

THE ADOLESCENCE SLEEP PHASE DELAY: CAUSES, CONSEQUENCES AND POSSIBLE INTERVENTIONS

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ABSTRACT

Adolescence is marked by, among other things, an increase in daily sleepiness as a consequence of insufficient sleep, more intense during school days. Partial sleep deprivation results from the tendency of adolescents to delay their sleeping and waking times. This behavior is known as the phase delay, and is in conflict with the students' morning school schedules. Excessive sleepiness during the day impairs their concentration and their capacity to learn. The purpose of this article was to discuss the role of sleep in consolidating learning. In addition, it also shows that the phase delay, in contrast to what was believed some decades ago, is caused not just by changes in the adolescent's habits but also by physiological changes that occur during puberal development. Lastly, this article presents strategies for intervention that aim to reduce excessive daily sleepiness. Such interventions involve increasing awareness in the school community of the importance of sleep habits, introducing educational programs on sleep in elementary school, and discussing the adequacy of school schedules.

Keywords: Adolescents; Phase delay; Excessive daily sleepiness; School performance.

EXCESSIVE DAILY SLEEPINESS: THE TIP OF THE "ICEBERG"

A typical adolescent school life involves struggling to wake up early, suffering a reduced concentration level due to excessive sleepiness, and napping during classes, particularly in the morning period. In the last two decades, groups of researchers in several countries, including Brazil (1-3), have dedicated their attention to this problem, and the results of their research have provided a foundation for

understanding this phenomenon, its consequences, and the possible interventions that could minimize its undesirable effects.

Usually, adolescents experience excessive daily sleepiness because they get an insufficient amount of sleep. An adolescent requires an average amount of daily sleep in the range of 8.5 to 9.25 hours. Studies of adolescents in several countries have shown that the student's average sleep period is reduced during school days to around 7 hours (4) due to a tendency of students to delay

bedtime while maintaining the same waking time to adhere to school schedules. A partial sleep deprivation that averages 1-2 hours per day during school days is enough to trigger symptoms of sleepiness, leading to a reduced school performance (5,6). On weekends, the sleep duration period is extended as a result of the so-called rebound effect from the sleep deprivation they are subjected to during the week.

It can be thus observed that the adolescent's sleep-wake cycle shows an irregular pattern that is characterized by a reduction in the sleep period during school days and an extension in the sleep period during weekends (7). The irregularity that results from partial sleep deprivation is associated with a reduction in concentration levels and alterations in mood (8).

The importance of cultivating healthy sleep habits in early childhood has long been acknowledged. In his book on thoughts about education, John Locke (9) argues that nothing contributes more to the child's development and health than sleep. The author emphasizes the importance of establishing a routine from an early age so that the child cultivates good sleep habits. Nevertheless, a careful analysis of results of studies conducted in the last 20 years shows that, in contrast to what has been thought, the problem does not derive exclusively from the lack of limits and discipline that should be imposed on adolescents. The difficulty in promoting earlier sleeping and waking times results from changes that take place in the adolescent's body during puberty. Through mechanisms not yet well understood, these changes in the adolescent physiology trigger the so-called phase delay: the tendency of the body to delay its biological rhythms, including sleeping and waking times.

It is already known that excessive sleepiness impairs concentration and learning capacity. It has been shown recently that there is a relationship between sleep and memory (10,11). Several sleep phases participate in the learning consolidation process and not just the paradoxical sleep as was previously believed (12).

Sleep deprivation alters the functioning of several brain regions, including the prefrontal cortex. This brain region is closely associated with the working memory and with other more complex cognitive functions, such as judgement and the decision making process (13).

Thus, changes in the sleep-wake cycle jeopardize learning in two ways: they reduce concentration and the capacity for quick learning, and they impair consolidation of what has been learned.

