The Transition of Sleep-Wake Patterns in Early Adolescence

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Study Objective: To examine the relationship between school grade level and sleep-phase preference in early adolescence.

Design: A school-based cross-sectional study using a Sleep Habit Questionnaire.

Setting: NA

Participants: One thousand five hundred and seventy-two students, grade 4 to grade 8, from 3 junior high schools and 3 elementary schools in Taipei were recruited using multistage sampling method. The response rates were 98.4% (1547) for participants and 95.9% (1509) for their parents.

Interventions: NA

Measurements and Results: Each student participant completed a Sleep Habit Questionnaire, including sleep schedules, the Morningness/Eveningness (M/E) scale, the Pubertal Developmental Scale, and the Sleepiness Scale. The morning (N = 367) and evening (N = 364) groups were operationally defined as participants with the top 25% and the bottom 25% of the M/E score, respectively. A mixed model was used in data analysis to address the cluster effects arising from the school-based study. We found that the M/E score decreased and the proportion of the evening type increased across grade 4 to grade 8. The evening type was associated with decreased nocturnal sleep and later bedtimes and rise times, as well as with increased daytime sleepiness and compensation for sleep on weekends.

Conclusions: Our findings support the hypothesis that school grade level is significantly associated with the transition to evening type in early adolescence. We report that environmental factors may play a more important role than biologic factors, such as age, sex, and pubertal development, in the transition from morning type to evening type at early adolescence. Future longitudinal study is necessary to determine the trajectories of sleep-wake patterns in adolescents and their predictors.

Key Words: sleep-wake patterns; Morning/Eveningness scale; evening type; school grade level; adolescence

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INTRODUCTION

STUDIES HAVE SHOWN THAT ADOLESCENTS ARE MORE LIKELY THAN YOUNG CHILDREN TO HAVE DECREASED NOCTURNAL SLEEP TIME, increased daytime sleepiness, later bedtime and rise time, and longer sleep duration on weekends than weekdays.[1-5] Studies also indicate that increased academic and social demands and chronic sleep shortage might increase the likelihood of daytime sleepiness in adolescents.[6-14] Different diurnal types have been recognized in terms of the differences in their sleep-wake patterns,[15-17] personality characteristics,[18-20] preferences of activities,[4] and biologic rhythms such as temperature[21-27] and melatonin secretion.[17,22,28-33] The morning type tends to sleep and wake up earlier and is better able to function in the morning, while the evening type tends to sleep and wake up later and prefers to arrange his or her activity in the afternoon. Various self-reported questionnaires have been developed to measure the sleep-phase preference.[34-36] Smith and colleagues[34] developed the adult Morningness/Eveningness (M/E) scale by integrating and modifying the two scales developed by Horne and Ostberg,[35] and Torsvall and Akerstedt.[36] This M/E scale, which reflects the time of a day at which an individual reports his or her peak function, has been used to measure circadian types and has been validated by body temperature.[24,26] Carskadon and colleagues further modified this M/E scale to suit children.[15,16,37]

Adolescent sleep-wake patterns have been found to be affected by pubertal development,[3,12,13,16,38-40] decreased parental monitoring of bedtime,[5] increased demand of school schedules,[2,6,38,41,42] increased exposure to extracurricular activities[43,44] and part-time jobs,[38,45] and changes in circadian rhythm.[42,46-50] Recent studies indicate that the later bedtime in teenagers may be due to decreased parental control[2,5,38] and increased schoolwork[2,14,51,52] and other social pressures.[2,14,51,52]

Using the M/E scale on the basis of the Horne's and Östberg's questionnaire to measure the sleep-wake patterns, Park et al[4] and Shinkoda et al [53] reported that the mean M/E score decreased with grade level. This decrease was significant around the seventh grade, indicating that a delay of sleep phase and transition to evening type occurred at around the seventh grade. Besides grade level, pubertal development has also been reported to be associated with sleep phase delay. [3,12,13,16,38-40] In addition, some studies have reported that M/E scores were not associated with several psychosocial factors but with adolescents' pubertal status, suggesting that pubertal development is a stronger predictor of the M/E score than are some psychosocial factors.[16]

The limitation of previous school-based studies is their lack of taking into account the cluster effects from school or class, failing to control the potential intracluster correlation. Without controlling for these effects in the statistical model, the association between sleep-wake pattern and pubertal development or school grade level is not convincing. In contrast to pubertal status, school grade level may explain most of the variation of sleep-wake patterns. Since the correlates of sleep-phase preference may consist of both biologic and psychosocial factors, school grade level may be a better representative of both factors than is either pubertal development or age because higher grade levels are correlated with increased psychosocial demands and pressure, such as schoolwork responsibility, extracurricular activities, social expectations, peer influences, and part-time jobs.

With the traditional expectation of higher education from parents and the tremendous academic competition in Taiwan's adolescents due to a limited number of students being able to go to high school after passing a Joint Entrance Exam (JEE) for Senior High School, the effect of school grade level on sleep-wake patterns may expand compared to age and pubertal status. Accordingly, the primary objective of this study is to

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identify the effect of grade level on the sleep-wake pattern after controlling for age, sex, and pubertal development, as well as the influence of the sleep-wake pattern on the daytime function and sleep schedule. Moreover, distinguishing the school grade effect from pubertal status on the M/E score in Taiwanese child population is another goal of this study. We hypothesize that the variable school grade will be a better predictor of the M/E scores than is pubertal status because school grade encompasses both maturational and psychosocial factors. We also expect that evening-type participants are more likely than morning-type participants to have shorter sleep times and greater weekend compensation of sleep shortage on school days. Moreover, the evening type is assumed to be associated with daytime sleepiness.

