Relationship Between Weekend Catch-up Sleep and Poor Performance on Attention Tasks in Korean Adolescents

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Objective: To investigate the relationship between insufficient sleep and poor attention in Korean adolescents, adjusting for potential confounding factors of depressed mood and habitual snoring.

Design: School-based cross-sectional study.

Setting: Eight high schools in 3 cities in the Republic of Korea.

Participants: A sample of 2638 urban high school students (42.2% male and 57.8% female; mean [SD] age, 17.3 [0.6] years [age range, 14-19 years]) completed questionnaires and computerized attention tasks during the school term.

Exposure: Weekend catch-up sleep.

Main Outcome Measures: Self-reported sleep schedules and habits, including sleep duration, bedtime, wake-up time, depressed mood, and habitual snoring. Also measured were numbers of omission and commission errors on computerized attention tasks.

Results: The mean (SD) sleep duration on weekdays was 5 hours 42 minutes (1 hour 0 minutes) per day and on weekends was 8 hours 24 minutes (1 hour 36 minutes) per day. The mean (SD) weekend catch-up sleep was 2 hours 42 minutes (1 hour 42 minutes) per day. After adjusting for age, sex, depressed mood (Beck Depression Inventory score, >10), habitual snoring, and weekday sleep duration, increased weekend catch-up sleep was significantly associated with more omission and commission errors on sustained attention tasks (P < .001 and P = .03, respectively) and on divided attention tasks (P = .01 and P = .04, respectively).

Conclusions: Increased weekend catch-up sleep as an indicator of insufficient weekday sleep is associated with poor performance on objective attention tasks. Assessment of catch-up sleep and sleep duration may be useful for physicians to evaluate sleep insufficiency and its adverse effects on attention in adolescents.

Arch Pediatr Adolesc Med. 2011;165(9):806-812

Sleep pattern changes during adolescence are common and include shorter sleep duration, delayed sleep phase, and greater discrepancy between weekday and weekend sleep.2,3 Insufficient sleep is common among teenagers, especially in Korea owing to competitive and academic workloads associated with university entrance examinations.2 Because sufficient sleep during adolescence is important for the development of psychosocial functioning, behavioral maturation, and cognition,2,3 inadequate sleep is a major health issue among Korean adolescents.

The relationship between short sleep duration and poor academic performance in adolescents has been widely examined.3,6-8 However, there has been little study of the association of insufficient sleep with inattention using objective measures in adolescents.

During adolescence, weekend catch-up sleep compensates for insufficient sleep on weekdays.2,9 Because individual sleep needs vary, weekend catch-up sleep can reflect the degree of sleep insufficiency better than sleep duration. To our knowledge, no research has been conducted on the relationship between weekend catch-up sleep and poor attention.

Confounding factors apart from sleep, including depressed mood, daytime sleepiness, and habitual snoring, adversely affect cognition in adolescents.10-12 Depressed mood is common among adolescents and is an important factor in impaired attention.12 Habitual snoring is associated with cognitive problems.11 Excessive daytime sleepiness can be a direct consequence of insufficient sleep and affects school performance and attention.13 However, little is known about whether insufficient sleep can impair attention independent of potential confounding factors.
Based on previous findings of the relationship between sleep and neuropsychological performance, we hypothesized that insufficient sleep would be associated with impaired attention in adolescents, after adjusting for potential confounding variables. To test this hypothesis, we examined the relationship between weekend catch-up sleep and performance on computerized attention tasks in a Korean adolescent population.

METHODS

PARTICIPANTS

Participants were high school students attending 8 schools in the 3 cities of Incheon, Anyang, and Gumi, all located in the Republic of Korea. During the school term, 2707 students aged 14 to 19 years (1167 males and 1540 females; mean [SD] age, 17.5 [0.9] years) completed questionnaires and computerized attention tasks. Data collection was between September 1 and November 30, 2009. Students completed questionnaires and attention tasks in their computer class during the morning hours. Sixty-nine students were excluded because of incomplete answers or substantial missing data. This study reports on data from the remaining 2638 participants (1112 males and 1526 females; mean [SD] age, 17.3 [0.6] years).

QUESTIONNAIRES

The study measures were from several sources. These included a questionnaire on sleep habits, the Korean version of the Epworth Sleepiness Scale (ESS),14 modified for adolescents, the Korean version of the Beck Depression Inventory (BDI),13,15 and the Korean Translation of Composite Scale.17,18

The modified version of the ESS consisted of 7 items designed to measure subjective daytime sleepiness in various situations. The modification omitted the driving situation item because the minimum legal age for obtaining a driving license in the Republic of Korea is 20 years.

