-times, bedtimes and midpoints of sleep and a greater social jetlag, when controlling for sex and age, only wake-times on free-days as children grow older reveal a statistically significant slight turn to morningness on 2016 when compared to 1996.

Overall, sleep disturbances had increased in 2016 since 1996. Year was a predictor for several bedtime disturbances and difficulty getting back to sleep after waking-up. Specifically, children in 2016 had more problems falling asleep when compared to children in 1996, with more children needing lights on and the presence of parents in order to go to sleep, more children fearing the dark and having trouble returning to sleep after waking during the night; and less children settling to sleep by themselves. Since the increase of sleep disturbances in only related to sleep onset difficulties, we may hypothesize these differences occur due to a change in parental attitudes and practices since 1996. It is possible that staying by their child's side until they fall asleep has become a common practice among parents in 2016, as opposed to putting children to bed and withdraw, allowing them to self-sooth, as we hypothesize it would be a more usual attitude in 1996. Self-soothing emerges as an important developmental milestone associated with sleep regulation. Whereas a fast cognitive development may lead to the emergence of nighttime fears and attachments that can result in separation anxiety at bedtime and difficulty fall back asleep without parental intervention, it is parental expectations and attitudes that determine whether such behaviors become problematic (Gruber, 2012). As parents may consider more adequate staying by their child's side until sleep onset or even letting children fall asleep in their beds, children do not learn how to go to sleep independently. In fact, a recent study on the sleep patterns of first graders found resistance to fall asleep to be the more prevalent sleep problem among children, with a prevalence of 30.7% (Khazaie, Zakiei, Komasi, & Brand, 2018). Those authors also performed a binary logistic regression, in which the components of sleep hygiene could predict 18-25% of the variance for bedtime problems.

We found that 65.24% and 34.84% of children were not willing to go to bed at bedtime in 1996 and 2016, respectively. About 14% of children from both 1996 and 2016 exhibited resistance to bedtime. In line with our results, Surani et al. (2005) studied the sleep habits among elementary school-age children in Texas and found a bedtime resistance prevalence of 25.31%, while 73.67% of children were not usually ready to sleep at usual bedtime. Another study that evaluated sleep problems' prevalence among school-age children in Saudi Arabia found daytime fatigue as the most prevalent sleep disturbance, followed by resistance to going to bed, with a prevalence of 26.2% (BaHammam, AlFaris, Shaikh, & Saeed, 2006).

*Afraid of the dark* factor showed a statistically significant difference between the two time marks when controlling for age and sex, with more children in 2016 presenting fear of the dark. Nighttime fears, such as fear of the dark, may lead to difficulty falling asleep and maintaining sleep, which can result in co-sleeping with parents. However, co-sleeping is associated with children's fears and separation anxiety (Rafihi-Ferreira, Lewis, McFayden, & Ollendick). In fact, co-sleepers show more fear of sleeping alone and in the dark and have a greater need of parent's presence and bedtime (Cortesi, Giannotti, Sebstiani, Vagnoni, & Marioni, 2008).

According to the third edition of the International Classification of Sleep Disorders (ICSD-3; American Academy of Sleep Medicine, 2014), although the estimates vary widely depending on the considered definition, the prevalence of snoring in children is reported to be 10 to 12%. Lumeng and Chervin (2008) suggested a prevalence of snoring, as reported by parents, of 7.45%. We found slightly lower prevalence rates on both time marks, of 6.25% in 1995 and

6.17% in 2016. The lifetime prevalence of sleepwalking is as high as 18.3% (American Academy of Sleep Medicine, 2014). A longitudinal study of children aged 6-16 (Klackenberg, 1982) reported only 3% of children had more than one episode of sleepwalking per month, albeit the yearly incidence varied from 6 to 17%. Another longitudinal study in children from 2.5 to 13 years of age reported that occasional or frequent sleepwalking was present in 14% of the children at some time during that period, and the yearly incidence was reported as varying from 2.5 to 7.5% (Laberge, Tremblay, Vitaro, & Montplaisir, 2000). We found rather lower prevalences of sleepwalking both in 1996 (1.44%) and 2016 (1.23%). The prevalence of sleep terrors has not been studied thoroughly but prevalence rates of 1 to 6.5% have been reported in children (American Academy of Sleep Medicine, 2014). Accordingly, we found prevalence rates of 2.64% in 1996 and 1.63% in 2016, which fall within the range of those findings. Occasional nightmares are quite common and occur in 60 to 75% oh children. However, frequent nightmares are uncommon, with ICSD-3 reporting an incidence in preadolescent children of 1 to 5% (American Academy of Sleep Medicine, 2014), prevalence rates slightly lower than the ones we found, of 5.27% in 1996 and 6.56% in 2016. Primary sleep enuresis is seen in approximately 5% of 10-year-olds and is more common in boys than girls in the ratio of 3:2 (Kumar & Vardhan, 2014). We found a prevalence of sleep enuresis of 2.87 in 1996 and 0.82% in 2016. Somniloquy is highly prevalent, with a life-time prevalence of 66% and current prevalence (in the past three months) of 17% (American Academy of Sleep Medicine, 2014). Our results show a prevalence of 14.60% and 13.93% in 1996 and 2016, respectively, with sleep talking arising as the most prevalent parasomnia in on both time marks of our study. Sleep related bruxism is highest in childhood, with a prevalence based on reports from parents of approximately 14 to 17%

(American Academy of Sleep Medicine, 2014), values higher than the ones we found for both 1996 (8.14%) and 2016 (9.47%).

This paper should be considered in the light of some limitations. Daytime sleep (napping) was not considered. Furthermore, MSC and MSF, and thus MSFsc and SJL, were calculated through bedtime instead of sleep onset time, as this information was not measured. At the time of data collection for study *a*, in 1995, solar time was 1 hour advanced when compared to the current solar time (Greenwich Meridian time prevailed 1 hour advanced during wintertime and 1 hour more during summer). Thus, although study *a* recorded later schedules regarding clock bedtimes and wake-times, children this sample would go to bed and wake-up 1 solar hour earlier. Hence, it is possible that the apparently earlier schedules in study *b* may occur due to the time difference of 1 hour between the two studies. Furthermore, although the 1996 and 2016 samples were collected in the same region of the country (Center), they were not collected exactly in the same schools (and cities), and therefore one may not rule out the possibility that some of the differences that were found may occur due to this factor. Hence, this work should be regarded as a preliminary study. A future study conducted in the same schools where the 1996 sample was collected would be the next research step to further clarify to what extent the sleep-wake patterns have changed (or not) in the two last decades. In addition, future research may resort to more objective methods, such as actigraphy or polysomnography, for data collection, as parental reports, in which our findings rely, are subjective and subject to biases arising from parents' interpretations. Indeed, children self-report more sleep problems than their parents (Gregory, Rijsdijk, & Eley, 2006). Notwithstanding such limitations, this study involved a large community sample, providing a basis for exploring Portuguese school-age children sleep-wake patterns' differences – timing, duration and disturbances – between 1996 and 2016.

Since bedtime problems can be effectively treated using behavioral approaches, an appropriate sleep hygiene is essential to develop and maintain normal sleep patterns. Positive sleep habits include a regular bedtime routine and helping children learn to fall asleep independently at bedtime, which will also help them learn to return to sleep independently after night wakings. These habits benefit attachment, security and mental health, despite caregivers worries about harmful effects on children's development and on the quality of the parent-child relationship. Prevention should be focused on parent education, providing information about helping children develop self-soothing skills and recommending positive sleep hygiene practices (Mindell & Moore, 2014).