SUBJECTS AND METHODS

Study Design

The study design was a school-based cross-sectional survey using a Sleep Habit Questionnaire (SHQ), which included the Chinese version of the Pubertal Development Scale (PDS)[54] and the Chinese version of the M/E scale.[55] We used a multistage sampling method to select grade-4 to grade-8 student participants from 204 primary and junior high schools in Taipei.

Sample Characteristics

Compulsory education in Taiwan is composed of 6 years in a primary school (grade 1 to grade 6) and 3 years in a junior high school (grade 7 to grade 9). Students are required to take a JEE to determine their eligibility for senior high schools.[2] Because students in grade 9 face tremendous pressure from taking the JEE, they were excluded from this study. The 12 districts of Taipei include 204 primary and junior high schools. In September 1995, we sent letters to the principals of Taipei primary and junior high schools to obtain their consent. We randomly selected 3 of these 12 districts and then again randomly selected 1 junior high school and 1 primary school within each of the 3 districts. Finally, 3 classes from each grade level (grade 4 to grade 8) were then randomly selected. All of the students in the selected classes (clusters) were examined. As a result, the sample included 45 classes with 1572 total participants.

In May 1996, 2 to 3 weeks after the second monthly examination, each student completed the SHQ at a designated school hour. Meanwhile, the teachers independently responded to 5 questions regarding their students' appearance and school behavior, such as interpersonal interaction, physical maturity, school performance, activity level, and daytime alertness. The parents completed their version of the SHQ at home. Of the original sample, 1547 students and their teachers, as well as 1509 parents, consented to participate in the study and completed the questionnaires. The response rates for students, teachers, and parents were 98.4%, 98.4%, and 95.9%, respectively. Consequently, the reports from 1547 students aged 10 to 14 years, 811 boys (52.4%) and 736 girls (47.6%), their parents, and their teachers were used for data analyses.

Instruments

SHQ - A self-administered SHQ was designed to survey sleep habits and sleep problems in primary-school and junior-high-school students. Part of the SHQ was modified using items similar to those in questionnaires designed by Carskadon et al, with their permission.[16] The SHQ was given to 54 fourth-year primary-school students, their parents, and their teachers as a pretest. The final SHQ student version included questions about demographic data, self-reported bedtime and rise time on school days and weekends, the M/E Scale, and the PDS. The parents' version included items regarding demographics and the PDS of their children.

Prior to the formal school-based survey, 109 sixth-year students from 3 classes and 190 seventh-year students from 5 classes, as well as their parents and teachers, were administered SHQ to test for reliability. Among these 299 dyads, 68 were randomly selected to complete the student and parental versions of the SHQ twice, with a 4-week interval, to examine the test-retest reliability of both SHQ versions.

Chinese Version of the Children's M/E Scale - The Chinese version of the children's M/E scale[55] was translated and modified from Carskadon et al's M/E Scale—child version.[15, 16] The M/E scale consisted of 10 questions regarding morningness, such as voluntary rise time, voluntary bedtime, easiness of getting up, alertness in the first half hour after getting up, performance of exercise at 7:00 AM, need for a physical alarm to awaken, time choice for a 2-hour exam, feelings about getting up at 6:00 AM, time for doing favorite work, and duration for returning to daytime baseline after waking up. These items were either a 4-level score or 5-level score. (Carskadon et al's paper includes details of the children's M/E scale.[16]) The results of reliability and validity studies of the M/E scale have been reported.[55] The values of the intraclass correlation (ICC) for each item ranged from 0.44 to 0.80. The ICC for the sum score of this scale was 0.75, indicating good test-retest reliability (sum scores ranged from 10 to 43). The Cronbach's alpha was 0.68, suggesting a fair to good internal consistency for this scale. The discriminative validity of each item was performed by comparing the mean scores of each item between the two quartiles with the lowest and the highest sum scores. The student t value for this comparison was called the critical ratio. The critical ratios ranged from 5.15 to 12.26, with the significance level less than 0.001. The M/E Scale was validated discriminatively comparing the two extreme quartiles using daytime function, bedtime, rise time, and sleep patterns as response variables. We found statistically significant differences between the two quartile groups in terms of sleep variables, suggesting a good discriminative validity of this scale.

Chinese Version of the Pubertal Development Scale - The PDS[37] consists of body hair, skin change, and growth spurt for both girls and boys, as well as facial hair and voice change for boys and breast growth and menarche for girls. The reliability study for PDS has been published.[54] In summary, for the test-retest reliability, we found that the Spearman correlations and the ICCs ranged from 0.49 to 0.92 and from 0.56 to 0.97, respectively, for girls, and from 0.56 to 0.95 and from 0.48 to 0.88, respectively, for boys. The 5 Tanner stages of pubertal development were based on the level of development reported on the 3 indices of pubertal change thought to be most salient for each sex. These were, for girls, pubic hair growth, breast development, and menarche, and, for boys, the development of pubic hair, facial hair, and voice change. The Spearman correlation and ICC were 0.95 and 0.94, respectively, for pubertal stage, suggesting good test-retest reliability of self-reported pubertal development. The Cronbach's alpha of this scale was 0.78 for boys and 0.79 for girls, indicating good internal consistency. Parent-child agreement on reports on the child's pubertal development were estimated using the Spearman correlation, ranging from 0.39 to 0.63 for boys and from 0.45 to 0.64 for girls and, using the ICC, ranging from 0.48 to 0.62 for boys and from 0.35 to 0.67 for girls. In addition, this scale demonstrated a greater parent-daughter agreement (ICC = 0.79) than parent-son agreement (ICC = 0.62) on the reports of the child's pubertal status. The PDS was validated by a pediatric endocrinologist who evaluated 22 males aged 11 to 19 and 22 females aged 9 to 16. The agreement between self-reports by the clinical participants and the clinician's assessment was high (Spearman correlation = 0.80 for males and 0.86 for females).