Sleep deprivation can also promote alterations in mood, exacerbate symptoms of psychiatric disorders such as depression (14), and cause metabolic changes, which increase appetite and, consequently, body mass (15). Irregular sleep patterns and/or insufficient sleep are associated with an increase in the number of medical appointments among children and adolescents (16).

Despite the need to overcome the biological/social dichotomy in studies that analyze behavior, this dichotomy is frequently present in works that seek an understanding of the origins of the phase delay.

For many years, the phase delay was attributed exclusively to social factors (16): greater independence to organize their own schedules, access to technology (TV, video games, computers, and the Internet), and a greater demand for social outings and events.

In the early 1990s, it was demonstrated that pubertal stages

of development were associated with a delay in the expression of biological rhythms. According to the classification proposed by Tanner (17), more mature adolescents have more delayed sleeping times than less mature adolescents, regardless of the age factor (1,18).

The identification of a biological factor for determining the phase delay demanded a reevaluation of the issue. An article has been recently published that developed the idea that this tendency to delay sleep time is part of the human species maturational calendar. The magnitude of the delay increases as puberty progresses until a reversion around the twenties, regardless of the changes in habits of young adults that may appear upon entering university or the job market. The authors of this article suggest that this reversion marks the end of adolescence (19).

In order to identify the possible social factors involved in the expression of the biological rhythmicity during adolescence, studies with rural populations, some of which did not have electric power at home, have been conducted (20,21). One of these studies compared the sleep patterns of adolescents living in the same community and attending the same school. Those who had electric power at home went to bed later than those who did not have electric power at home. These results complement recent studies conducted in native communities (22) that reinforce the major influence exerted by social factors upon the phase delay. The magnitude of this delay in urban populations, particularly those that have access to technological resources, is greater and, consequently, sleep deprivation during school days is also greater.

We can thus conclude that changes associated with pubertal maturation render the individual more susceptible to delays in sleep time. It is as if the same stimuli have a different effect depending on the function of the pubertal stage. In more advanced pubertal stages, the adolescent's body is more sensitive to stimuli capable of promoting delays in the biological rhythms.

PHASE DELAY PHYSIOLOGICAL BASES

"Do teenagers sleep late because they go to the disco or do they go to the disco because they cannot sleep until late?" (19).

Subsequent to the question asked by Roenneberg and collaborators lays a discussion on the factors involved in the adolescence phase delay. In attempt to answer this question, it is necessary to discuss the mechanisms behind the control of circadian rhythmicity in humans.

Like with other organic behaviors and functions, sleeping and waking times are controlled by the Circadian Temporization System (CTS). This system consists of a set of structures comprising the suprachiasmatic nuclei, which are small neuron clusters localized in the hypothalamus. Today, these nuclei are recognized as elements that make up the mammalian CTS. This temporization system, commonly known as the "biological clock", generates a regular circadian rhythm even when the body is isolated from environmental cycles and under normal conditions accomplishes the synchronization between endogenous rhythms and environmental cues (23). When adjusting to the day/night cycle, the result of such synchronization is the presence of behavioral and endocrine rhythms and also of multiple variables that have a

24-hour duration. These circadian rhythms allow us to adjust our behaviors to social schedules.

A clear circadian rhythm is the secretion of the melatonin hormone by the pineal gland. This gland, which was seen by Descartes as the part of the human body associated with the soul (24), is an important time signal for our body. By varying melatonin levels, low during the day and high at night, the pineal gland communicates to the body the time of day. Such signaling creates in our body the so-called biological night that is characterized by high melatonin levels, a drop in body temperature and, in humans, the occurrence of a sleep episode. Light stimuli, even of low intensity (25), can drastically reduce melatonin secretion, changing the biological night.

In the last two decades, several studies have shown the importance of the day/night cycle for the adjustment of our biological rhythms (26). It was once believed that the social schedules of humans would seriously affect this adjustment. Today, however, it is known that a large part of the effects that social schedules have is exerted through changes in light intensity. In other words, when we set the clock to ring one hour earlier, we are advancing the light stimuli sent to the CTS by one hour. In the same way, when we decide to participate in a night event, we are increasing the light stimuli during a period when normally our eyes would be closed. By using electric power to produce artificial light, contemporary society has shortened the environmental night. As a result, the biological night and the night sleep have been shortened.