**Acknowledgments**

We are grateful to the Faculty of Psychology and Educational Sciences of the University of Coimbra, where currently Dr. Maria Inês Clara is conducting her master degree and research work, under the supervision of Ana Allen Gomes. The authors are deeply grateful to parents/tutors, teachers and school directors, for participating in the present study.

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Tables

Table 1

Sample characteristics

| | | *a* (1996) (N=421) | *b* (2016) (N=245) | Total (N=666) |
|---|---|---|---|---|
| Sex | Girls | 215 (51.07%) | 129 (52.65%) | 344 (51.65%) |
| | Boys | 206 (48.93%) | 116 (47.35%) | 322 (48.35%) |
| Age | 8 | 117 (27.79%) | 67 (27.35%) | 184 (27.63%) |
| | 9 | 204 (48.46%) | 119 (48.57%) | 323 (48.50%) |
| | 10 | 88 (20.90%) | 54 (22.04%) | 142 (21.32%) |
| | 11 | 12 (2.85%) | 5 (2.04%) | 17 (2.55%) |
| School-grade level | $3^{rd}$ | 223 (52.97%) | 109 (44.49%) | 332 (49.85%) |
| | $4^{th}$ | 198 (47.03%) | 136 (55.51%) | 334 (50.15%) |

Table 2

Motive for bedtime

| | *a* (1996) (N=412) | *b* (2016) (N=243) |
|---|---|---|
| Family routine | 94 (22.82%) | 105 (43.21%) |
| Is sleepy | 70 (16.99%) | 16 (6.58%) |
| TV show is over | 9 (2.18%) | 12 (4.94%) |
| Siblings go to bed | 11 (2.70%) | 6 (2.47%) |
| Has to sleep enough for the next day activities | 218 (52.91%) | 103 (42.39%) |
| Other | 10 (2.43%) | 1 (0.41%) |

Table 3

Motive for wake-time

| | *a* (1996) (N=414) | *b* (2016) (N=244) |
|---|---|---|
| Alarm | 17 (4.11%) | 27 (11.07%) |
| Parents/family | 311 (75.12%) | 188 (77.05%) |
| Noise | 0 (0%) | 2 (0.82%) |
| Needs to go to the bathroom | 5 (1.21%) | 1 (0.41%) |
| By him/herself | 80 (19.32%) | 26 (10.66%) |
| Other | 1 (0.24%) | 0 (0%) |

Table 4

Comparison of sleep parameters (1996-2016) (*a*-*b*)

| Sleep parameters | | 1996 | 2016 | *t*-test | *p* | *d* | (*a*-*b*) |
|---|---|---|---|---|---|---|---|
| NSD | SC | 9h35m±50m | 9h35m±37m | *t*(590.424)=.118 | .906 | .010 | - |
| | FR | 10h18m±59m | 10h11m±1h01m | *t*(645)=1.310 | .191 | .103 | - |
| Wake-time | SC | 7:52±51m | 7:39±30m | *t*(657.468)=4.115 | <.001 | .321 | *a>b* |
| | FR | 9:34±1h | 8:56±1h | *t*(654)=7.833 | <.001 | .613 | *a>b* |
| Bedtime | SC | 21:57±35m | 21:43±31m | *t*(660)=5.292 | <.001 | .412 | *a>b* |
| | FR | 22:58±41m | 22:25±42m | *t*(658)=9.975 | <.001 | .778 | *a>b* |
| MS | FR | 2:46±38m | 2:31±26m | *t*(618.513)=5.740 | <.001 | .462 | *a>b* |
| | SC | 4:07±50m | 3:31±42m | *t*(548.027)=9.855 | <.001 | .842 | *a>b* |
| MSFsc | | 3:53±43m | 3:18±39m | *t*(638)=9.838 | <.001 | .779 | *a>b* |
| Sleep need | | 9h47m±45m | 9h45m±36m | *t*(562.041)=.705 | .481 | .060 | - |
| SJL_R | | 1:22±46m | 1:00±36m | *t*(568.860)=6.572 | <.001 | .551 | *a>b* |
| SJLsc | | 1:05±37m | 00:37±33m | *t*(127)=4.055 | <.001 | .720 | *a>b* |
| Sleep restriction-extension pattern | | 42m±58m | 35m±1h | *t*(641)=1.421 | .156 | .112 | - |

Table 5

Classification of sleep durations according to sleep recommendations of the NSF

| NSD | Study | <7h<br>Not recommended | 7-9h<br>May be appropriate | 9-11h<br>Recommended | 11-12h<br>May be appropriate | >12h<br>Not recommended |
|---|---|---|---|---|---|---|
| SC | *a* (N=417) | - | 42 (10.07%) | 363 (87.05%) | 12 (2.88%) | - |
| | *b* (N=230) | - | 42 (18.26%) | 186 (80.87%) | 2 (0.87%) | - |
| FR | *a* (N=416) | - | 10 (2.40%) | 346 (83.17%) | 51 (12.26%) | 9 (2.16%) |
| | *b* (N=231) | 1 (0.43%) | 24 (10.39%) | 160 (69.26%) | 40 (17.32%) | 6 (2.60%) |

Table 6

Comparison of sleep disturbances factors between 1996 and 2016

| Factor | 1996 (M±SD; Med) | 2016 (M±SD; Med) |
|---|---|---|
| Parents help to sleep | 6.326±.749; 6.000 | 6.423±.896; 6.000 |
| Parasomnias | 5.827±1.447; 6.000 | 6.029±1.368; 6.000 |
| Sleep difficulties | 5.885±.423; 6.000 | 5.910±.340; 6.000 |
| Afraid of dark | 3.101±1.889; 2.000 | 3.830±2.031; 3.000 |
| Daytime sleep consequences | 5.885±.423; 6.000 | 5.910±.340; 6.000 |
| Sleep limit setting | 3.715±1.485; 4.000 | 4.589±.850; 5.000 |

Med= median.

Sleep parameters' means on 1996 and 2016:

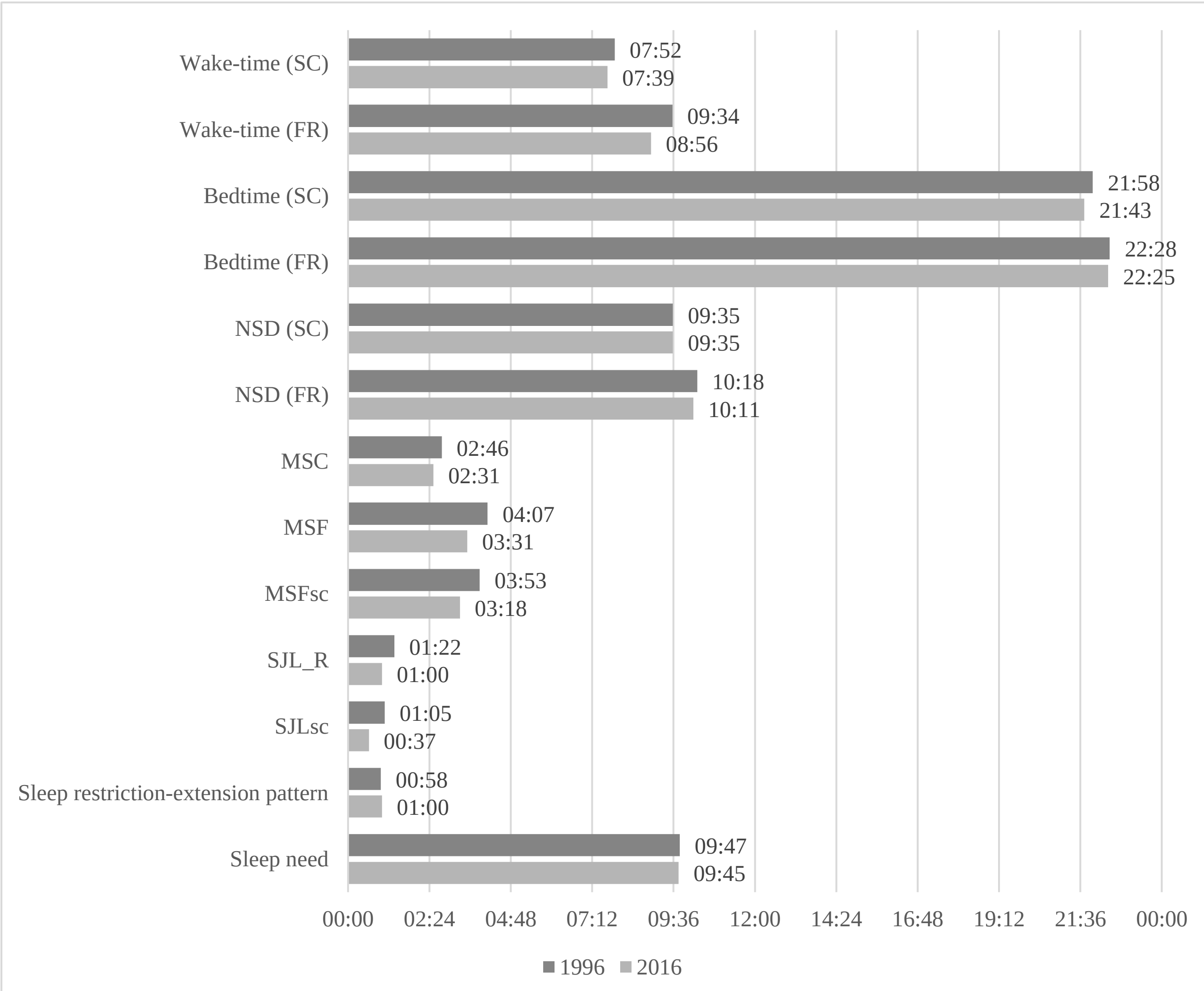



*Figure 1*. Children's schedules (wake-time and bedtime on school and free-days) were earlier in 2016 than they were in 1996. Children presented more social jetlag in 1996 than they did on 2016, as well as a later midpoint of sleep. On school-days, mean night sleep duration was the same for the two time points. In 1996, school-age children's mean night sleep duration on free-days was slightly longer than it was in 2016, but did not reach statistical significance. There were also no statistically significant differences between 1996 and 2016 regarding sleep need or sleep restriction-extension pattern.

Prevalence of bedtime disturbances in 1996 and 2016:

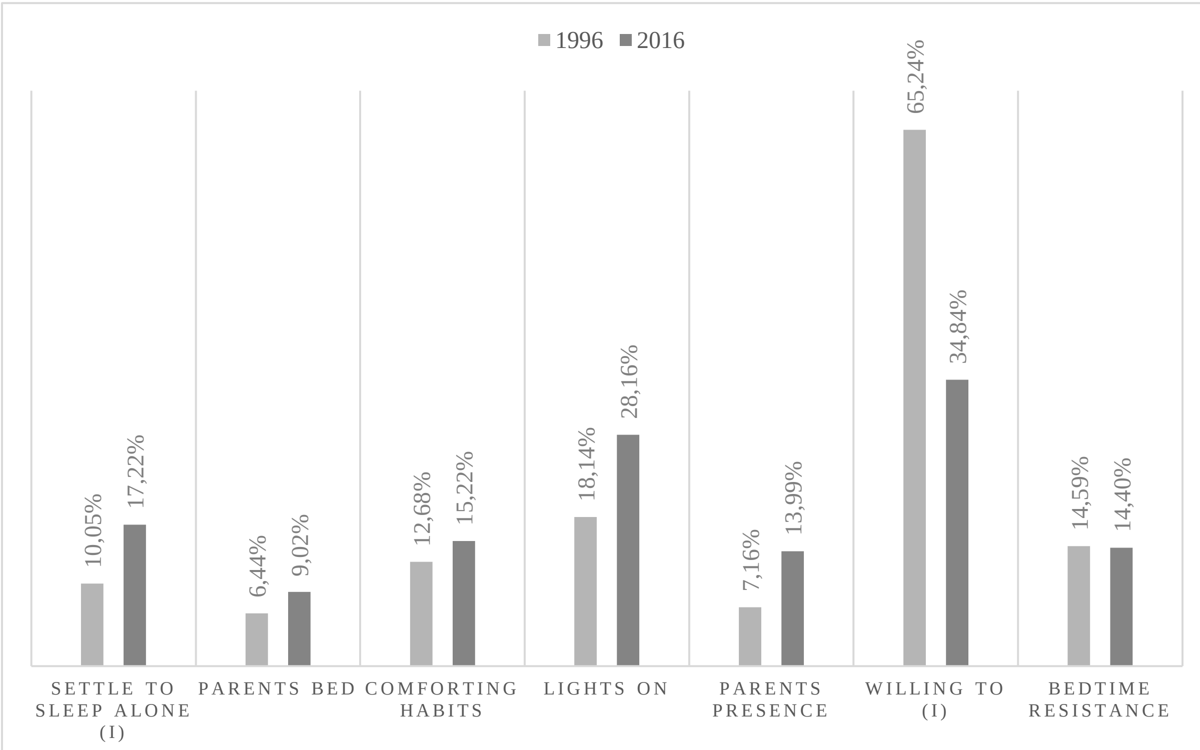



*Figure 2.* Overall, bedtime disturbances were more prevalent in 2016 when compared to 1996, except for bedtime resistance. The prevalence of children not to settle to sleep alone, needing to fall asleep in their parents' bed, needing a comforting object/something special to fall asleep, needing lights on or the presence of their parents in the bedroom in order to fall asleep was higher in 2016 when compared to 1996. The percentage of children not willing to go to bed was fairly higher on 1996 when compared to 2016. Albeit bedtime resistance was similar for both time marks, it was slightly higher in 1996. See Appendix 4 for detailed information on nighttime disturbances.