Sleepiness Scale - Daytime sleepiness was included in the Sleepiness Scale by testing for inadvertent napping in 7 situations and lateness for school due to oversleeping. These 7 situations were composed of reading, walking, watching television, doing homework, taking a test, eating a meal, and being on a bus or in a car. Each item was a binary variable. The kappa values and ICC for the test-retest reliability within the 68 participants ranged from 0.27 to 0.51 and from 0.57 to 0.73, respectively. The Pearson correlation and ICC of sum score of this scale, ranging from 0 to 8, were 0.62 and 0.53, respectively, indicating moderate to good test-retest reliability. The Cronbach's alpha for the internal consistency of these original 8 items was 0.58 and, after removing the 2 variables with low item-total correlation (inadvertent napping in a car and lateness for school due to oversleeping), the Cronbach's alpha for the remaining 6 items reached 0.64. The Sleepiness Scale with 6 items was used in the present study.

Data Analysis

The data were analyzed statistically using SAS 8.1 and MIXOR.[56] Cronbach's alpha was calculated for the internal consistency of the scales. Pearson correlation for continuous variables and Spearman correlation for ordinal variables were computed to address parent-child agreement and test-retest reliability. A mixed model with a random effect addressing the repeated measures within the same subjects was used to calculate the ICC for parent-child agreement and test-retest reliability. The ICC was computed using SAS 8.1 PROC MIXED[57] for continuous variables and MIXOR,[56] a computer program for mixed effects analysis, for binary and ordinal variables.

There was strong agreement between adolescent and parent reports on PDS, and the M/E Scale had satisfactory reliability and validity. Therefore, we used only adolescent reports for final data analysis. Because this current study is a school-based study using multistage sampling method, a mixed model with random effects was used to address the lack of independence in the same clusters (school, class). Bivariate analyses were performed before multivariate regression analyses using the mixed model. When we analyzed the effect of grade level on the M/E score, the dependent variable was the M/E score and the independent variables might include the main effect of grade level, as well as the potential confounding factors, including subject's age, sex, and pubertal development. The posthoc Sheffe method was used to compare the M/E scores among the 5 school grade levels.

The two extreme groups of morningness were created based on the quartile distribution of M/E score [range =16-43; mean (SD) = 29.40 (4.32)]—the top highest 25% of the M/E score (larger than 32) for the morning group and the bottom lowest 25% of the M/E score (less than 27) for the evening group. Analysis of variance was also performed using the mixed model for sleep schedule for the 2 extreme groups, while controlling for sex, pubertal development, and grade at school. In addition, in order to examine the effect of the two extreme groups on daytime inadvertent napping (never, sometimes, daily), we conducted a logistic regression model with polytomous response using generalized logits model, controlling all sleep schedules. The preselected alpha value was 0.05.

RESULTS

Demographic Data and Bivariate Analysis

The 1547 participants consisted of 811 (52.4%) males (M) and 738 (47.6%) females (F). Their grade distributions were 307 (M: 173; F: 134) at the fourth grade, 342 (M: 175; F: 167) at the fifth grade, 333 (M: 180; F: 153) at the sixth grade, 281 (M: 144; F: 137) at the seventh grade, and 284 (M: 139; F: 145) at the eighth grade. According to the quartile distribution of the M/E Score, 2 groups with extreme sleep-wake patterns were revealed. There were 367 and 364 participants in the morning and evening groups, respectively. There was no significant difference in gender distribution across the 5 school years. The subjects' ages ranged from 9 to 16 years, with mean age of 12.01 (SD = 1.46). The mean age for male participants (11.99, SD= 1.43) did not differ from that for female participants (12.03, SD = 1.49; $F_{(1, 1528)} = 0.37$, $p = 0.545$).

Before conducting multivariate analysis, we conducted bivariate analyses to explore the individual effect of each predictor using one-way analysis of variance and to determine the departure from linear trend for some potential ordinal variables such as grades at school and pubertal development using the goodness of fit test. The response variable was the M/E score. Table 1 presents the F statistics for bivariate analyses and the goodness of fit statistics for model comparisons. The results showed that the models that treated grade level as a categorical variable fitted the data better than did their counterparts. In comparison, models with pubertal development were fit equally well when pubertal development was treated as an ordinal variable as when it was treated as a categorical variable. We found that age and grade level displayed significant effect on the M/E score. In contrast, gender and pubertal development did not show significant effect on the M/E score. The bivariate correlations revealed that pubertal development was moderately correlated with age (r= 0.503) and school grade level (r = 0.537), yet age was highly correlated with school grade level (r = 0.877). Since there was obvious correlation among the three variables, the effect of age and pubertal status was controlled for when we estimated the effect of school grade level on the M/E score.

