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Association between Puberty and Delayed Phase Preference

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Summary: Many teenagers go to bed and wake up significantly later than younger children, a developmental progression thought to reflect adolescent psychosocial processes. To determine whether biological processes may underlie a delay of phase preference in adolescents, 183 sixth-grade boys and 275 sixth-grade girls completed questionnaires for morningness/eveningness (M/E) and pubertal status. School environment and birth order were also evaluated. A significant relationship of pubertal status to M/E was found in girls, with a similar though nonsignificant trend in boys. No relationship between M/E and psychosocial factors was found. These data support involvement of a biological factor in the adolescent phase preference delay and indicate that our current understanding of adolescent sleep patterns may need revision. **Key Words:** Adolescent sleep patterns—Delayed phase preference—Puberty—Circadian rhythms.

The timing of sleep is generally stable during childhood. In children aged 7–9 years, for example, the timing of sleep on weekdays and weekends is quite constant; in particular, morning rising time is generally spontaneous and consistently timed (1). This pattern indicates a stable circadian phase position for this important marker of sleep–wake timing. In adolescents, by contrast, sleep patterns on weekends show a considerable delay versus weekdays, with sleep onset and offset both occurring significantly later on the weekends (2). This shift in sleep phase may be primarily attributed to psychosocial factors that become increasingly salient at the childhood-to-adolescence transition, such as an increase in academic and social demands and opportunities. On the other hand, the shift may result from physiological concomitants of puberty. We have previously identified a midpubertal augmentation of daytime sleepiness (3). When examined using physician's ratings of pubertal stages, peak daytime sleep tendency also showed a phase delay from mid- to late puberty (4). In the present study, we examined data from a survey designed to evaluate the hypothesis that the adolescent tendency to phase delay may be initiated by a biological process rather than principally as a response to a changing psychosocial milieu. The origins of this behavioral change may have significant implications for understanding adolescent sleep patterns.

METHODS

This study was part of a larger survey of fourth through sixth graders and their parents from across the United States. The January 1991, teacher's issue of *SuperScience Blue* (Scholastic, Inc., New York), a science magazine for 4th, 5th and 6th graders, carried a letter to teachers requesting that they write to the senior author if interested in having their students participate in a research project examining physical maturation and body clocks. Of 127 teachers (112 schools) who expressed interest, 93 (78 schools) had their students take part, including 36 schools with 6th graders. Students completed a questionnaire anonymously as a classroom exercise and then took the questionnaire home, along with a letter to parents, forms for parents to complete and a postage-paid return envelope. The letter to parents explained the project, requested that parents complete anonymous questionnaires about their child's patterns and their own and asked parents to decide whether their data and their child's data could be used in the research by choosing whether or not to mail the forms. Forms were sent to teachers of 3,942 students (2,016 boys; 1,926 girls). Student forms were returned for 955 boys (47.4%) and 1,060 girls (55.0%). Of these, 238 boys and 313 girls were 6th-grade students aged 11 or 12 years. Surveys were included in the present analysis if the student completed all the

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1*. Imagine: School is canceled! You can get up whenever you want to. When would you get out of bed? Between...

a. 5:00 and 6:30 am
b. 6:30 and 7:45 am
c. 7:45 and 9:45 am
d. 9:45 and 11:00 am
e. 11:00 am and noon

2. Is it easy for you to get up in the morning?

a. No way!
b. Sort of
c. Pretty easy
d. It's a cinch

3*. Gym class is set for 7:00 in the morning. How do you think you'll do?

a. My best!
b. Okay
c. Worse than usual
d. Awful

4*. The bad news: You have to take a two-hour test. The good news: You can take it when you think you'll do your best. What time is that?

a. 8:00 to 10:00 am
b. 11:00 am to 1:00 pm
c. 3:00 to 5:00 pm
d. 7:00 to 9:00 pm

5*. When do you have the most energy to do your favorite things?

a. Morning! I'm tired in the evening
b. Morning more than evening
c. Evening more than morning
d. Evening! I'm tired in the morning

6*. Guess what? Your parents have decided to let you set your own bedtime. What time would you pick? Between...

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

7. How alert are you in the first half hour you're up?

a. Out of it
b. A little dazed
c. Okay
d. Ready to take on the world

8*. When does your body start to tell you it's time for bed (even if you ignore it)? Between...

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

9. Say you had to get up at 6:00 am every morning: What would it be like?

a. Awful!
b. Not so great
c. Okay (if I have to)
d. Fine, no problem

10*. When you wake up in the morning how long does it take for you to be totally "with it?"

a. 0 to 10 minutes
b. 11 to 20 minutes
c. 21 to 40 minutes
d. More than 40 minutes

FIG. 1. Morningness/eveningness scale for children. A score is derived by adding points for each answer: a = 1, b = 2, c = 3, d = 4, e = 5, except as indicated by *, where point values are reversed. The maximum score is 42 (maximal morning preference) and the minimum is 10 (minimal morning preference).

relevant questions about preferred schedule and physical development (final sample: boys n = 183; girls n = 275). Sixth graders were selected for this analysis because they were likely to span pubertal development stages, yet to occupy a narrow age range and psychosocial sphere. The children completing this survey were generally living in single-family dwellings with their parents, largely (85%) Caucasian, and chiefly from small to medium-sized towns or small cities. The sample was neither randomly selected nor is it necessarily a representative sample of 6th graders.