Prevalence of nighttime disturbances in 1996 and 2016:

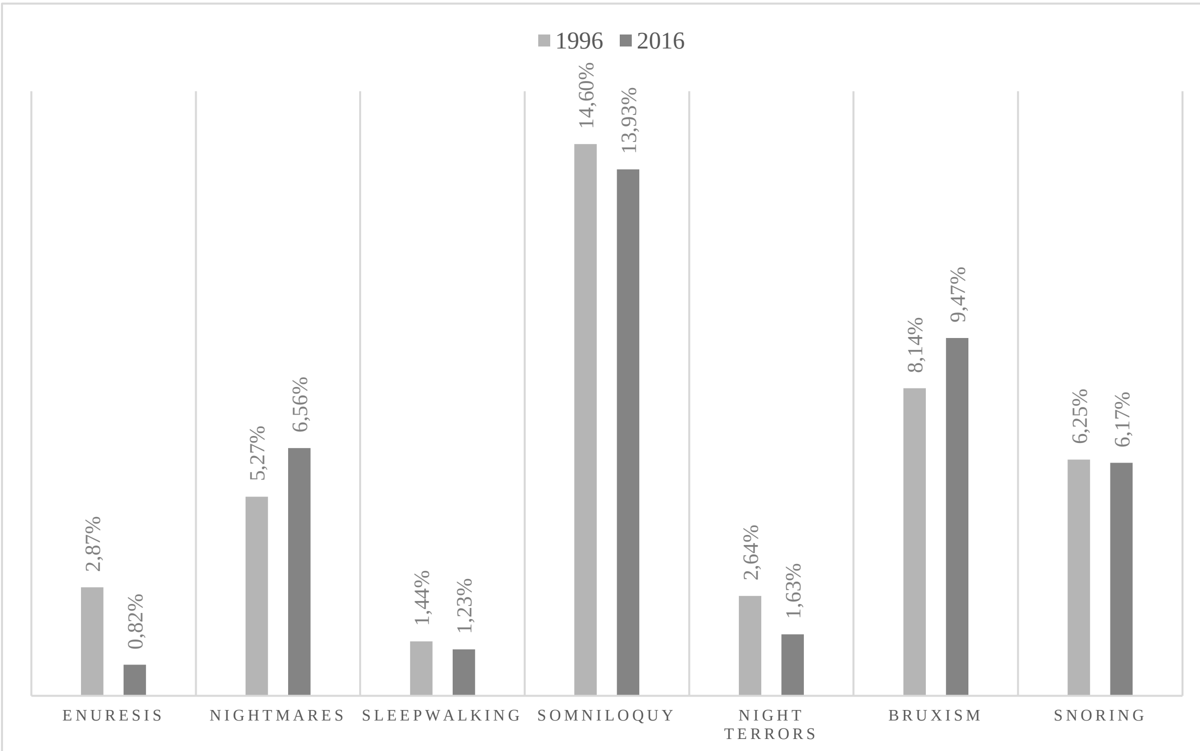



*Figure 3*. Both in 1996 and 2016 somniloquy was the most prevalent nighttime disturbance, followed by bruxism and nightmares. In 1996, sleepwalking was the less prevalent parasomnia, followed by night terrors and enuresis. The less prevalent parasomnia in 2016 was enuresis, followed by sleepwalking and night terrors. Enuresis, sleepwalking, somniloquy and night terrors were more prevalent in 1996 than 2016, while nightmares and bruxism were more prevalent in 2016 when compared to 2016. Snoring's prevalence was similar for both time marks.

Prevalence of daytime disturbances in 1996 and 2016:

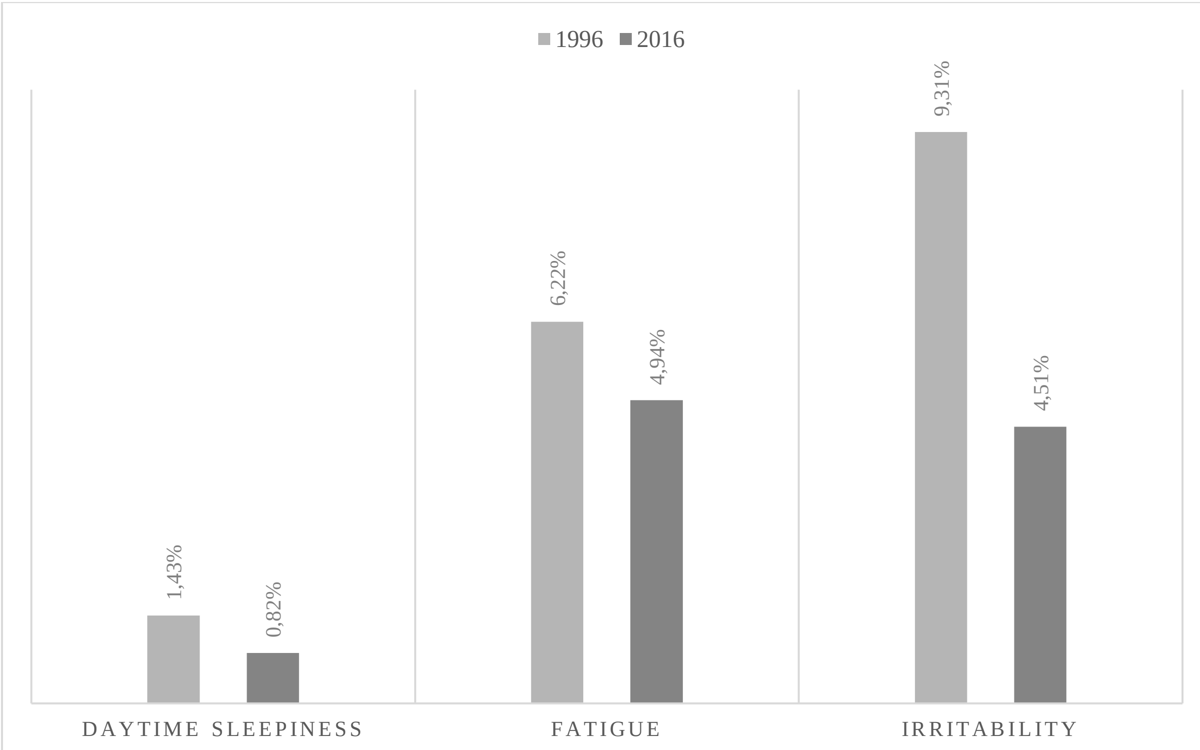



*Figure 4.* Daytime sleepiness, fatigue and irritability were slightly more prevalent in 1996 than 2016, albeit there were no statistically significant differences.