The Grade Effect on the M/E Score

To delineate the main effect of school grade level on the M/E score, we conducted a mixed model controlling for potential confounding factors such as age, sex, and pubertal development (Table 2). Based on the type 3 tests of fixed effects in the mixed model, we found that school grade level was the only independent variable that maintained significant effect on the M/E score ($F_{(4, 1385)} = 7.77$, $p < 0.001$), and the effects of age ($F_{(1, 1385)} = 1.98$, $p = 0.160$), sex ($F_{(1, 1385)} = 0.02$, $p = 0.879$) and pubertal status ($F_{(4, 1385)} = 0.08$, $p = 0.989$) were not significant. This result suggests that the effects of age and pubertal development were explained by school grade levels. Regarding the grade effect, we found that the fourth and fifth graders had significantly higher M/E scores than

Table 1—F statistics for Bivariate Analyses and Goodness of Fit for Model Comparison

Variables	F-statistics	Goodness of Fit
Sex	$F_{(1, 1473)} = 0.00$, p = 0.976	
Age	$F_{(1, 1393)} = 13.44$, p < 0.001	
Year at school	$F_{(4, 1471)} = 13.73$, p < 0.001	ÄG = 7.9, p = 0.048
Pubertal development	$F_{(1, 1409)} = 1.22$, p = 0.269	ÄG = 3.3, p = 0.069

ÄG (Goodness of Fit statistics) is equal to −2 logarithm of likelihood for model with the variable of interest treated as linear or ordinal variable minus −2 logarithm of likelihood for model with the variable of interest treated as categorical variable. ÄG is distributed as χ^2 distribution with 1 degree of freedom.

Table 2—Mean Morningness/Eveningness Score by Gender and by Years at School

	Years at School Grade 4 Mean (SD)	Grade 5 Mean (SD)	Grade 6 Mean (SD)	Grade 7 Mean (SD)	Grade 8 Mean (SD)	Significance*
Boys	**N=166**	**N=174**	**N=177**	**N=139**	**N=135**	$F_{(4, 687)}$= 6.42, P<.001
	30.72	30.67	28.88	28.64	27.72	grade 4 vs. grade 8
	(4.74)	(4.44)	(4.64)	(4.06)	(4.04)	grade 5 vs. grade 7
						grade 5 vs. grade 8
Girls	**N=133**	**N=166**	**N=152**	**N=136**	**N=141**	$F_{(4, 666)}$= 6.63, P<.001
	30.52	30.69	29.06	28.33	28.10	grade 4 vs. grade 7
	(3.95)	(3.94)	(4.02)	(4.14)	(3.48)	grade 4 vs. grade 8
						grade 5 vs. grade 6
						grade 5 vs. grade 7
						grade 5 vs. grade 8
Total	**N=299**	**N=340**	**N=329**	**N=275**	**N=276**	$F_{(4, 1402)}$= 11.49, P<.001
	30.63	30.68	28.97	28.49	27.92	grade 4 vs. grade 6
	(4.40)	(4.19)	(4.36)	(4.09)	(3.77)	grade 4 vs. grade 7
						grade 4 vs. grade 8
						grade 5 vs. grade 6
						grade 5 vs. grade 7
						grade 5 vs. grade 8

*using mixed model with intercept random effect to address the cluster effect (school and class) using Sheffe method for multiple comparisons.

did any subgroups among the sixth, seventh, and eighth graders, indicating that the fourth and fifth graders are less likely to have an evening-oriented sleep-wake pattern (Table 2). After stratifying for sex, our results showed that among female participants there was no longer a significant difference in M/E score between the fourth and sixth graders. Among male subjects, the only comparisons with significant results were seventh versus fifth graders and eighth graders versus fourth and fifth graders.

Sleep Schedule for the Two Groups with the Extreme Sleep Phase

Table 3 presents the distribution of gender, pubertal stage, and school grade level by the morning and evening groups. The results show that the morning group was over-presented to be at the earlier pubertal development and at the lower school grade levels. There was no difference in gender distribution between these two groups.

Table 4 provides the information about the sleep schedules and patterns for the morning and the evening groups. The participants in the morning group tended to go to bed and get up earlier than those in the evening group throughout school days and weekends. Moreover, compared to the evening group, the morning group slept longer during the nighttime and had less discrepancy between required sleep time and total sleep time, a finding only noted during school days. The morning group but not the evening group slept longer than the required sleep time during weekends. Here, the required sleep time was reported by the participants on the basis of their subjective estimates of the duration of nighttime sleep that they needed to maintain their daytime functioning. All participants tended to go to bed and get up later, as well as sleep longer, on weekends. The differences between weekends and school days in terms of bedtime, rise time, and total nocturnal sleep were greater for the evening group than for the morning group.

Daytime Sleepiness of the Two Extreme Groups

In order to examine the effect of the two extreme M/E groups on the severity of daytime sleepiness, we conducted the logistic regression for polytomous responses using the frequency of inadvertent napping as response variables. Since the assumption of proportional odds was rejected ($\chi 2$ = 14.71, df = 3, p = 0.002), we performed the generalized logits model. Our results revealed that participants in the evening group were 2.85 times (95% confidence limits: 1.75, 4.66) more likely than the morning group to have daily inadvertent napping and were 1.48 times (95% confidence limits: 1.19, 1.86) more likely to sometimes nap inadvertently. In addition, the evening group had higher scores in sleepiness than did the morning group ($F_{(1, 660)}$= 6.48, P = 0.011). The effects of bedtime, rise time, nighttime sleep duration, sex, school grade levels, and pubertal development were controlled in the above two models.