A new morningness/eveningness (M/E) questionnaire for children was used to evaluate M/E preference. M/E is a construct developed to estimate phase tendencies from self descriptions (5). The child M/E score was derived from responses to 10 questions about preferred timing of such activities as recess, tests, bedtime, rising time and so forth (see Fig. 1). These items were

TABLE 1. *Spearman rank order correlations with M/E scale score*

Variable	Boys Spearman *r*	Girls Spearman *r*
Weekday bedtime	−0.339*	−0.236*
Weekend bedtime	−0.301*	−0.330*
Weekday wake-up time	−0.253*	−0.134
Weekend wake-up time	−0.521*	−0.482*
School start time	−0.009	−0.011

* $p < 0.001$.

modified from similar questionnaires constructed for use in adults that are valid and reliable (6); we have reported good full-scale reliability for this children's M/E scale, as well as significant relationships of this M/E scale to self-reported sleep variables in pre- and early pubertal 6th graders from this sample (7). M/E scores ranged from 14 to 42, with higher scores indicative of greater morningness. M/E score was the dependent variable used to measure phase preference and scores did not differ between boys and girls (boys mean M/E score = 28.5, SD = 5.6; girls mean M/E score = 28.7, SD = 5.3).

Separate "boys" and "girls" versions of a physical development questionnaire (8) were included in the survey to assess physical maturation and pubertal status. Pubertal development scores were collapsed into three groups for the girls: 1 = no or few signs of pubertal changes (n = 26); 2 = pubertal changes evident (n = 165); 3 = pubertal changes quite marked (n = 84). All girls in group 3 were postmenarchal. Only 2 pubertal categories were derived for boys, because fewer boys rated themselves as showing marked pubertal changes. Therefore, for boys: 1 = no or few signs of pubertal changes (n = 102); 2 = pubertal changes evident, but not completed (n = 81). Pubertal status determined by these scales was an independent variable marking a presumed biological factor that may affect phase preference.

Birth order and a measure of peer group were used as markers for psychosocial factors that might affect M/E scores. Birth order was used to group children into eldest or only sibling (n = 204) or those with older siblings (n = 254). Peer group was determined by the type of school the children attended: 6th graders in primary schools where 6th grade was the highest grade were designated the Primary School Group (n = 258); 6th graders in middle schools or other school environments that included older students (e.g. grades 5–8, K–9, 6–12) were designated the Secondary School Group (n = 200).

Evaluations were also performed to examine additional factors that may have been related to the findings, such as parental influence on bedtime, school starting time and the students' self-reported bedtimes and wake-up times. Each of these variables was assessed with a question (e.g. What is the *main reason* you usually go to bed . . . ?) followed by categorical choices (e.g. my parents set bedtime; I feel sleepy; my TV shows are over; I finish my homework; my brothers/sisters go to bed; I feel bored; other). Choices for times were offered in 1-hour ranges.

RESULTS

Separate boys and girls contingency tables were prepared for puberty scores versus the items regarding reason for going to bed on weeknights, bedtimes and wake-up times on weekdays and weekend days and school starting time. In both boys and girls, weekday bedtime was significantly related to puberty stage, with later bedtimes reported by students with higher puberty scores (boys chi-square = 8.4, df = 2, $p < 0.02$; girls chi-square = 15.2, df = 4; $p < 0.004$). Weekend night bedtimes showed a similar significant relationship in boys (chi-square = 9.7, df = 3, $p < 0.05$), though in girls the relationship was not significant (chi-square = 6.4, df = 4, $p < 0.10$). No relationships were found between pubertal stage and reason for going to bed on weekend or weekday nights; thus, parents were equally likely to set bedtime for each group (though consistently less so on weekends than weekdays). The start time of school also did not differ as a function of pubertal stage.

To provide further validation of the M/E scale used in this study, Spearman rank order correlations were performed among the bedtime and wake-up time data. As shown in Table 1, M/E scores were significantly correlated with weekday and weekend bedtimes for girls and boys. Though not highly correlated with weekday wake-up time, a significant correlation was found between M/E and weekend wake-up time.

M/E scores were evaluated separately for girls and boys by analysis of variance with pubertal stage, school type and birth order as independent variables. As illustrated in Fig. 2, pubertal status showed a significant main effect on M/E in girls [$F(2,263) = 3.119$, $p < 0.05$], and a similar though nonsignificant trend was found in boys [$F(1,175) = 3.461$, $p < 0.10$]. The two psychosocial factors—school type and birth order—were not significantly related to M/E, nor were there any significant interactions.