Individual differences in sleep-wake cycles can be noticed even in the early months of life. These differences are reflected in their preferred sleeping and waking up times. People who prefer waking up early and going to sleep early are called “morning-types.” Those who prefer going to sleep late and waking up late are called “evening-types.” This observation indicates that people establish different temporal relations between their own rhythms and the environmental cycles (27). This characteristic constitutes what is called a chronotype. For example, some people wake up one hour after daybreak. Others, if possible, prefer waking up four or five hours after daybreak. Without intending to resume the nature/culture dichotomy, it is necessary to point out that there are studies that show that there is an influence of some pairs of genes on the determination of chronotype: we are born with a trend to be morning people or evening people. This result does not minimize the critical influence of social interactions; on the contrary, it helps us understand them. The adolescence phase delay is associated with this trend: morning children become less emphatic morning adolescents; evening children become still more emphatic evening adolescents and thus face greater difficulties in adapting to school schedules.

With all the knowledge that is currently available, it is a likely possibility that the phase delay originates from changes in the temporization system that are triggered by hormone modifications associated with puberty. The endogenously generated circadian rhythms do not have a precise 24-hour period; in humans, they usually extend for more than 24 hours (28). The expression of a circadian rhythm that is adjusted to the 24-hour environmental cycles (day/night, social interaction) depends on the body's interaction with these cycles. Recent studies have shown that evening-type individuals have a longer endogenous period compared to

morning-type individuals (28). We could say that individuals with an endogenous period shorter than 24 hours tend to be morning people, whereas individuals with an endogenous period longer than 24 hours tend to be evening people. One hypothesis that might explain the origin of the phase delay is that a change in the endogenous period occurs during puberty. Hormonal changes would modify the CTS functioning speed, which would suffer a reduction, thus resulting in a longer endogenous period.

Another approach to investigating changes in the phase delay is based on a widely accepted model that suggests that the tendency to feel sleepy results from the interaction between the homeostatic (S) and circadian (C) processes (29). The homeostatic process (S) is associated with the number of wakefulness hours: the longer we remain awake, the greater the tendency to feel sleepy. Accordingly, the sleep trend starts low at the beginning of the day and increases as the day progresses, reaching a maximum after 14 or 16 waking hours, after which we usually fall asleep. The homeostatic process does not on its own explain the complexity of our sleep habits. For example, often we are more attentive at the end of the afternoon than soon after waking up; this fact contradicts the tendency to accumulate sleepiness throughout the day and points to the existence of another mechanism that acts in concert, called the circadian process (C). The circadian process dictates that the tendency to sleep increases throughout the night, regardless of the number of waking hours. The relationship between the S and C processes makes us feel a strong tendency to sleep after sunset, as a result from the action of both processes; the outcome is an extended sleep episode during the night. After a few hours of sleep, when the tendency to sleep generated by process S is reduced, we remain asleep due to the action of process C, which is in full operation at daybreak.

The results of studies conducted in recent years suggest that the puberal maturing modifies process S (30). During this phase of life, a larger number of waking hours are necessary to trigger the feeling of sleepiness, explaining the fact that adolescents have an increased ability to remain awake for extended periods of time.

The two processes mentioned above are subject to continuous modulation performed by several environmental stimuli. A boring, non-stimulating class can increase sleepiness levels, whereas a highly motivating activity can mask high sleepiness levels. As a result, many educators interpret signs of sleepiness as a reflex of the activities developed at school and disregard the physiological mechanisms underlying attention control.