DISCUSSION

Researchers on sleep behavior science have long examined the biologic and psychosocial factors related to sleep-wake patterns. Among these factors, pubertal development and school grade level have been attributed to be related to the transition of the sleep-wake patterns in adolescence. The findings of this study support our hypotheses that the M/E score decreased and the proportion of participants belonging to the evening group increased across grade 4 to grade 8. In addition, evening type was associated with decreased nocturnal sleep, delayed bedtime and rise time, increased daytime sleepiness, and increased sleep compensation during weekends.

Consistent with previous reports,[4,18,19,53,55] our results showed that compared to the morning group, the evening group tended to sleep less, go to bed and get up later, have more daytime sleepiness, and have greater differences between school days and weekends in terms of bedtime, rise time, and nocturnal sleep. This finding further validates the Chinese version of the children's M/E scale. Combining several lines of data[2 5,52,58,59] and the findings of this study, we found that delayed bedtime and decreased nocturnal sleep were responsible for daytime sleepiness, manifested by inadvertent napping in several settings such as classroom, study room, bus, and so on. The finding that there is no delay in getting up during school days among students with evening type is understandable because no matter what kind of sleep-wake patterns they have, without exception, these students should arrive at school on time in the morning. Therefore, the evening type may not have sufficient sleep during school days and, as a result, may suffer from greater weekend compensation of sleep. This partially explains our observation on the marked delay in getting up on weekends. Another explanation for this apparent delay in rise time is that without external restraints such as school attendance, the evening type may demonstrate her or his typical sleep-delay pattern on weekends.

Few studies have reported an association between sleep-wake pattern and school grade level[4,53]; however, lack of control for age and pubertal development in their models limited the persuasiveness of this association. Similar to the findings in Park et al[4] and Shinkoda et al,[53] our results showed that the M/E score decreased and the proportion of the evening type increased across grade 4 to grade 8. We improved upon this finding by controlling for cluster effect and the effects of the subject's sex, age, and pubertal development in the model. A primary finding was that grade level was a more important factor than was age or pubertal development in contributing to the transition of sleep-phase preference. Unlike previous studies,[4, 3] which found that the significant switching

Table 3—The Distribution of Gender, Pubertal Stage, and Years at School by the two Morningness Groups of Children

Variables	Morning group (N = 367) N (%)	Evening group (N = 364) N (%)	Chi-square Statistics
Gender			
Male	**195** (53.1)	**193** (53.0)	$\chi 2$ = 0.00, df = 1, p = 0.976
Female	**172** (46.9)	**171** (50.0)	
Pubertal stage			
Prepubertal	**112** (32.4)	**72** (20.8)	$\chi 2$ = 16.98, df = 4, p < 0.002
Early pubertal	**88** (25.4)	**84** (24.2)	
Midpubertal	**79** (22.8)	**89** (25.6)	
Late pubertal	**66** (19.1)	**99** (28.5)	
Postpubertal	**1** (0.3)	**3** (0.9)	
Years at school			
Grade 4	**103** (28.1)	**49** (13.5)	$\chi 2$ = 79.00, df = 4, p < 0.001
Grade 5	**116** (31.6)	**57** (15.7)	
Grade 6	**69** (18.8)	**90** (24.7)	
Grade 7	**48** (13.1)	**75** (20.6)	
Grade 8	**31** (8.5)	**93** (25.6)	

Table 4—Sleep Patterns by the Morningness and Eveningness Groups

Variables	Morning group (N = 367) Mean (SD)	Evening group (N = 364) Mean (SD)	Statistics*
School days			
Bed time[a]	10:01pm (54)	11:05pm (69)	$F_{(1, 673)}$= 119.2, P<.001
Rise time[a]	6:30am (29)	6:40am (26)	$F_{(1, 673)}$= 61.7, P<.001
Difference[b]	32 (90)	119 (165)	$F_{(1, 511)}$= 54.4, P<.001
Nocturnal sleep[c]	8 hr 29 min (65)	7 hr 35 min (75)	$F_{(1, 666)}$= 48.6, P<.001
Weekends			
Bed time[a]	11:01pm (73)	00:33pm (94)	$F_{(1, 671)}$= 176.8, P<.001
Rise time [a]	8:25am (80)	10:05am (95)	$F_{(1, 666)}$= 191.0, P<.001
Difference[b]	-17 (105)	1 (167)	$F_{(1, 534)}$= 4.7, P = <.05
Nocturnal sleep[c]	9 hr 24 min (94)	9 hr 32 min (107)	$F_{(1, 656)}$= 0.91, P = .340
Difference between weekends and school days (in minutes)			
Bed time	60 (76)	87 (102)	$F_{(1, 667)}$= 27.7, P<.001
Rise time	32 (90)	119 (165)	$F_{(1, 662)}$= 126.5, P<.001
Nocturnal sleep	54 (99)	118 (127)	$F_{(1, 649)}$= 24.7, P<.001

*: using mixed model for analysis of variance controlling for subjects' sex and years at school, and cluster effect from school and class.
a: means of bed time and rise time expressed by timetable and SD expressed in minutes
b: difference between required sleep time and daily total sleep time, mean and SD are expressed in minutes
c: means expressed in hours and minutes and SD expressed in minutes

point of transition to the evening type was around the seventh grade,[4,53] we found that the transition to the evening type was around grade 6. In Taiwan, because parents strongly emphasize high academic achievement and the competition to enter senior high school is very keen, most junior high school students (grade 7 to grade 9) and most sixth graders attend cram schools in the spring semester to study English and arithmetic; and they also have heavy homework loads and take tests every school day. Since this study was carried out in May 1996, the finding of the switch point being at the sixth grade is as expected when the assumption is made that the social or school effect is as important as biologic factors in determining the sleep-wake patterns. Accordingly, different cultural and school contexts might affect this minor difference in the switch points of the evening type, as the previous studies were based on the Japanese population whereas ours is based on the Taiwanese population.