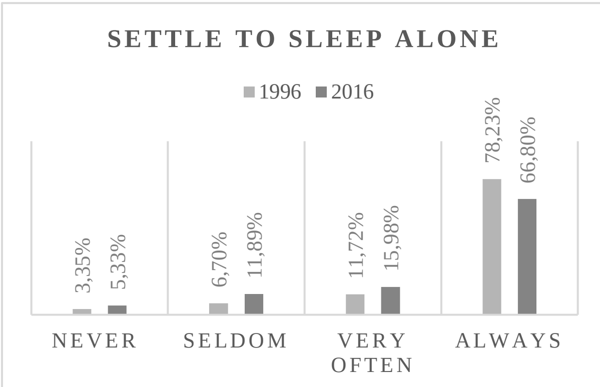
**Appendix 1: Sleep patterns in 1996**

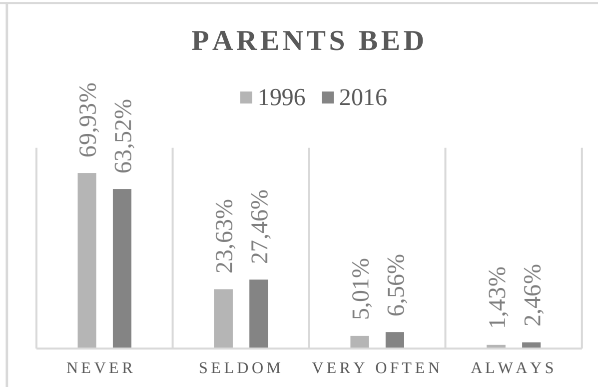
| | Wake-time | | Bedtime | | NSD | | MS | | MSFsc | SJLR | SJLsc | Sleep restriction-extension pattern | Sleep need |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SC | FR | SC | FR | SC | FR | SC | FR | | | | | |
| 8 | 7:49 ±43m | 9:17 ±1h02m | 21:48± 37m | 22:45 ±45m | 9h41m ±47m | 10h11m ±1h | 2:45 ±42m | 4:02 ±50m | 3:51 ±44m | 1:16 ±46m | 1h05m ±42m | 29m ±53m | 9:50 ±48m |
| 9 | 7:46 ±43m | 9h23m ±1h03m | 21:54 ±32m | 22:48 ±44m | 9h32m ±43m | 10h15m ±58m | 2:43 ±36m | 4:06 ±51m | 3:50 ±43m | 1:23 ±47m | - | 46m ±1h | 9:44 ±41m |
| 10 | 7:51 ±49m | 9:22 ±1h01m | 21:55 ±33m | 22:49 ±44m | 9h34m ±44m | 10h18m ±59m | 2:52 ±36m | 4:18 ±45m | 4:00 ±39m | 1:25 ±45m | - | 49m ±55m | 9:49 ±45m |
| 11 | 7:34 ±1h04m | 9:26 ±1h04m | 21:39 ±43m | 22:39 ±43m | 9h50m ±1h20m | 10h42m ±1h21m | 2:41 ±45m | 4:10 ±58m | 3:50 ±54m | 1:28 ±38m | - | 55m ±1h14m | 10:04 ±1h24m |
| Girls | 7:50 ±50m | 9:25 ±1h03m | 21:54 ±37m | 22:45 ±44m | 9h34m ±49m | 10h20m ±59m | 2:47 ±43m | 4:10 ±49m | 3:52 ±43m | 1:22 ±45m | 1h12m ±35m | 48m ±56m | 9:47 ±49m |
| Boys | 7:45 ±38m | 9:17 ±1h01m | 21:50 ±31m | 22:49 ±43m | 9h37m ±42m | 10h10m ±59m | 2:43 ±33m | 4:05 ±50m | 3:53 ±43m | 1:22 ±47m | 59m ±47m | 36m ±1h | 9:48 ±41m |

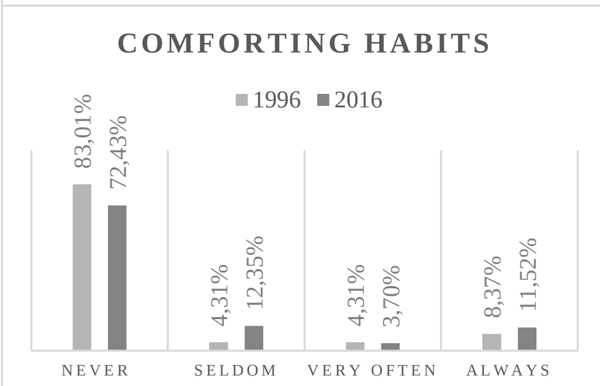
**Appendix 2: Sleep patterns in 2016**

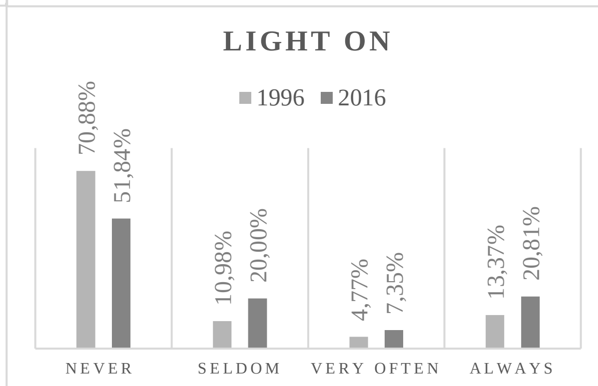
| | Wake-time | | Bedtime | | NSD | | MS | | MSFsc | SJLR | SJLsc | Sleep restrictiom-extension pattern | Sleep need |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SC | FR | SC | FR | SC | FR | SC | FR | | | | | |
| 8 | 7:41 ±29m | 8:59±58m | 21:38 ±31m | 22:24 ±38m | 9h40m ±37m | 10h11m ±1h04m | 2:28 ±24m | 3:30 ±40m | 3:19 ±38m | 1:02 ±35n | 37m ±33m | 31m ±58m | 9:49 ±38m |
| 9 | 7:41 ±30m | 8:58±1h02m | 21:48 ±32m | 22:28 ±44m | 9h34m ±38m | 10h13m ±58m | 2:35 ±26m | 3:35 ±44n | 3:22 ±40m | 1:00 ±37m | - | 38m ±1h01m | 9:45 ±35m |
| 10 | 7:33 ±30m | 8:46±56m | 21:41 ±29m | 22:21 ±40m | 9h31m ±34m | 10h05m ±58m | 2:26 ±25m | 3:24 ±39m | 3:12 ±39m | 00:57 ±34m | - | 34m ±54m | 9:40 ±35m |
| 11 | 7:19 ±38m | 8:36±1h17m | 21:27 ±26m | 22:12 ±45m | 9h33m ±37m | 10:06 ±1h56m | 2:13 ±21m | 3:15 ±27m | 3:03 ±29m | 1:01 ±39m | - | 33m ±1h59m | 9:42 ±44m |
| Girls | 7:39 ±32m | 8:59±1h | 21:43 ±34m | 22:21 ±41m | 9h36m ±41m | 10h18m ±56m | 2:30 ±27m | 3:30 ±43m | 3:15 ±40m | 59m ±35m | 39m ±36m | 42m ±1h01m | 9:48 ±36m |
| Boys | 7:38 ±28m | 8:51±1h 7:00-11:00 | 21:43 ±28m | 22:30 ±42m | 9h34m ±32m | 10h01m ±1h05m | 2:31 ±23m | 3:32 ±40m | 3:22 ±39m | 1:01 ±36m | 35m ±30m | 27m ±58m | 9:42 ±35m |

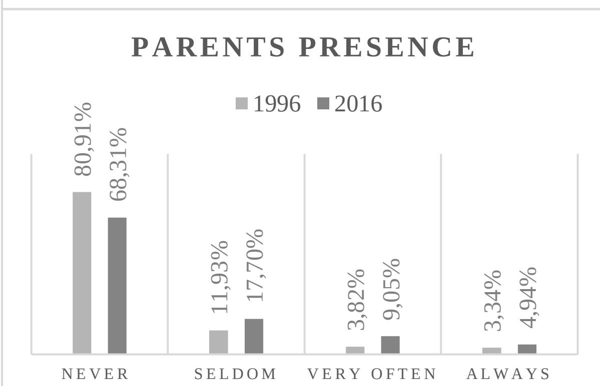
## Appendix 3: Details on sleep onset and bedtime disturbances