DISCUSSION

Although the results of this study are based upon self-reported data, the scales used to measure phase preference and pubertal status have shown quite good psychometric properties (7,8), and these results provide pilot data that favor our hypothesis regarding the influence of puberty on the adolescent phase delay. In this age group, the psychosocial factors were less influential. Thus, if the phase preference delay were influenced by peer-group factors, we expected that children in the Secondary School Group would demonstrate a later phase preference than those in the Primary School Group, predicting that the proximity of older peers would influence preferred timing toward later hours. For example, children with older friends might be influenced or socialized through late-night telephone calls or tastes in late-night television shows. If family influences were involved in the phase preference delay, then 6th graders with older siblings were expected to have a later phase preference than those with no older siblings, since later bedtimes in older children might accelerate a phase delay in younger siblings. On the other hand, if physical maturation were a principal factor related to the adolescent late phase preference, then we expected those children with higher puberty scores to have a preferred later phase than those with lower puberty scores. Our results indicate that pubertal maturation at this transitional phase (age 11/12 years) has a significant influence upon phase preference and that psychosocial factors are less influential than anticipated. This pattern was significant only in girls, perhaps because a higher percentage of our female sample had achieved a more advanced stage of maturation than the boys.

The absence of a significant influence of school type or birth order was surprising and may indicate that our groupings along this dimension were not sensitive or that these peer-group factors do not have a marked effect on sleep/wake cycles and circadian patterns until later in adolescence when youngsters achieve greater capacity to act on available opportunities. In the 6th graders evaluated here, parental influence on bedtime was unrelated to pubertal status. Thus, a "release" of parental control on this sleep behavior did not occur in relationship to puberty and thus did not seem to influence the initiation of a phase preference delay.

Our previous MSLT data from youngsters at various pubertal stages showed a midpubertal phase delay in the timing of daytime sleep tendency (4). In isolation, this finding was not thought to be of significance; however, in light of the present result, the pubertal delay of peak sleep tendency provides additional support for a biologically mediated phase delay linked to pubertal development. The source of such a biological process likely involves biological timing mechanisms. A link between the brain mechanisms controlling circadian rhythms and pubertal timing has been suggested principally due to the inverse relationship of melatonin and luteinizing hormone (LH) secretion across pubertal development (9). The potential links of melatonin to circadian as well as maturational processes make it a candidate to mediate a biological influence on a change in sleep phase position, which may influence phase preference.

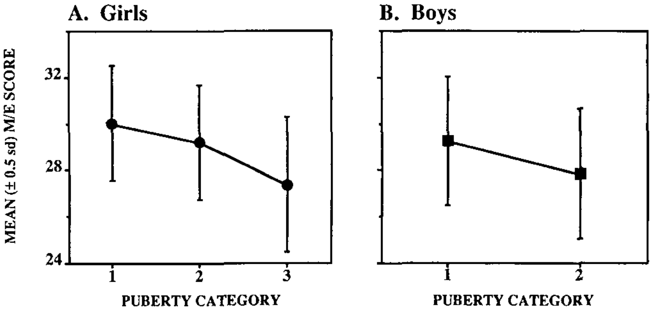

FIG. 2. Mean and standard deviation of morningness/eveningness (M/E) scores as a function of pubertal stage. For girls, puberty category 1 = no or few signs of pubertal changes (n = 26); puberty category 2 = pubertal changes evident (n = 165); puberty category 3 = pubertal changes quite marked (n = 84). For boys: puberty category 1 = no or few signs of pubertal changes (n = 102); puberty category 2 = pubertal changes evident, but not completed (n = 81).

Many important questions remain about mechanisms that may underlie the adolescent sleep preference delay. Do changes in gonadotropin secretion (associated with the secondary sexual and maturational characteristics used by our subjects in estimating their pubertal status) have a direct impact upon biological timing? Is the putative relationship between melatonin and puberty crucial or central to the change in phase preference? The physical changes of puberty may simply trigger a cascade of changes in the child's family milieu that include a transformation in the way parents control bedtime and secondarily encourage a delay in phase preference, although the present data indicating a lack of relationship between pubertal stage and parental bedtime setting do not favor this hypothesis.

If biological factors in early adolescence initiate a phase preference delay, then certain assumptions about teenagers' sleep patterns may need to be reexamined. For example, we have previously noted that insufficient sleep length may create a significant vulnerability in adolescents and that sleep extension may be a reasonable intervention (10). Behavioral approaches to intervene by altering the psychosocial milieu or the youngster's perception of it—perhaps, by encouraging "early to bed, early to rise"—may be difficult in the presence of a biologically driven delayed phase preference. Furthermore, the widespread practice in U.S. school districts for school buses to run and for the opening bell to ring earlier at high schools than junior high schools, and earlier in junior high schools than primary schools, may run precisely counter to children's biological needs. By the same token, teenagers faced with long school bus rides in addition to early starting time for school may confront incremental challenges in conflict with their biological propensities.

Teenagers' work schedules may need to be reevaluated as well. If an adolescent's phase preference is delayed, he or she may find it quite difficult to fall asleep sufficiently early to obtain adequate sleep before an early morning work shift. Factors such as these may need to be taken into account to provide acceptable lifestyle options for teenagers, options that will limit their exposure to situations that produce insufficient sleep and may interfere with achieving their maximum potential.

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