Inconsistent with previous studies,[3,12,13, 16,38-40] we did not find that pubertal status was predictive of the M/E score. Although the Chinese version of the PDS has been proven to be an instrument with good reliability and validity,[54] Taiwanese students may not be very accurate at estimating their pubertal development because of conservative cultural characteristics, a possibility that cannot be completely excluded. Accordingly, the possible measurement errors derived from using the Chinese version of the PDS to measure pubertal status must be taken into account while any inference is made based on this finding. In contrast, some previous studies that show a significant effect of pubertal development on the sleep-wake patterns either did not consider grade levels as covariates or restricted their sample to one grade level, consequently limiting their ability to examine the grade effect on the M/E scale in their populations. Moreover, the findings in this study and the studies in Japanese adolescents[4,53] suggest that school influence may play a more important role on sleep-wake patterns in Eastern Asian countries than in Western countries due to different education systems and cultural contexts. Future studies that examine grade effect on the M/E score in other populations may improve our knowledge about the crosscultural influences on the sleep-wake patterns.

Limitations

This study has several limitations with respect to methodologic issues that should be considered when interpreting the findings. First, the fact that study participants were sampled only from Taipei makes it difficult to generalize these findings to the broader Taiwanese population. Second, since this is a school-based cross-sectional study covering 5 grades of students rather than a longitudinal study design with annual follow-up for 5 years, the findings of this study would not allow us to make any inferences either about a causal relationship or at the individual level. Therefore, only the existence of an association could be inferred. Lastly, information about subjects' sleep schedules and daytime sleepiness was collected based on participants' self-reports and validated by their parents but was not validated by a laboratory examination. It would not be feasible to measure sleep schedules at a sleep laboratory and to measure daytime sleepiness using the Multiple Sleep Latency Test[6,60,61] in this study due to the large sample size. Moreover, sleep schedules measured in a strange environment such as a sleep laboratory may not represent those measured at subjects' homes for children aged 10 to 14 years. Counteracting the limitations of using self-reports of sleep schedule and daytime sleepiness, the strengths of the self-report include its relative accuracy and ability to provide information on individual behaviors or habits.[62-65] Self-reporting also makes it feasible, easy, and inexpensive to conduct a study with a large sample size. In addition, although studies have shown that adult participants with chronic insomnia or poor sleep quality tend to overestimate their sleep latency and underestimate their sleep duration,[66,67] the nonclinical Taiwanese participants of this study come from a school setting and are, therefore, more likely to objectively and honestly provide personal and sensitive information. They may not accurately report sleep-schedule information and daytime sleepiness due to recall bias. Such recall bias should only result in nondifferential misclassification bias, reducing the study's power to detect true associations. Therefore, our findings are convincing.

Strengths

This study has several strengths. First, our findings support our hypothesis that grade at school, a proxy of social factor, is a stronger indicator than are age and pubertal development of sleep-phase preference, while taking the effects of age, sex, and pubertal development into consideration. Moreover, this study distinguishes the effect of school grade level from pubertal development to provide evidence of impact of different educational systems. Additionally, it is the first study to control for cluster effects from school and class. Another methodologic strength is that we used multistage random sampling to obtain a representative sample in Taipei, with very satisfactory response rates. Additional advantages of this study are that we employed the self-reported measures with good reliability and validity and that we collected information from multiple informants, including student participants and their parents and teachers.

Implication

The literature review of previous studies and our findings contribute to our understanding of sleep patterns in adolescents. Transition to the evening type, and its consequence of daytime sleepiness, as well as the role of school grade level on pubertal development, indicate that decreasing the amount of school work and social demands, which are highly correlated to school grade level, may help to offset daytime sleepiness and its complications.

Conclusion

The findings of this school-based cross-sectional study support the hypothesis that when the effects of the subjects' age, sex, and pubertal development are controlled, school grade level is significantly associated with the transition to evening type, especially noted around grade 6. Evening type is related to delayed bedtime and rise time, shortened nocturnal sleep, daytime sleepiness, and greater weekend compensation for sleep. Our findings suggest that environmental factors, such as academic and social demands, may play at least as important a role as biologic factors in the transition of sleep-wake patterns. Future population-based longitudinal study is necessary to investigate the trajectory of sleep-wake patterns and the predictors of this trajectory throughout adolescence.