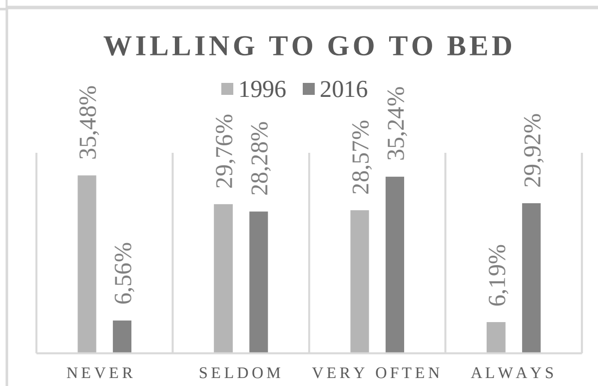


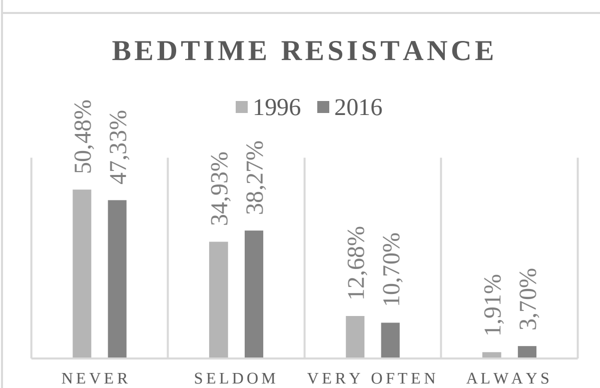



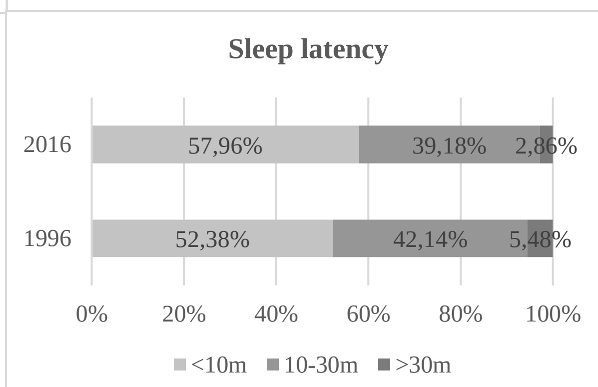



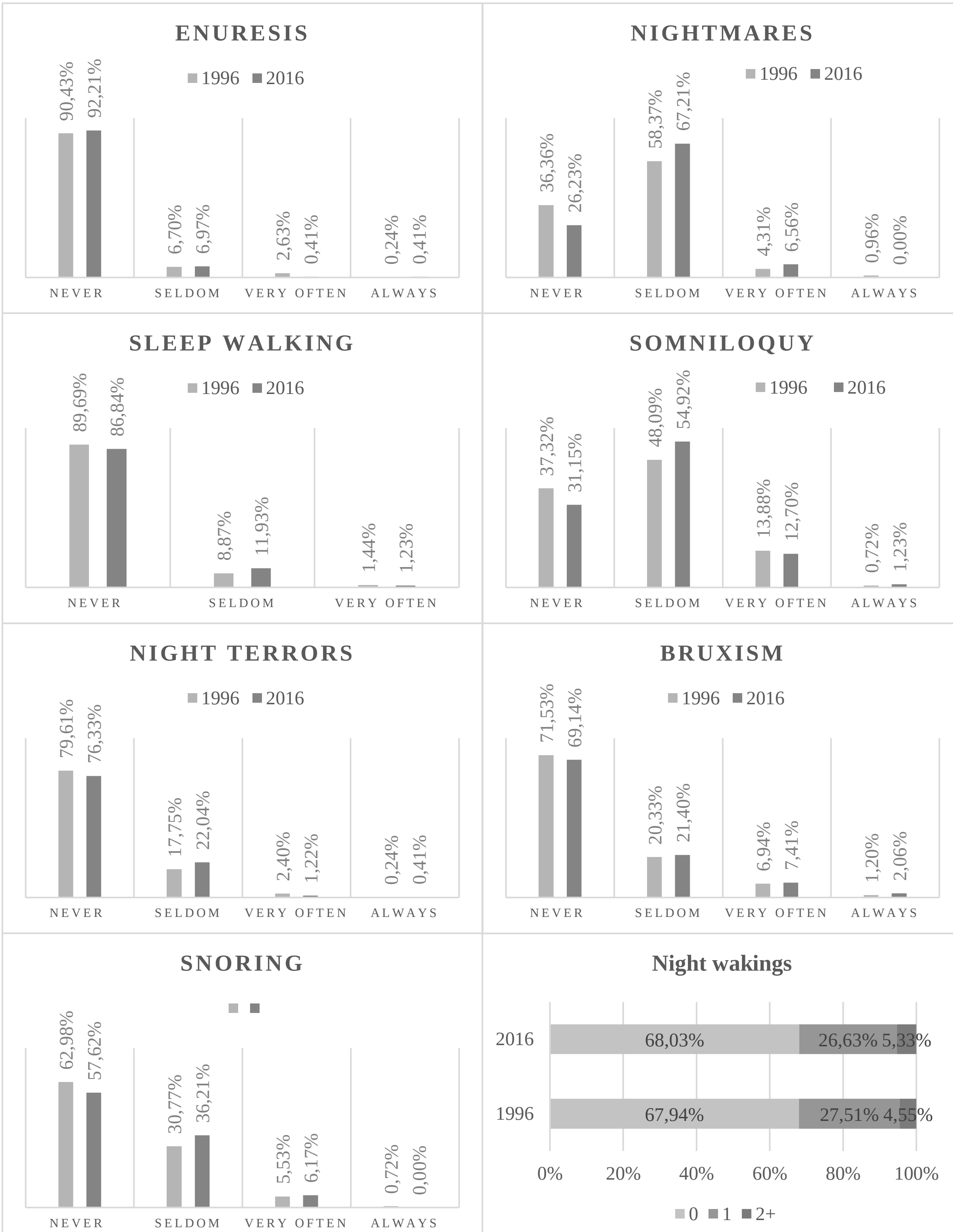



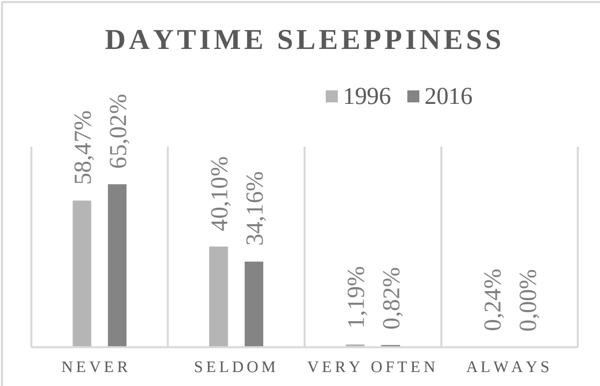



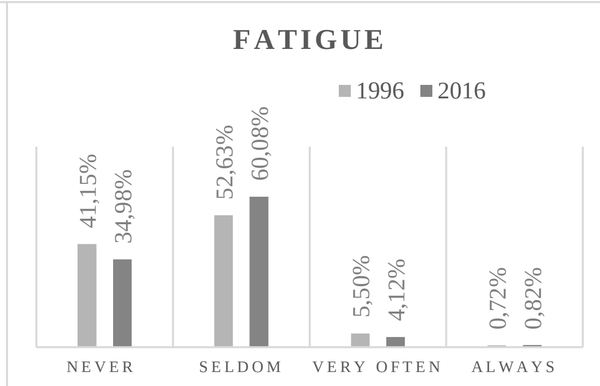



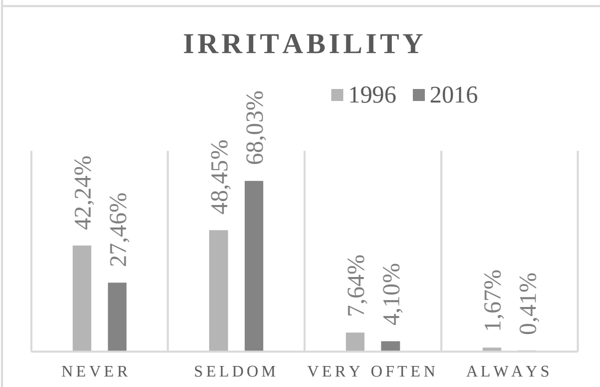
**Appendix 4: Details on nighttime disturbances**