The 21-stem BDI was administered to measure symptoms of depression. As in a previous study,16 participants with a score of 10 or higher were defined as having depressed mood. The BDI has been standardized and was shown to have adequate reliability (Cronbach \( \alpha = .84 \)).16

The Korean Translation of Composite Scale consisted of 13 items, was used to measure morningness-eveningness, and has been validated.17,18 Evening, intermediate, and morning types were defined by scores of 26 or less, 27 to 40, and 41 or higher, respectively.

The questionnaire on sleep habits included the following items: (1) On average, how many hours do you sleep on weekdays? (2) On average, what time do you go to bed on weekdays? (3) On average, what time do you get out of bed in the morning on weekdays? The same questions were repeated for weekends. Participants were informed that sleep duration could differ from time in bed. Self-reported sleep duration for question 1 was used for the analysis. Questions about the presence and frequency of snoring were also included. Habitual snoring was defined as snoring on more than 3 nights per week.19

Variables of weekend catch-up sleep, bedtime delay, and wake-up time delay were calculated. Individual weekend catch-up sleep was calculated as weekend sleep duration minus weekday sleep duration. Bedtime delay was calculated from bedtimes on weekdays and weekends based on self-report. Wake-up time delay was calculated in the same way. Time in bed was calculated from bedtimes and wake-up times.

COMPUTERIZED ATTENTION TASKS

Sustained attention and divided attention were tested using the computerized Comprehensive Attention Test,20 which was developed by the Korean Academy of Child and Adolescent Psychiatry. It is a modified visual and auditory continuous performance test for Korean children and adolescents. The test-retest reliability and validity of the Comprehensive Attention Test were found to be acceptable by Yoo et al.20 In that study, the mean of the correlation coefficient for the test-retest scores was 0.715. Results from the factor analyses explained 91.7% of the cumulative variance.

The sustained attention task assesses the ability to maintain a consistent behavioral response during a continuous and repetitive activity. Visual stimuli in various shapes are presented every 2 seconds for 10 minutes. Participants are instructed to respond to all shape stimuli except the X shape. Therefore, the task measures the capacity of participants to inhibit responses to certain stimuli under conditions of sustained attention.

The divided attention task demands more attention than the sustained attention task. Divided attention involves the ability to respond simultaneously to multiple tasks or multiple task demands. Auditory and visual stimuli are presented simultaneously every 2 seconds for 3 minutes 20 seconds, and participants are instructed to respond only when an auditory or visual stimulus is the same as that presented in the preceding pair of stimuli.

Two major dependent variables were numbers of omission and commission errors on each of the 2 attention tasks. Omission errors were measures of inattention and were defined as failures to respond to the target. Commission errors were measures of impulsivity and were defined as inappropriate responses to the nontarget.

Written informed consent was obtained from participants and their parents. The study protocol was approved by the institutional review board of Gachon University of Medicine and Science, Incheon, Republic of Korea.

STATISTICAL ANALYSIS

Data were analyzed using commercially available software (SPSS 15.0; SPSS Inc, Chicago, Illinois). For continuous variables, group data stratified by sex were subjected to independent t test for comparison. Analysis of variance was used for group data stratified by age. The \( \chi^2 \) test was used for between-group comparisons involving categorical data.

To examine the relationship between weekend catch-up sleep (or sleep variables) and performance on attention tasks, we conducted multiple linear regression analyses in which the dependent variables were the 2 error scores on each of the attention tasks. The independent variables were age, sex, depressed mood (BDI score, \( \geq 10 \)), habitual snoring (\( \geq 3 \) nights per week), ESS score, and sleep variables. \( P < .05 \) was considered statistically significant in all analyses.

