Development of Sleep-Wake Schedules During Childhood and Relationship With Sleep Duration

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Objectives: To present a longitudinal overview of the sleep schedules during weekdays and the weekend in a large sample of children and to examine the sleep-wake schedules in relation to nocturnal sleep duration and birth season.

Design: Longitudinal survey design.

Setting: Data were collected by home interviews and questionnaires.

Participants: Data for sleep schedules at the ages of 4, 5, and 6 years on weekdays were obtained for 1112 children. Data for bedtimes on the weekend were available for 1094 children, and data for wake times on the weekend were available for 1083 children.

Outcome Measures: Habitual bedtimes and wake times during weekdays and the weekend were reported by the mothers at the 3 ages. Nighttime sleep duration was calculated from bedtime to wake time. Birth characteristics came from medical records.

Results: As children grow up, we found later bedtimes on the weekend for a given bedtime on weekdays. Interestingly, most children slept less during the weekend compared with weekdays. No significant difference (P > .10 for all) was found in the seasonal distribution of births in any of the sleep-wake schedules.

Conclusions: Despite a lack of a strong preference for sleep timing during childhood, the displacement of bedtime toward later hours during the weekend starts early in life. More important, sleep-wake patterns are associated with sleep duration and later bedtimes on the weekend seem to shorten sleep duration in most children.

and a longer sleep duration on the weekend. Parental evaluation of the child’s habitual sleep patterns, especially when there are no timing constraints (as may be observed on the weekend), may give valuable information about preferred sleep timing in childhood and its association with sleep duration.

Chronotype in young adults and teenagers is in part influenced by birth season.16–19 A spring birth increases the tendency toward eveningness, while a fall birth increases the tendency for morningness. An association between birth season and sleep patterns in childhood could indicate that sleep-timing preference at that age is already an indication of chronotype.

This study presents, for the first time to our knowledge, a longitudinal overview of the sleep schedules during weekdays and the weekend in a large sample of children. It also examines the sleep-wake schedules in relation to nocturnal sleep duration. Finally, if sleep-wake schedules are an indication of preferred sleep timing in childhood, we predict an association between extreme schedules and specific seasons of birth.

## METHODS

### SUBJECTS

This study is part of the Quebec Longitudinal Study of Child Development, a large epidemiological study conducted by the Quebec Institute of Statistics. The children were recruited from the Quebec Master Birth Registry of the Ministry of Health and Social Services. Most children (84.5%) had a Canadian non-immigrant mother. Most of the sample was white (88.4%). Other ethnic groups, such as black Africans, Native Americans, Arabs, Asians, and others represent 3.4%, 0.3%, 2.0%, 1.6%, and 4.3% of the sample, respectively. Most mothers spoke French as a first language (76.3%). 8.7% spoke English, and 15.0% had another first language. Children with serious neurodevelopmental or health problems were excluded from the study. The present article focused on the habitual bedtimes and wake times during weekdays and the weekend when children were approximately aged 4 years (mean [SD] age, 49.5 [3.1] months), 5 years (mean [SD] age, 61.4 [3.1] months), and 6 years (mean [SD] age, 73.8 [3.1] months). Longitudinal data for sleep schedules at the 3 ages on weekdays were obtained for 1112 children; data were available for 1094 children for bedtimes on the weekend and for 1083 children for wake times on the weekend. Before particip-

## OUTCOME MEASURES

The data for the present article were collected from a questionnaire and an interview with the person who best knew the child. First, the Self-administered Questionnaire for the Mother, which took about 20 minutes to complete, provided information on the infant’s sleep-wake schedules at the ages of 4, 5, and 6 years, such as bedtimes and wake times during weekdays and the weekend in the following wording: “In general, at what time do you put your child to bed for the night?” and “In general, at what time does your child wake up or that you wake up your child in the morning?” Friday and Saturday nights had been used to assess habitual bedtime during the weekend. Saturday and Sunday mornings had been used to evaluate habitual wake time during the weekend. Mothers had to write down the exact times (no intervals because of multiple choice answers). Nighttime sleep duration was calculated from bedtime to wake time. Birth characteristics came from medical records: birth date, sex of the child, and prematurity (defined as <37 weeks’ gestation).