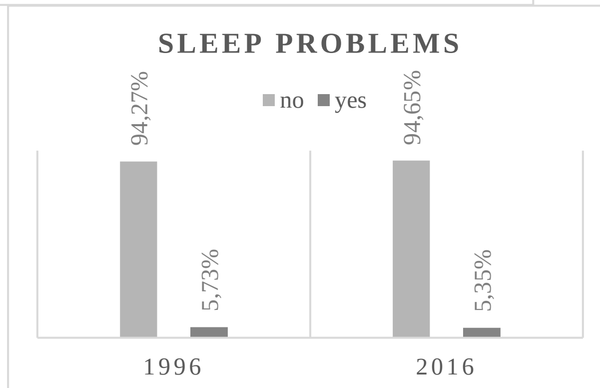


## Appendix 5: Details on daytime disturbances and other aspects

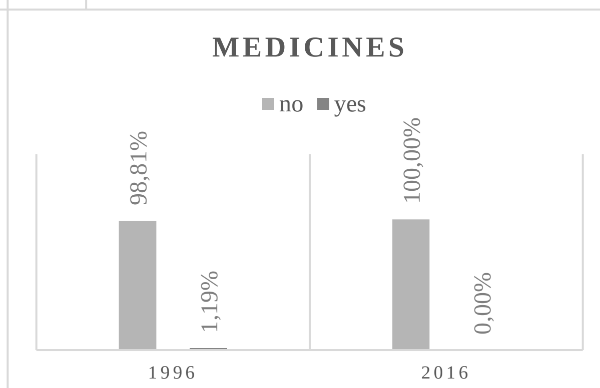






**Appendix 6: Comparison of sleep disturbances in 1996 and 2016**

| Sleep disturbances | Girls | Boys | Overall sample | (*a*-*b*) |
|---|---|---|---|---|
| **Bedtime disturbances** | | | | |
| Sleep latency | [$\chi$2 (2, n= 343)= 3.728, p=.155, phi=.104] | [$\chi$2 (2, n= 321)=1.347, p=.510, phi=.065] | [$\chi$2 (2, n= 662)=3.644, p=.162, phi=.074] | - |
| Settle to sleep alone (i) | [$\chi$2 (3, n= 343)= 3.644, p=.266, phi=.107] | [$\chi$2 (3, n= 319)=8.020, p=.046, phi=.159] | [$\chi$2 (3, n= 662)=11.114, p=.011, phi=.130] | *a*<*b* |
| Falls asleep in parents bed | [$\chi$2 (3, n= 342)= .594, p=.898, phi=.042] | [$\chi$2 (3, n= 320)=4.714, p=.194, phi=.121] | [$\chi$2 (3, n= 662)=3.329, p=.344, phi=.071]. | - |
| Comforting habits to fall asleep | [$\chi$2 (3, n= 341)= 13.539, p=.004, phi=.199] | [$\chi$2 (3, n= 319)=5.952, p=.114, phi=.137] | [$\chi$2 (3, n= 660) = 17.484, p=.001, phi=.163] | *a*<*b* |
| Lights on to fall asleep | [$\chi$2 (3, n=343)= 13.125, p=.004, phi=.196] | [$\chi$2 (3, n=320)=13.008, p=.005, phi=.202] | [$\chi$2 (3, n= 663)= 25.077, p<.001, phi=.194] | *a*<*b* |
| Needs parents to fall asleep | [$\chi$2 (3, n=342)= 1.823, p=.610, phi=.073] | [$\chi$2 (3, n=319)=21.332, p<.001, phi=259] | [$\chi$2 (3, n= 661) = 15.050, p=.002, phi=.151] | *a*<*b* |
| Willingness to go to bed (i) | [$\chi$2 (3, n=342)= 76.259, p<.001, phi=.472] | [$\chi$2 (3, n=321)=38.159, p<.001, phi=.345] | [$\chi$2 (3, n= 663)=112.447, p<.001, phi=.412] | *a*<*b* |
| Bedtime resistance | [$\chi$2 (3, n=340)= 9.375, p=.025, phi=.166] | [$\chi$2 (3, n=320)=2.009, p=.571, phi=.079] | [$\chi$2 (3, n= 660)=3.273, p=.351, phi=.070]. | - |
| **Nighttime disturbances** | | | | |
| Snoring | [$\chi$2 (3, n=343)= 1.805, p=.614, phi=.073] | [$\chi$2 (3, n=316)=2.561, p=.464, phi=.090] | [$\chi$2 (3, n= 659)=3.975, p=.264, phi=.078]. | - |
| Enuresis | [$\chi$2 (3, n=343)= 4.286, p=.117, phi=.112] | [$\chi$2 (3, n=319)=3.926, p=.270, phi=.111] | [$\chi$2 (3, n= 662)=4.414, p=.220, phi=.082]. | - |
| Nightmares | [$\chi$2 (3, n=343)= 5.423, p=.143, phi=.126] | [$\chi$2 (3, n=319)=5.300, p=.151, phi=.129] | [$\chi$2 (3, n= 662)=10.658, p=.014, phi=.127] | *a*<*b* |
| Sleepwalking | [$\chi$2 (2, n=342)= .379, p=.827, phi=.033] | [$\chi$2 (2, n=318)=1.674, p=.433, phi=.073] | [$\chi$2 (3, n= 660)=1.627, p=.443, phi=.050]. | - |
| Somniloquy | [$\chi$2 (3, n=343)= .959, p=.811, phi=.053] | [$\chi$2 (3, n=319)=6.303, p=.098, phi=.141] | [$\chi$2 (3, n= 662)=3.699, p=.296, phi=.075]. | - |
| Night terrors | [$\chi$2 (2, n=344)= 1.970, p=.373, phi=.076] | [$\chi$2 (3, n=318)=4.547, p=.208, phi=.120] | [$\chi$2 (3, n= 660)=2.913, p=.405, phi=.066]. | - |
| Bruxism | [$\chi$2 (3, n=344)= 1.070, p=.784, phi=.056] | [$\chi$2 (3, n=317)= 2.873, p=.412, phi=.095] | [$\chi$2 (3, n= 661)=1.010, p=.799, phi=.039]. | - |