RESULTS

CHARACTERISTICS BY SEX

Table 1 gives characteristics by sex for the final sample of 2638 participants. Included are demographic information, sleep duration on weekdays and weekends, time in bed, weekend catch-up sleep, frequency of habitual snoring, and scores on the ESS, BDI, and Korean Translation of Composite Scale.
Table 1. Demographic and Clinical Characteristics of 2638 Participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n=2638)</th>
<th>Boys (n=1112)</th>
<th>Girls (n=1526)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>17.3 (0.6)</td>
<td>17.3 (0.6)</td>
<td>17.3 (0.6)</td>
<td>.12</td>
</tr>
<tr>
<td>Weekday sleep time, mean (SD) per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration</td>
<td>5 h 42 min (1 h 0 min)</td>
<td>5 h 54 min (1 h 0 min)</td>
<td>5 h 36 min (1 h 0 min)</td>
<td>&lt;.001, t=7.151</td>
</tr>
<tr>
<td>Bedtime</td>
<td>12:40 AM (0 h 49 min)</td>
<td>12:43 AM (0 h 48 min)</td>
<td>12:38 AM (0 h 50 min)</td>
<td>.02</td>
</tr>
<tr>
<td>Wake-up time</td>
<td>6:35 AM (0 h 31 min)</td>
<td>6:46 AM (0 h 29 min)</td>
<td>6:28 AM (0 h 29 min)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time in bed</td>
<td>5 h 56 min (0 h 55 min)</td>
<td>6 h 3 min (0 h 53 min)</td>
<td>5 h 50 min (0 h 55 min)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weekend sleep time, mean (SD) per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration</td>
<td>8 h 24 min (1 h 36 min)</td>
<td>8 h 18 min (1 h 36 min)</td>
<td>8 h 36 min (1 h 42 min)</td>
<td>&lt;.001, t=-4.714</td>
</tr>
<tr>
<td>Bedtime</td>
<td>1:17 AM (1 h 14 min)</td>
<td>1:23 AM (1 h 16 min)</td>
<td>1:13 AM (1 h 11 min)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Wake-up time</td>
<td>9:36 AM (1 h 38 min)</td>
<td>9:31 AM (1 h 33 min)</td>
<td>9:40 AM (1 h 41 min)</td>
<td>.03</td>
</tr>
<tr>
<td>Time in bed</td>
<td>8 h 25 min (1 h 19 min)</td>
<td>8 h 22 min (0 h 53 min)</td>
<td>8 h 37 min (1 h 50 min)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weekend minus weekday difference, mean (SD) per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekend catch-up sleep</td>
<td>2 h 42 min (1 h 42 min)</td>
<td>2 h 24 min (1 h 36 min)</td>
<td>3 h 0 min (1 h 42 min)</td>
<td>&lt;.001, t=-8.830</td>
</tr>
<tr>
<td>Bedtime delay</td>
<td>0 h 37 min (1 h 4 min)</td>
<td>0 h 41 min (1 h 5 min)</td>
<td>0 h 35 min (1 h 2 min)</td>
<td>.02</td>
</tr>
<tr>
<td>Wake-up time delay</td>
<td>3 h 1 min (1 h 37 min)</td>
<td>2 h 46 min (1 h 31 min)</td>
<td>3 h 11 min (1 h 40 min)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Score, mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epworth Sleepiness Scale</td>
<td>7.2 (2.8)</td>
<td>7.0 (2.8)</td>
<td>7.3 (2.9)</td>
<td>.02</td>
</tr>
<tr>
<td>Beck Depression Inventory</td>
<td>9.6 (6.0)</td>
<td>9.4 (5.7)</td>
<td>9.8 (6.2)</td>
<td>.10</td>
</tr>
<tr>
<td>Korean Translation of Composite Scale</td>
<td>32.2 (5.7)</td>
<td>32.2 (5.5)</td>
<td>32.2 (5.8)</td>
<td>.82</td>
</tr>
<tr>
<td>Habitual snoring, No. (%)</td>
<td>128 (4.9)</td>
<td>80 (7.2)</td>
<td>48 (3.1)</td>
<td>&lt;.001a</td>
</tr>
<tr>
<td>Sustained attention task, mean (SD), No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omission error</td>
<td>4.5 (10.9)</td>
<td>4.5 (10.5)</td>
<td>4.6 (11.1)</td>
<td>.86</td>
</tr>
<tr>
<td>Commission error</td>
<td>7.6 (6.0)</td>
<td>6.3 (5.7)</td>
<td>8.7 (6.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Divided attention task, mean (SD), No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omission error</td>
<td>7.9 (9.4)</td>
<td>8.3 (9.6)</td>
<td>7.7 (9.2)</td>
<td>.10</td>
</tr>
<tr>
<td>Commission error</td>
<td>8.0 (7.4)</td>
<td>7.3 (7.6)</td>
<td>8.4 (7.2)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

aIndependent t test. All other comparisons are by χ² test.

CHARACTERISTICS BY AGE

Table 2 gives characteristics of participants by age. Sleep durations on weekdays (F=31.416, P < .001) and weekends (F=4.003, P=.02) were significantly different among the 3 age groups. Those aged 18 years had the shortest sleep durations on weekdays and on weekends. However, weekend catch-up sleep did not differ significantly among the 3 age groups (F=1.853, P=.16).