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REFERENCES

1. Carskadon MA. Evaluation of excessive daytime sleepiness. Neurophysiol Clin 1993;23:91-100.
2. Gau SF, Soong WT. Sleep problems of junior high school students in Taipei. Sleep 1995;18:667-73.
3. Andrade MM, Benedito-Silva AA, Domenice S, Arnhold IJ, Menna-Barreto L. Sleep characteristics of adolescents: a longitudinal study. J Adoles Health 1993;14:401-6.
4. Park YM, Matsumoto K, Seo YJ, Shinkoda H. Sleep and chronotype for children in Japan. Percept Mot Skills 1999;88:1315-29.
5. Ferber R. Sleep schedule-dependent causes of insomnia and sleepiness in middle childhood and adolescence. Pediatrician 1990;17:13-20.
6. Carskadon MA, Wolfson AR, Acebo C, Tzischinsky O, Seifer R. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. Sleep 1998;21:871-81.
7. Carskadon MA, Dement WC. Nocturnal determinants of daytime sleepiness. Sleep 1982;5:S73-81.
8. Carskadon MA, Dement WC. Cumulative effects of sleep restriction on daytime sleepiness. Psychophysiology 1981;18:107-13.

9. Anders TF, Carskadon MA, Dement WC. Sleep and sleepiness in children and adolescents. Pediatr Clin North Am 1980;27:29-43.
10. Carskadon MA, Dement WC. Effects of total sleep loss on sleep tendency. Percept Mot Skills 1979;48:495-506.
11. Carskadon MA, Harvey K, Dement WC. Acute restriction of nocturnal sleep in children. Percept Mot Skills 1981;53:103-12.
12. Ishihara K, Miyake S. A longitudinal study of the development of daytime sleepiness in children. Psychiatry Clin Neurosci 1998;52:178-81.
13. Mercer PW, Merritt SL, Cowell JM. Differences in reported sleep need among adolescents. J Adolesc Health 1998;23:259-63.
14. Saarenpaa-Heikkila O, Laippala P, Koivikko M. Subjective daytime sleepiness in schoolchildren. Fam Pract 2000;17:129-33.
15. Carskadon MA, Acebo C. Relationship of a Morningness/Eveningness Scale to sleep patterns in preadolescents. Sleep Res 1992;21:367.
16. Carskadon MA, Vieira C, Acebo C. Association between puberty and delayed phase preference. Sleep 1993;16:258-62.
17. Duffy JF, Rimmer DW, Czeisler CA. Association of intrinsic circadian period with morningness-eveningness, usual wake time, and circadian phase. Behav Neurosci 2001;115:895-9.
18. Park YM, Matsumoto K, Seo YJ, Shinkoda H, Park KP. Scores on morningness-eveningness and sleep habits of Korean students, Japanese students, and Japanese workers. Percept Mot Skills 1997;85:143-54.
19. Ishihara K, Miyasita A, Inugami M, Fukuda K, Miyata Y. Differences in sleep-wake habits and EEG sleep variables between active morning and evening subjects. Sleep 1987;10:330-42.
20. Kerkhof GA. Inter-individual differences in the human circadian system: a review. Biol Psychol 1985;20:83-112.
21. Baehr EK, Revelle W, Eastman CI. Individual differences in the phase and amplitude of the human circadian temperature rhythm: with an emphasis on morningness-eveningness. J Sleep Res 2000;9:117-27.
22. Oren DA, Turner EH, Wehr TA. Abnormal circadian rhythms of plasma melatonin and body temperature in the delayed sleep phase syndrome. J Neurol, Neurosurg Psychiatry 1995;58:379.
23. Uchiyama M, Okawa M, Shibui K, et al. Altered phase relation between sleep timing and core body temperature rhythm in delayed sleep phase syndrome and non-24-hour sleep-wake syndrome in humans. Neurosci Lett 2000;294:101-4.
24. Fukuda K, Ishhara K, Takeuchi T, Yamamoto Y, Inugami M. Core temperature pattern and self-rated lifestyle. Psychiatry Clin Neurosci 1998;52:243-5.
25. Ozaki S, Uchiyama M, Shirakawa S, Okawa M. Prolonged interval from body temperature nadir to sleep offset in patients with delayed sleep phase syndrome. Sleep 1996;19:36-40.
26. Waterhouse J, Folkard S, Van Dongen H, et al. Temperature profiles, and the effect of sleep on them, in relation to morningness-eveningness in healthy female subjects. Chronobiol Int 2001;18:227-47.
27. Duffy JF, Dijk D-J, Hall EF, Czeisler CA. Relationship of endogenous circadian melatonin and temperature rhythms to self-reported preference for morning or evening activity in young and older people. J Investig Med 1999;47:141-50.
28. Shibui K, Uchiyama M, Okawa M. Melatonin rhythms in delayed sleep phase syndrome. J Biol Rhythms 1999;14:72-6.
29. Nagtegaal E, Peeters T, Swart W, Smits M, Kerkhof G, van der Meer G. Correlation between concentrations of melatonin in saliva and serum in patients with delayed sleep phase syndrome. Ther Drug Monit 1998;20:181-3.
30. Oldani A, Ferini-Strambi L, Zucconi M, Stankov B, Fraschini F, Smirne S. Melatonin and delayed sleep phase syndrome: ambulatory polygraphic evaluation. Neuroreport 1994;6:132-4.
31. Keret R, Ashkenazi IE, Wasserman M, Bauman B, Pertzelan A, Ticher A, et al. Two types of growth hormone rhythm in boys with constitutional short stature. J Pediatr Endocrinol Metab 1996;9:599-607.
32. Lack LC, Bailey M. Endogenous circadian rhythms of evening and morning types. Sleep Res 1994;23:501.