### STATISTICAL ANALYSES

The comparisons of sleep-wake schedules between age and between weekdays and the weekend were assessed using repeated-measures analyses of variance. The effect size of analyses of variance was determined using the Cohen’s f value from the partial η² value to give a sense of the level of importance of the effects.20 An effect size around 0.1 is considered small, one around 0.25 is medium, and one around 0.4 is large. Pearson product moment correlations were used to assess relationships between sleep variables and between ages. Then, we compared children in the study, all families received detailed information by mail on the aims and procedures of the research program and signed a consent form. The protocol was approved by the Sacré-Cœur Hospital ethics committee.

### SLEEP-WAKE SCHEDULE COMPARISONS AND CORRELATIONS

Table 1 shows averaged bedtimes and wake times on weekdays and the weekend at the ages of 4, 5, and 6 years. The...
average bedtime was later during the weekend compared with weekdays ($F_{1,100}=3639.1, P<.001, \text{Cohen } f=1.8$). Also, bedtime during weekdays was earlier at the age of 6 years than at the ages of 4 and 5 years, while bedtime during the weekend was earlier at the age of 4 years than at the ages of 5 and 6 years ($F_{2,2184}=18.4, P<.001, \text{Cohen } f=0.18$). Wake time was also later during the weekend compared with weekdays ($F_{1,1006}=1678.0, P<.001, \text{Cohen } f=1.2$). Wake time during weekdays was earlier at the age of 6 years than at the ages of 4 and 5 years, while wake time during the weekend was earlier at the age of 4 years than at the ages of 5 and 6 years ($F_{2,2184}=23.1, P<.001, \text{Cohen } f=0.2$).

In general, sleep schedule variables were highly correlated with each other. Bedtimes and wake times were highly correlated on weekdays at the ages of 4, 5, and 6 years ($r=0.44, r=0.47, \text{and } r=0.47$, respectively; $P<.001$ for all) and on the weekend ($r=0.53, r=0.51, \text{and } r=0.50$, respectively; $P<.001$ for all). Weekday and weekend bedtimes were also highly correlated at the ages of 4, 5, and 6 years ($r=0.73, r=0.68, \text{and } r=0.63$, respectively; $P<.001$ for all); the same applies to wake times ($r=0.73, r=0.67, \text{and } r=0.50$, respectively; $P<.001$ for all). However, the shape of the association differed across ages for correlations between bedtime and wake time on weekdays. Accordingly, the relationship between bedtime and wake time was modified at the age of 6 years, showing that wake time occurred earlier for bedtimes later than 8 PM (different slope: $F_{2,460}=13.8, P<.001$). Correlations between weekdays and the weekend for bedtimes differed between ages, with a later weekend bedtime for a given weekday bedtime at the age of 6 years compared with the ages of 4 and 5 years; and at the age of 5 years compared with the age of 4 years (different intercepts: $F_{2,472}=90.0, P<.001$). Correlations between weekdays and the weekend for wake times also showed between-ages differences, with a later weekend wake time for a given weekday wake time at the age of 5 years compared with the ages of 4 and 6 years; and at the age of 6 years compared with the age of 4 years (different intercepts: $F_{2,456}=46.6, P<.001$). Table 2 reveals that between-age sleep-wake schedule correlations were stronger between the ages of 4 and 5 years than between the ages of 4 and 6 years. Sleep-wake schedules observed at the age of 5 years were highly correlated with those observed at the age of 6 years for the weekend, whereas they were modestly associated for weekdays.

### Table 2. Pearson Product Moment Correlation Coefficients Between the 3 Age Groups for the Sleep Times Reported on Weekdays and the Weekend

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Data for Bedtime</th>
<th>Data for Wake Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 y</td>
<td>5 y</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
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<td>5</td>
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<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>0.57⁺</td>
<td>0.65⁺</td>
</tr>
</tbody>
</table>

Abbreviation: NA, data not applicable.  
⁺Data were obtained courtesy of the Quebec Institute of Statistics.  
P<.001.