PERFORMANCE ON THE COMPUTERIZED ATTENTION TASKS

On sustained attention tasks, the mean (SD) number of omission errors was 4.5 (10.9), and the mean (SD) number of commission errors was 7.6 (6.0). Girls had more commission errors than boys on sustained attention tasks (t = -10.343, P < .001).

On divided attention tasks, the mean (SD) number of omission errors was 7.9 (9.4), and the mean (SD) number of commission errors was 8.0 (7.4). Although boys had more omission errors than girls on divided attention tasks, the difference was not statistically significant (t = 1.641, P = .10). However, girls had significantly more commission errors than boys (t = -3.793, P < .001).

When participants were grouped by age, there were significant differences in the number of commission errors on sustained (F=3.166, P = .04) and divided (F=3.472, P = .03) attention tasks. Those aged 18 years had the fewest commission errors on sustained and divided attention tasks.

RELATIONSHIPS AMONG WEEKDAY SLEEP DURATION, WEEKEND CATCH-UP SLEEP, AND ATTENTION

After controlling for age, sex, depressive mood, and habitual snoring, weekday sleep duration did not predict the number of omission (β = −.26, P = .23) and commission (β = −.13, P = .26) errors on sustained attention tasks. There was no significant association between weekday sleep duration and both omission (β = −.11, P = .55) and commission (β = −.22, P = .14) errors on divided attention tasks.

Increased weekend sleep duration was significantly associated with more omission errors on sustained (β = .40, P = .02) and divided (β = .26, P = .02) attention tasks. There was no significant relationship between weekend sleep duration and commission errors on sustained (β = .13, P = .07) and divided (β = .13, P = .14) attention tasks.

Bedtime delay was not associated with the number of omission (β = −.15, P = .47) and commission (β = .05, P = .65) errors on sustained attention tasks. Bedtime delay did not predict the number of omission (β = −.16, P = .35) and commission (β = −.04, P = .78) errors on divided attention tasks.

Increased wake-up time delay was associated with more commission errors on sustained attention tasks (β = .16, P = .03). There was no significant relationship between wake-up time delay and omission errors on sustained attention tasks (β = .23, P = .09). There was no significant relationship between wake-up time delay and the num-

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ber of omission (β = .16, P = .18) and commission (β = .13, P = .15) errors on divided attention tasks.

There were no significant associations of ESS scores with sustained or divided attention tasks. Detailed results are given in Table 3.

In the regression model (Table 4) with adjustment for weekday sleep duration in addition to age, sex, depressive mood, and habitual snoring, increased weekend catch-up sleep was a significant predictor of more omission (β = .48, P < .001) and commission (β = .16, P = .03) errors on sustained attention tasks. Increased weekend catch-up sleep also predicted more omission (β = .29, P = .01) and commission (β = .18, P = .04) errors on divided attention tasks.

To our knowledge, this is the first study on the relationship between weekend catch-up sleep and objective measures of attention in the adolescent population. Moreover, we adjusted for potential confounding factors. We found that poor performance on attention tasks in adolescents was associated with increased weekend...
catch-up sleep but not with weekday sleep duration. Our findings are supported by a previous review article reporting that sleep deprivation leads to increased numbers of omission and commission errors in vigilance attention. Our results are in part consistent with previous research showing no relationship between sleep duration and executive function; however, another study reported the opposite results.

Weekend catch-up sleep compensating for insufficient sleep has been consistently reported in adolescents. Herein, we found substantial sleep insufficiency, with sleep duration on average only 5.7 hours per day, among Korean adolescents. Adolescent sleep durations in other countries are longer, reported as 8.4 hours for Spain, 7.23 hours for Hong Kong, 7.8 hours for India, 8.0 hours for Australia, and 8.04 hours for Germany. Moreover, sleep duration among Korean adolescents described herein was shorter than that among adolescents in a review of 30 other studies. This sleep insufficiency may reflect academic demands and competition among Korean adolescents. In Korea, academic pressure is highest for third-year high school students who are preparing for university entrance examinations. In line with this, the group aged 18 years (third-year high school students) had the shortest sleep durations on weekdays and on weekends. Delayed sleep phase in adolescents can also affect weekend catch-up sleep. In the present study, wake-up time delay exceeded bedtime delay by 2.5 hours, which may mean that weekend catch-up sleep can reflect overall sleep insufficiency on weekdays rather than circadian change.

