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Sleep, circadian rhythms, and delayed phase in adolescence

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Abstract

Sleep/wake timing shifts later in young humans during the second decade of life. In this review we describe sleep/wake patterns, changes in these patterns across adolescence, and evidence for the role of environmental, psychosocial, and biological factors underlying these changes. A two-process model incorporating circadian (Process C) and sleep/wake homeostatic (Process S) components is outlined. This model may help us to understand how developmental changes translate to shifted sleep/wake patterns. Delayed sleep phase syndrome (DSPS), which has a typical onset during the second decade of life, may be an extreme manifestation of homeostatic and circadian changes in adolescence. We describe symptoms, prevalence, and possible etiology of DSPS, as well as treatment approaches in adolescents.

Keywords: Adolescent; Development; Circadian rhythms; Sleep patterns; DSPS; Delayed sleep phase syndrome

1. Introduction

This review describes changes to sleep/wake behavior during adolescent development and the contribution of the circadian and sleep/wake homeostatic systems to this changing behavior. We also review delayed sleep phase syndrome (DSPS), which may be an extreme manifestation of these changes or may be a distinct clinical entity. Last, we describe approaches to treat DSPS in adolescents. For the purpose of this review, we consider biological adolescence to span the second decade of life.

2. Developmental changes in sleep/wake (light/dark) patterns

Sleep/wake patterns of developing adolescents are often described in the context of a school year and have been described separately for school (weekday) and non-school (weekend) days. Sleep timing is often quite different during school vacations. Describing sleep patterns during both school and vacation times provides a more comprehensive account of developmental sleep/wake behavior changes, yet few studies have examined vacation sleep patterns.

Table 1 summarizes adolescent self-reported sleep patterns derived from survey studies that reported weekend and weekday data during the school year. These data show that adolescents report going to bed later as they get older. Studies from such countries as Canada [1], Poland [2], Belgium [3], Australia [4], Finland [5], and Brazil [6] show similar trends. Investigators associate this age-related change in bedtime on school nights with a number of environmental factors, including reduced parental influence on bedtimes [7,8], increased homework [9], and extra-curricular activities, such as sports, musical groups, clubs, and service groups [10], or part-time work [7,10,11]. Other environmental, usually stimulating activities, that often affect bedtime

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Table 1
Mean self-reported school-year weekend and weekday sleep patterns from survey reports in the U.S

Reference	age/school grade	Weekday Bedtime[a]	Weekend Bedtime[a]	Weekday Rise Time[a]	Weekend Risetime[a]
Middle School Years (11-13 years old)					
Carskadon, 1990 [7]	11 years	2130 (2140)	2222 (2250)	0705 (0700)	0825 (0745)
NSF Poll 2006 [8]	Grade 6	2124	2231	0642	0853
Carskadon, 1990 [7]	12 years	2145 (2150)	2255 (2305)	0655 (0705)	0835 (0835)
NSF Poll 2006 [8]	Grade 7	2152	2305	0635	0912
Manber et al., 1995 [9]	middle school	2137	2311	0610	0847
Carskadon, 1990 [7]	13 year	2206 (2228)	2320 (2342)	0650 (0700)	0845 (0845)
NSF Poll 2006 [8]	Grade 8	2153	2326	0636	0921
Wolfson & Carskadon, 1998 [13]	13-14 years	2205	2354	0559	0922
High School Years (14-19 years old)					
O'Brien & Mindell, 2005 [12]	Grade 9	2238	2359		
NSF Poll 2006 [8]	Grade 9	2215	2353	0628	0954
Wolfson et al., 2003 [16]	13.8 - 19.9 years	2246	0017	0620	0940
Carskadon, 1990 [7]	14 years	2210 (2216)	2357 (0006)	0556 (0615)	0914 (0912)
Carskadon, 1990 [7]	15 years	2224 (2243)	0011 (0027)	0605 (0627)	0924 (0925)
Wolfson & Carskadon, 1998 [13]	15 years	2220	0006	0600	0940
O'Brien & Mindell, 2005 [12]	Grade 10	2307	0042		
NSF Poll 2006 [8]	Grade 10	2232	0003	0623	0952
Link & Ancoli-Israel, 1995 [15]	15-18 years	2244	0041	0555	0951
Manber et al., 1995 [9]	high school	2238	2356	0608	0915
Carskadon, 1990 [7]	16 years	2252 (2308)	0028 (0044)	0613 (0638)	0921 (0937)
Wolfson & Carskadon, 1998 [13]	16 years	2237	0030	0605	0946
O'Brien & Mindell, 2005 [12]	Grade 11	2313	0115		
NSF Poll 2006 [8]	Grade 11	2251	0025	0623	1006
Carskadon, 1990 [7]	17 years	2258 (2314)	0039 (0051)	0626 (0645)	0921 (0927)
Wolfson & Carskadon, 1998 [13]	17-19 years	2251	0049	0610	0932
O'Brien & Mindell, 2005 [12]	Grade 12	2324	0124		
NSF Poll 2006 [8]	Grade 12	2302	0045	0631	0951

[a] Values followed by parentheses indicate that authors computed means for boys and girls separately in the original report; the first value = mean time reported by girls; parenthetical value = mean time reported by boys.

include watching TV, playing video games, and using the computer [3,8].

Adolescents consistently report going to bed later on weekend nights compared to school nights (see Table 1). The difference between weekend and school-night bedtimes (*weekend bedtime delay*) in adolescents averages between 1 and 2 h [7–9,12–16], usually greater in the older than the younger adolescents.

Most school systems in the United States are organized so that high school students are required to report to school earlier than middle school students [8]. Rise time on school days reflects this pattern (see Table 1). Several reports note that girls rise significantly earlier than boys on school mornings [7–9,13,15]. Early rising for school is unwelcome and forced for most adolescents. For example, one survey study showed that 61% of a suburban high school student sample reported commonly being "too sleepy to get out of bed in the morning" [17]. A longitudinal study completed in Switzerland reported that about 63% of participants at the average age of 15 and 17 years reported being tired upon awakening [18]. A more recent telephone poll by the U.S. National Sleep Foundation reported that approximately 70% of middle school and high school students required an adult to wake them on school mornings [8].

Another consistent finding is that the reported rise times on weekend mornings are significantly later than those on school mornings, especially for older adolescents (see Table 1). Findings are inconsistent about whether or not boys and girls have different sleep patterns. For example, LaBerge and colleagues found sex difference in a group of 10–13 year olds, with girls sleeping later on weekends compared to boys [1]; however, in another study this difference did not emerge in a group of 13- to 19-year-old adolescents [13]. With an average school-day rise time between 0600 and 0700 h, the difference between weekday and weekend rise time (*weekend rise time delay*) averages about 1.5–3 h in 10–13 year olds and 3–4 h in high school students. One study marks this weekend sleep delay at almost 3 h in adolescents, defined as less than 21 years old [19].

The adolescent's social milieu changes from school months to vacation months. Most adolescents experience less constrained daily schedules during vacation, yet little research has focused on changes to sleep/wake patterns under this more unconstrained schedule.

Hansen and colleagues [20] studied sleep patterns of fourth-year high school students in August (before school started) and again in September (after school started). Sleep diary data showed that weekday bedtimes