| Sleep disturbances | Girls | Boys | Overall sample | (*a*-*b*) |
|---|---|---|---|---|
| Fear of the dark | [χ2 (3, n=342)= 24.217, p<.001, phi=.266] | [χ2 (3, n=317)= 17.996, p<.001, phi=.238] | [χ2 (3, n= 659)=40.749, p<.001, phi=.249] | *a*<*b* |
| Night wakings | [χ2 (4, n=343)=2.655, p=.617, phi=.088] | [χ2 (3, n=319)=1.883, p=.597, phi=.077] | [χ2 (4, n= 662)=1.076, p=.898, phi=.040] | - |
| Back to sleep alone after night wakings (i) | [χ2 (3, n=341)=281.756, p<.001, phi=.909] | [χ2 (3, n=317)=254.816, p<.001, phi=897] | [χ2 (3, n= 658)=535.735, p<.001, phi=.902] | *a*>*b* |
| **Daytime disturbances** | | | | |
| Daytime sleepiness | [χ2 (2, n=341)=.319, p=.852, phi=.031] | [χ2 (2, n=320)=4.728, p=.094, phi=.122] | [χ2 (3, n= 661)=3.183, p=.364, phi=.069]. | - |
| Fatigue | [χ2 (3, n=341)=1.389, p=.708, phi=.064] | [χ2 (2, n=319)=2.173, p=.337, phi=.083] | [χ2 (3, n= 660)=3.547, p=.315, phi=.073]. | - |
| Irritability | [χ2 (3, n=342)=22.093, p<.001, phi=.254] | [χ2 (3, n=320)=10.085, p=.018, phi=.178] | Irritabilidade [χ2 (3, n= 662)=24.592, p<.001, phi=.193]. | a<b |
| **Other aspects** | | | | |
| Sleep problems | [χ2 (1, n=341)=.015, p=.903, phi=-.007] | [χ2 (1, n=320)=.167, p=.683, phi=.023] | [χ2 (1, n= 661)=.045, p=.833, phi=.008]. | - |
| Seeing a doctor | [χ2 (1, n=342)=.035, p=.852, phi=-.010] | [χ2 (1, n=320)=.973, p=.324, phi=.055] | [χ2 (1, n= 662)=.279, p=.597, phi=.021] | - |
| Taking medicines | [χ2 (1, n=342)=1.833, p=.176, phi=.073] | [χ2 (1, n=320)=1.129, p=.288, phi=.059] | [χ2 (1, n= 662)=2.941, p=.086, phi=.067]. | - |

**Appendix 7: Logistic regression predicting likelihood of reporting sleep disturbances**

| Sleep disturbances | | B | S.E. | Wald | df | *p* | Odds ratio | 95.0% C.I. for Odds Ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Lights on to fall asleep | Year | .582 | .191 | 9.245 | 1 | .002* | 1.789 | 1.230 | 2.603 |
| | Age | -.094 | .125 | .563 | 1 | .453 | .910 | .713 | 1.163 |
| | Sex | -.298 | .192 | 2.426 | 1 | .119 | .742 | .510 | 1.080 |
| | Constant | -.540 | 1.129 | .229 | 1 | .632 | .583 | | |
| Comforting object to fall asleep | Year | .204 | .233 | .766 | 1 | .381 | 1.227 | .776 | 1.938 |
| | Age | -.408 | .158 | 6.678 | 1 | .010* | .665 | .488 | .906 |
| | Sex | -.447 | .233 | 3.666 | 1 | .056 | .640 | .405 | 1.011 |
| | Constant | 1.905 | 1.406 | 1.837 | 1 | .175 | 6.722 | | |
| Needs parents in to fall asleep | Year | .744 | .265 | 7.896 | 1 | .005* | 2.105 | 1.253 | 3.539 |
| | Age | -.123 | .175 | .496 | 1 | .481 | .884 | .628 | 1.245 |
| | Sex | .023 | .265 | .008 | 1 | .930 | 1.023 | .609 | 1.721 |
| | Constant | -1.468 | 1.575 | .869 | 1 | .351 | .230 | | |
| Settle to sleep alone (i) | Year | .632 | .236 | 7.153 | 1 | .007* | 1.881 | 1.184 | 2.988 |
| | Age | -.346 | .160 | 4.662 | 1 | .031 | .708 | .517 | .969 |
| | Sex | .103 | .236 | .190 | 1 | .663 | 1.108 | .698 | 1.759 |
| | Constant | .836 | 1.427 | .344 | 1 | .558 | 2.308 | | |
| Fear of the dark | Year | .619 | .213 | 8.464 | 1 | .004* | 1.858 | 1.224 | 2.820 |
| | Age | .015 | .138 | .012 | 1 | .913 | 1.015 | .774 | 1.331 |
| | Sex | -.354 | .215 | 2.712 | 1 | .100 | .702 | .460 | 1.070 |
| | Constant | -1.863 | 1.255 | 2.204 | 1 | .138 | .155 | | |
| Back to sleep alone (i) | Year | -5.368 | .335 | 257.234 | 1 | .000* | .005 | .002 | .009 |
| | Age | .012 | .212 | .003 | 1 | .955 | 1.012 | .668 | 1.532 |
| | Sex | .257 | .325 | .625 | 1 | .429 | 1.293 | .684 | 2.442 |
| | Constant | 3.066 | 1.920 | 2.549 | 1 | .110 | 21.453 | | |
| Willingness to go to bed (i) | Year | 1.311 | .188 | 48.552 | 1 | .000* | 3.709 | 2.568 | 5.358 |
| | Age | .080 | .107 | .552 | 1 | .458 | 1.083 | .878 | 1.336 |
| | Sex | -.057 | .166 | .119 | 1 | .731 | .944 | .682 | 1.308 |
| | MSFsc | .000 | .000 | 1.469 | 1 | .226 | 1.000 | 1.000 | 1.000 |
| | Constant | -5.305 | 3.438 | 2.381 | 1 | .123 | .005 | | |

(i)=Inverted item.

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# Appendices

## Appendix 1: Acceptance letter from Sleep Medicine

| | |
|---|---|
| **Date:** | Jun 26, 2019 |
| **To:** | "Maria Inês Santos Clara" maria.ines.s.clara@gmail.com |
| **From:** | "Sleep Medicine" eesserver@eesmail.elsevier.com |
| **Reply To:** | "Sleep Medicine" sleep@elsevier.com |
| **Subject:** | SLEEP-D-19-00194R1 accepted for publication |

Ref.: Ms. No. SLEEP-D-19-00194R1
An epidemiological study of sleep-wake timings in school children from 4 to 11 years old: insights on the sleep phase shift and implications for the school starting times' debate

Dear Miss Clara,

I am pleased to confirm that your paper An epidemiological study of sleep-wake timings in school children from 4 to 11 years old: insights on the sleep phase shift and implications for the school starting times' debate has been accepted for publication in Sleep Medicine + OA Mirror or Sleep Medicine + OA Mirror X, depending on which journal you chose during the submission process. We will ensure that we process your paper in the correct journal that you have chosen.

Here at Elsevier we offer The Christian Guilleminault WASM Award for Sleep Research and The Elio Lugaresi WASM Award for Sleep Medicine. Any papers accepted by May 1 2019 will be eligible for consideration. Please note that the application period begins June 1 2017, with an application deadline of May 1 2019. Papers that qualify are those published or accepted for publication in Sleep Medicine between June 1, 2017 to May 1, 2019. The awards will be presented at the World Sleep 2019 congress in Vancouver, Canada from September 20-25.

Would you like to be considered for either, or both, of these awards? To apply, please:

- Reply to this email, adding CReimer@JFKHealth.org to the Cc field (please retain sleep@elsevier.com in the 'to' field)
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- Attach your CV and a copy of your accepted paper

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Upon transfer of your paper to our production department, your article proof will be created and sent to you for checking. You will also be asked to complete a number of online forms required for publication. If we need additional information from you during the production process, we will contact you.

With kind regards,
Oliviero Bruni, MD
Field Editor

# Appendix 2: Poster presented on the 30th Conference of the International Society for Chronobiology