Weekday sleep duration showed no association with attention in the present study. Previous studies have reported contrary results on the relationship between short sleep duration and poor academic performance or reduced cognitive function. The inconsistency may be explained by the fact that individual sleep needs vary and that sleep duration on school nights only may not accurately represent accumulated sleep insufficiency. In addition, enforced sleep-wake schedules on weekdays are dependent on external factors.

Because attention deficit is known to be multifactorial, the present study was designed to examine independent effects of sleep on attention by adjusting for potential confounding factors, such as depressed mood and habitual snoring. Concentration difficulty is a cardinal feature of major depressive disorder. Several meta-analyses reported that reduced attention is a neurocognitive feature of depression. Depressed adolescents performed below “normative standards” on the California Verbal Learning Test. In addition to a direct relationship between depression and attention, an indirect link mediated by sleep duration may be feasible considering associations of insomnia with attention and mood.

Snoring or sleep-related breathing disorders in children are related to attention deficit. Results of previous studies indicate that intermittent hypoxia and sleep disruption from respiratory events may have neurocognitive consequences.

Findings in prior studies suggest that sleepiness may mediate the relationship between insufficient sleep and poor cognition. However, a study showed no difference in academic performance between children with and without excessive daytime sleepiness. In line with that study, subjective sleepiness as measured by the ESS showed no association with attention in the present study. This suggests that sleep insufficiency in adolescents may adversely affect attention in a manner other than through the indirect pathway of sleepiness. This theory is supported by researchers who reported that sleep deprivation was related to changes in neural structure.

In this study, girls slept less than boys on weekdays and slept more than boys on weekends. In addition, girls reported greater sleepiness. Previous findings on sex differences have been inconsistent. Longer sleep among girls was reported for German adolescents but not among a Spanish sample. Variations may occur because of differences in hormone levels or social roles (eg, time spent grooming in the morning). Regarding daytime sleepiness, one study showed greater sleepiness among girls, while another study demonstrated no sex differences. These discrepancies may be caused in part by differences in the age of participants, methods of assessment, or national diversity in schooltimes and student workloads.

The 4.9% prevalence of habitual snoring found in the present study is in line with previous observations. Our finding that male participants were more likely to be snorers is also supported by prior results.
On the attention tasks, girls had significantly more commission errors than boys, a result that is inconsistent with findings by Conners et al. Because impulsivity seems to be positively associated with sleep disruption, a plausible explanation is that girls in our study made more commission errors because they sleep less. In addition, unequal sex proportions in our study population might have contributed to this discrepancy.

Our study has several limitations. First, self-report questionnaires were used to assess sleep habits, depressed mood, habitual snoring, and daytime sleepiness. Second, the study design was cross-sectional. In the future, a prospective study with interventions is needed to confirm the causal relationships between sleep and attention. Third, no information was obtained about external variables influencing weekend wake-up times (eg, scheduled activities). These may affect sleep-wake schedules on the weekend, especially catch-up sleep. Despite these limitations, advantages of the study are its large sample size, the use of objective computerized attention tasks, and adjustment for confounding factors.

In conclusion, increased weekend catch-up sleep among adolescents as an indicator of insufficient weekday sleep is associated with poor performance on objective attention tasks. Assessment of catch-up sleep and sleep duration may be useful for physicians to evaluate sleep insufficiency and its adverse effects on attention.

Accepted for Publication: March 2, 2011.

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Financial Disclosure: None reported.

Funding/Support: This study was supported by grant A090059 from the Korea Healthcare Technology Research and Development Project, Ministry for Health, Welfare and Family Affairs, Republic of Korea.

REFERENCES


Poetry in Pediatrics

My Sunflower Seed

Finding the right spot for planting, a sunflower seed.

Then waiting, hoping, and pondering as to its potential.

My sunflower seed.

At times forgetting it’s even there—but only briefly.

Providing water, nutrients, fresh air.

Dancing around its whereabouts, ensuring neither sole nor soul treads upon it—or at least not too heavily.

More waiting, going about other business.

Alas, it breaks through.

Like a new tooth, with surprise, joy, tenderness, minimal pain.

Growing up and up at a visible pace.

Now a seedling. Deer may chew upon its new green leaves. A hurricane may battle against the strength of its stalk.

And still up and up.

Weathering storms, bending, and almost breaking.

Not to be bullied, standing tall again, now with experience.

And the proud parent looks on.

Terry Kind, MD, MPH