33. Liu X, Uchiyama M, Shibui K, et al. Diurnal preference, sleep habits, circadian sleep propensity and melatonin rhythm in healthy human subjects. Neurosci Lett 2000;280:199-202.
34. Smith CS, Reilly C, Midkiff K. Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. J Appl Psychol 1989;74:728-38.
35. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chronobiol 1976;4:97-110.
36. Torsvall L, Akerstedt T. A diurnal type scale. Construction, consistency and validation in shift work. Scand J Work, Environ Health 1980;6:283-90.
37. Carskadon MA, Acebo C. A self-administered rating scale for pubertal development. J Adolesc Health 1993;14:190-5.
38. Carskadon MA. Patterns of sleep and sleepiness in adolescents. Pediatrician 1990;17:5-12.
39. Carskadon MA, Harvey K, Duke P, Anders TF, Litt IF, Dement WC. Pubertal changes in daytime sleepiness. Sleep 1980;2:453-60.
40. Laberge L, Petit D, Simard C, Vitaro F, Tremblay RE, Montplaisir J. Development of sleep patterns in early adolescence. J Sleep Res 2001;10:59-67.
41. Carskadon MA, Mancuso J. Sleep habits in high school adolescents: boarding versus day students. Sleep Res 1988;17:74.
42. Carskadon MA, Mancuso J. Daytime sleepiness in high school adolescents: influence of curfew. Sleep Res 1988;17:75.
43. Carskadon MA. Adolescent sleepiness: Increased risk in a high-risk population. Alcohol, Drugs Driving 1989;5:317-28.
44. Matsumoto K, Kaku R, Nakagawa K, Kaneko Z. Private school activities and psychosomatic problems in Japanese children. Child Psychiatry Hum Dev 1975;5:161-5.
45. Carskadon MA, Mancuso J, Rosekind MR. Impact of part-time employment on adolescent sleep patterns. Sleep Res 1989;17:74.
46. Acebo C, Sadeh A, Seifer R, et al. Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? Sleep 1999;22:95-103.
47. Dagan Y, Stein D, Steinbock M, Yovel I, Hallis D. Frequency of delayed sleep phase syndrome among hospitalized adolescent psychiatric patients. J Psychosomat Res 1998;45:15-20.
48. Okawa M, Uchiyama M, Ozaki S, Shibui K, Ichikawa H. Circadian rhythm sleep disorders in adolescents: clinical trials of combined treatments based on chronobiology. Psychiatry Clin Neurosci 1998;52:483-90.
49. Ohta T. Circadian rhythm sleep disorders: a brief review with special reference to long-term follow-up. Nagoya J Med Sci 1995;58:83-93.
50. Ohta T, Iwata T, Kayukawa Y, Okada T. Daily activity and persistent sleep-wake schedule disorders. Prog Neuropsychopharmacol Biol Psychiatry 1992;16:529-37.
51. Levy D, Gray-Donald K, Leech J, Zvagulis I, Pless IB. Sleep patterns and problems in adolescents. J Adolesc Health Care 1986;7:386-9.
52. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. Child Dev 1998;69:875-87.
53. Shinkoda H, Matsumoto K, Park YM, Nagashima H. Sleep-wake habits of schoolchildren according to grade. Psychiatry Clin Neurosci 2000;54:287-9.
54. Gau SF, Soong WT, Tsai WY, Chiu YN. A Chinese version of a self-administered rating scale for pubertal development. Taiwanese J Psychiatry 1997;11:129-40.
55. Gau SF, Soong WT, Lee WY, Chiu YN. Reliability and validity of the Chinese version of the Morningness/Eveningness Scale. Taiwanese J Psychiatry 1998;12:98-109.
56. Hedeker D, Gibbons RD. MIXOR: a computer program for mixed-effects ordinal regression analysis. Comput Methods Programs Biomed 1996;49:157-76.
57. Singer JD. Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. J Educ Behav Stat 1998;23:323-55.
58. Manber R, Bootzin RR, Acebo C, Carskadon MA. The effects of regularizing sleep-wake schedules on daytime sleepiness. Sleep 1996;19:432-41.
59. Thorpy MJ, Korman E, Spielman AJ, Glovinsky PB. Delayed sleep phase syndrome in adolescents. J Adolesc Health Care1988;9:22-7.
60. Carskadon MA, Dement WC, Mitler MM, Roth T, Westbrook PR, Keenan S. Guidelines for the multiple sleep latency test (MSLT): a standard measure of sleepiness. Sleep 1986;9:519-24.
61. Carskadon MA, Dement WC. Multiple sleep latency tests during the constant routine. Sleep 1992;15:396-9.
62. Etter JF, Humair JP, Bergman MM, Perneger TV. Development and validation of the Attitudes Towards Smoking Scale (ATS-18). Addiction 2000;95:613-25.
63. Fournier L, Kovess V. A comparison of mail and telephone interview strategies for mental health surveys. Can J Psychiatry 1993;38:525-33.
64. O'Toole BI, Battistutta D, Long A, Crouch K. A comparison of costs and data quality of three health survey methods: mail, telephone and personal home interview. Am J Epidemiol 1986;124:317-28.
65. Siemiatycki J. A comparison of mail, telephone, and home interview strategies for household health surveys. Am J Pub Health 1979;69:238-45.
66. Carskadon MA, Dement WC, Mitler MM, Guilleminault C, Zarcone VP, Spiegel R. Self-reports versus sleep laboratory findings in 122 drug-free subjects with complaints of chronic insomnia. Am J Psychiatry 1976;133:1382-8.
67. Adam K, Tomeny M, Oswald I. Physiological and psychological differences between good and poor sleepers. J Psychiatr Res 1986;20:301-16.