### LONGITUDINAL OVERVIEW OF SLEEP-WAKE SCHEDULES

Although averaged sleep-wake schedules are generally stable throughout early childhood, this pattern may not be typical for all children. Rather than assume that all children follow the same developmental pattern of sleep-wake schedule over time, Figure 1 shows 3 patterns (early, medium, and late) for habitual bedtimes and wake times on weekdays and on the weekend. Most of the children were put to bed around 8 PM (51.4%) and woke up between 6 and 7 AM (53.8%) on weekdays. On the weekend, most children were put to bed around 9 PM (58.0%) and woke up between 7 and 8 AM (46.7%)

Often, children were not classified in the same pattern for all sleep-wake variables. For example, a child in the early pattern for wake time on weekdays may be found in the middle pattern for wake time on the weekend. The most common combinations of sleep-wake schedules were as follows: (1) middle patterns for bedtimes (weekdays and the weekend) and wake time on weekend, with an early pattern for wake time on weekdays (n=141) and (2) early patterns for bedtimes (weekdays and the weekend) and wake time on the weekend, with a middle pattern for wake time on weekdays (n=129).

### ASSOCIATION BETWEEN SLEEP-WAKE PATTERNS AND SLEEP DURATION

A significant effect of sleep pattern was found for all sleep-wake variables ($F_{2,1006}=52.7, P<.001$). In general, for bedtime patterns, sleep duration was the longest in the early pattern, shorter in the middle pattern, and shortest in the late pattern, whereas the late patterns of wake time showed the longest sleep duration. For bedtime on weekdays (Figure 2A), significant pattern × week/weekend interaction ($F_{2,1006}=28.0, P<.001$) showed that sleep duration decreases on the weekend in a stronger way in the early pattern compared with the middle pattern. In the late pattern, the sleep duration increases in the weekend compared with the weekdays, which differs significantly from middle and early patterns. For wake time on weekdays (Figure 2B), we found a significant pattern × age × week/weekend interaction ($F_{4,2112}=9.8, P<.001$). Children in the early and late patterns at age 4 decreased their sleep duration...
from weekdays to the weekend, which significantly differs from the middle pattern decrease. At the age of 5 years, the sleep duration decreased on the weekend in the 3 patterns of wake time on weekdays and to a larger extent in the late pattern compared with the middle one. At the age of 6 years, the decrease in sleep duration from weekdays to the weekend was similar in the early and middle patterns but differed from the late pattern in which no
difference in sleep duration was found between weekdays and the weekend.

For bedtime on the weekend (Figure 2C), significant pattern × week/weekend interaction ($F_{1,1062}=4.1, P=.02$) revealed that the sleep duration significantly decreases on the weekend in a weaker way in the early pattern compared with the middle and late patterns. The late and middle patterns had a similar decrease of sleep duration between weekdays and the weekend. For wake time on the weekend (Figure 2D), a significant 3-way interaction was also found ($F_{4,2132}=14.2, P<.001$). Children in the early and middle patterns at age 4 decreased their sleep duration from weekdays to the weekend, which significantly differs from the late pattern's nonsignificant increase. The difference in sleep duration between weekdays and the weekend differs significantly between the 3 patterns of wake time at the ages of 5 and 6 years. The sleep duration decreases on the weekend in the early pattern and increases on the weekend in the late pattern, whereas it was equivalent during weekdays and the weekend in the middle pattern, at the age of 5 years. The sleep duration decreases on the weekend in the early and middle patterns and increases on the weekend in the late pattern at the age of 6 years.