A third way of explaining the physiological mechanisms behind phase delay is a change in the CTS sensitivity to light (31). The adjustment between endogenous rhythms and environmental cycles results from advances and delays in the circadian rhythms. Light stimuli between sunset and the end of the night delay circadian rhythms, whereas light stimuli in the early morning hours advance these rhythms. One possibility is that the adolescent's body is susceptible to delays due to an increased sensitivity of the temporization system to light at the beginning of the night or a reduced sensitivity in the early morning. Since the physiological mechanisms behind the delaying and advancing processes are the same, the possibility that the change occurs in only one of the components should be acknowledged.

Nightly social activities favor exposure to light at moments

when the STC responds by promoting a delay in the biological rhythms and, consequently, delaying waking time. This delay reduces the exposure to light in the early morning, which contributes to the advance of biological rhythms. As a result, the time of exposure to light becomes unbalanced at moments when the STC is delayed or advanced.

During vacation, when there is no obligation to comply with school schedules, the adolescent's eyes remain closed during most of the time when the CTS is susceptible to advances. Waking up after midday and, in some situations, at sunset, the adolescent remains awake and exposed to artificial light only at moments when the CTS is delayed. Such a behavior that is adopted for several weeks causes a significant delay. Often, after classes resume, a 12-hour inversion in sleeping and waking times is necessary: instead of waking up at 06:00pm, the adolescent will wake up at 06:00am. Adaptation does not take place immediately, and brings about the consequences already described.

THE SLEEP PHASE DELAY AT SCHOOL: POSSIBLE INTERVENTIONS

Based on the information provided above, schools need to incorporate into their pedagogical proposal measures that would reduce the impact of phase delay on the student's performance.

The first step would be to reconsider the school's temporal organization, in particular its class schedules, and systematize the results of possible interventions that aim to reduce the student's daily sleepiness and thereby improve performance. This systematization would include, in addition to an educational evaluation, a tracking of the sleep-wake cycle patterns and of some correlated sleep behaviors before and after the implementation of the change. Today, we have available questionnaires and tests to evaluate these interventions in a simple and inexpensive way.

The changes we propose are apparently simple modifications, such as delaying the beginning of morning classes. Nevertheless, changing class schedules involves the participation of the whole community – parents, teachers, and transport service providers – and should be discussed and planned before implementation. This change has been implemented in some North-American schools (32) and also in some Israeli institutions.

Another intervention relates to the teaching of sciences. It is a consensus among educators that access to information is crucial for the students to develop healthier habits, in particular in scientific areas, such as those related to sex, psychotropic drugs, and nutrition. The same access should be delivered for sleep habits. By knowing the aspects of the sleep-wake cycle physiology and the temporization system, the students will be able to develop healthier sleep habits. In some countries, this concern has started to yield results in elementary and high school institutions. In the US, in early 2004, the National Center on Sleep Disorders Research (NCSDR) and the NIH Scientific Education Sector launched a program of activities on Sleep and Biological Rhythms for high school students. This program complies with the country's educational guidelines and includes printed material for teachers, interactive activities and computer simulations. In Brazil, the texts of the Parâmetros Curriculares Nacionais (PCNs)

(National Curricular Parameters) for elementary school include proposals on the theme in the module Human Body and Health. Science educational books have gradually incorporated this subject into their units.

A third intervention is related to the characteristics of the temporization system. Light stimuli after sunset contribute to delaying the circadian rhythms. Light stimuli after daybreak – even one or two hours before daybreak – advance circadian rhythms. Increasing the exposure to light in the early morning hours may help students to forward their rhythms. When the students resume classes after vacation, the first morning classes should be attended in open spaces or in well-lighted areas to accelerate the adjustment process and thus promote a higher alertness level and a lower sleepiness level during the day. Only a few studies have evaluated the effect of such an intervention, however (33).

We understand that the discussion about school schedules should, at a given moment, go through the considerations approached in the present article, whether under a more academic viewpoint, that is, incorporating contemporary knowledge, or under a practical viewpoint, that is, improving the conditions of the learning process in the school environment.

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