**BIRTH SEASON DISTRIBUTION OF EARLY AND LATE SLEEP-WAKE SCHEDULES**

A recent study$^{24}$ found that preterm birth shifts toward morningness the distribution of chronotypes in adolescence. We found more preterm-born children in the early bedtime on weekend group (6.5% vs 3.3% and 1.9% in the middle and late groups, respectively; $\chi^2=7.3, P=.03$) and a similar trend in the early wake time on weekend group (6.2% vs 3.3% and 2.8% in the middle and late groups, respectively; $\chi^2=5.6, P=.06$). No significant difference appears for weekday's sleep-wake schedules. Nevertheless, preterm-born children were excluded in further analysis to minimize the effects of this factor. The distributions of full-term children in early and late patterns of sleep schedules in function of seasons were as follows. (1) For bedtime on weekdays, in spring-summer, early included 51.7% and late included 50.0%; and in fall-winter, early included 48.3% and late included 50.0% ($P=.82$). (2) For wake time on weekdays, in spring-summer, early included 53.7% and late included 56.7%; and in fall-winter, early included 46.3% and late included 43.3% ($P=.57$). (3) For bedtime on the weekend, in spring-summer, early included 59.1% and late included 51.5%; and in fall-winter, early included 40.9% and late included 48.5% ($P=.18$). (4) For wake time on the weekend, in spring-summer, early included 50.6% and late included 58.7%; and in fall-winter, early included 49.4% and late included 41.3% ($P=.10$). In sum, no significant difference was found in the distribution of births in spring-summer and fall-winter in any of the 4 variables of sleep-wake schedules.

**COMMENT**

Our results showed that the 6-year-old subjects in our sample had earlier bedtimes and wake times during weekdays than when their were either 4 or 5 years old. Moreover, the correlation between bedtimes and wake times on weekdays revealed that the wake time at the age of 6 years occurred earlier for bedtimes later than 8 PM. Therefore, between-age correlations for bedtimes and wake times during weekdays became weaker through the years. These age-dependent differences in schedules during weekdays most probably result from the beginning of school at the age of 6 years, producing an advance in the sleep schedule and a modification of the bedtime–wake time relationship toward a decrease in sleep duration. School start time has also been reported as an environmental constraint on sleep schedule and sleep duration in teenagers.$^{25}$

A displacement of sleep-wake patterns toward later hours during the weekend was shown as early as the first years of life.$^6$ There was a shift of bedtimes during the weekend to later hours with age in comparisons with sleep schedules during weekdays. We also observed a shift of wake times during the weekend to later hours between 4 and 6 years of age compared with sleep schedules during weekdays. Two reasons might explain the whole displacement of sleep-wake patterns toward later hours during the weekend. First, the parents could be less strict with bedtime on the weekend knowing that their children do not have to get up early the next morning. Second, this phase delay could be related to characteristics of the endogenous circadian clock. The average human circadian period has been reported to be close to 24.2 hours in adults$^{26}$ and 24.3 hours in teenagers.$^{27}$ If the endogenous circadian period in children is already longer than 24 hours, the sleep schedule would naturally tend to delay.

Most children in our cohort were put to bed around 8 PM and woke up between 6 and 7 AM during weekdays. Similar bedtimes have been reported in the United States,$^5$ Switzerland,$^7$ and Belgium.$^8$ On the other hand, several studies found later bedtimes in other countries, eg, in Italy$^4$ and Iceland$^6$ or earlier bedtimes, eg, in Australia.$^28$ In addition, similar wake times were shown in the United States,$^3$ whereas most countries reported later wake times, as in Italy,$^4$ Iceland,$^6$ Switzerland,$^7$ and Belgium.$^8$ The between-country discrepancies about sleep-wake patterns are probably because of the influence of environmental and sociocultural differences. Indeed, a cross-national survey on sleep habits of adolescents revealed significant variations between the 11 European countries studied.$^{29}$ However, these studies did not examine the distinction between weekdays and weekend sleep schedules, except for the study of Thorleifsdottir and coworkers.$^6$

The present study has been able to identify a minority of children with late sleep patterns. In particular, we observed that 9.4% of children were put to bed around 10 PM and 13.4% awaken around 9 AM on the weekend. It would be of particular interest and possible with this ongoing project to verify the sleep patterns of these children when they reach adolescence. Those children might be at particular risk of developing a delayed sleep phase syndrome, a condition characterized by abnormally late sleep-wake patterns and often showing early signs of schedule delay.$^{30}$
More important, we observed that most children slept less during the weekend compared with weekdays, while the reverse is habitually observed in adults and teenagers. This probably results from 2 combined factors: (1) a more liberal parental attitude during the weekend toward bedtime and (2) a spontaneous early wake time in most children. Moreover, later bedtimes on weekdays and the weekend are specifically associated with shorter nocturnal sleep duration. Touchette and coworkers\textsuperscript{11} have found that children with short sleep are at greater risk of having a high hyperactivity score or a lower cognitive performance. Short sleep duration was also associated with increased risk of excess weight and obesity in children.\textsuperscript{33,34} Future studies should seek to verify whether health or family conditions are potentially associated with different sleep-wake patterns.

However, a few children slept more during the weekend than during weekdays: children with late weekday bedtimes and children with late weekend wake times. Our results showed that children with a late bedtime on weekdays have the shortest sleep duration; we can speculate that they are attempting to recover sleep during the weekend, as adolescents do.\textsuperscript{33,34} For the children with a late wake time on the weekend, the lengthening of their sleep on the weekend might indicate that this small proportion of children has early signs of capacity for delaying sleep schedules.

In our study, although there was a trend for children with late wake times on weekdays and the weekend to be born more often during spring-summer than during fall-winter, extreme sleep-wake schedules were not associated with birth season. This could be explained by several factors. First, sleep-wake schedules assessed by parents may not be a reliable sign of diurnal preference partly because sleep-wake schedules in early childhood might mostly represent parental choice rather than the endogenous preferred schedules of the children. This might be linked to the question used for determining bedtime in the present study: "At what time do you put your child to bed?" Then, variations in wanted sleep timing during early childhood might not correspond to the diurnal preference observed in teenagers and adults given the larger sleep need in children. Presently, our results do not permit strong support of this last assumption.

The major strength of this project was the high number of children measured longitudinally. However, spurious significant results could have occurred because of the large sample (eg, the between-age differences in sleep schedules might not all be clinically relevant, given the small effect sizes). Moreover, the study is limited by parental reports of sleep-wake schedules. Sleep duration reported herein should be interpreted as time in bed because sleep onset and time spent awake may particularly be difficult to estimate for parents.\textsuperscript{8} Fortunately, the reliability between actigraphy and parental reports for sleep duration is high.\textsuperscript{35-38} Another limitation is that daytime sleep data were not taken into consideration in the present study. However, in a previous study\textsuperscript{39} based on the same cohort, daytime napping was not associated with patterns of nighttime sleep duration. Finally, children were generally whites; thus, the results might not be applicable to other ethnic groups.

Despite these limitations, this research draws a large overview of the development of sleep-wake schedules during the first part of childhood. Our results support earlier findings showing that the displacement of bedtime and wake times toward later hours during the weekend begins early in life. We also observed different patterns of sleep schedules that seemed relatively stable across ages. Despite the observation of differences in schedule timing, our results indicated that the sleep pattern for most children is probably the reflection of the absence of a strong preference for sleep timing in combination with a sleep-wake schedule most likely influenced by parental choice and school constraints. Surprisingly, we found that most children slept less during the weekend than during weekdays. Finally, this article highlights the importance of putting children early to bed and maintaining regular sleep schedules during weekdays and the weekend to optimize sleep duration and, in turn, maximize development.

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Author Contributions: Dr Touchette had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Touchette, Mongrain, and Montplaisir. Acquisition of data: Tremblay and Montplaisir. Analysis and interpretation of data: Touchette, Mongrain, Petit, and Montplaisir. Drafting of the manuscript: Touchette and Mongrain. Critical revision of the manuscript for important intellectual content: Touchette, Mongrain, Petit, and Montplaisir. Administrative, technical, and material support: Montplaisir. Study supervision: Mongrain, Petit, and Montplaisir.

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