The ABCs of ZZZs: The Impact of Sleep on Student Health and Performance

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Myths and Misconceptions

- Teens would go to sleep earlier if their parents just made them do it
- Some teens might need 9 hours of sleep, but mine does just fine with 6 (and so do I!)
- Take the cell phones (TV, laptops, tablets) away and kids will fall asleep
- If school starts later, they’ll just stay up later
  - And if school lets out later, they’ll have to cram in the same amount of stuff in even less time
- Teens can just make up lost sleep by sleeping late on weekends or going to school later one day/wk
- Kids need to learn to get up early; that’s real life
- They’ll survive
Both Sleep Time and Sleep Timing are “Biological Imperatives”

In addition to a “master clock” in the brain, each cell in the body possesses a “circadian oscillator”/“clock” which must be synchronized with one another and the environment.

“Misalignment” between internal circadian clocks and the external light-dark cycle results in profound impairments in physiologic function and health.

Frontiers in Neuroscience, 2013
“Two Process” Model of Sleep Regulation

Homeostatic Sleep Drive (accumulation of adenosine + other somnogens)

Alertness Level

Circadian Wake Drive (melatonin)

Now, imagine all of this shifting later by 2 hours…

“Forbidden Zone”

“Circadian Nadir”

Now, imagine all of this shifting later by 2 hours…
Adolescent Sleep: The “Perfect Storm”?

*Includes middle and high school students*
Sleep in Adolescents: Later Bedtimes

- All adolescents experience a normal shift in circadian rhythms with age and in association with the onset of puberty.
- This results in a biologically-based shift (delay) of up to several hours in both the natural fall sleep and morning wake times.
- On a practical level, due to the “forbidden zone” this means that it’s almost impossible for the average adolescent to fall asleep much before 11pm on a regular basis.
- Teens cannot “make” themselves fall asleep earlier.
Sleep in Adolescents: Later Bedtimes

- Environmental factors
  - Competing priorities for sleep: homework, activities, after-school employment, “screen time”, social networking
  - Circadian phase delay may be further exacerbated by evening light exposure
    - Suppresses brain release of melatonin
Adolescents: Later Wake Times

- These biological changes are in direct conflict with earlier high school start times (before 8:30am) because adolescents are biologically programmed to wake at 8am or later.
- As a result, students are required to wake for the day and function during the “circadian nadir” (the lowest level of alertness during the 24 hour day).
- Early wake times also selectively rob teens of REM (rapid eye movement) sleep, which is critical for learning (of new information in particular) and memory.
Adolescents: “Make-Up” Sleep

- Increasing discrepancy between bed and wake times weekday/end
  - Associated with learning deficits, behavior problems in school
- Adequate compensation for sleep loss?
  - Does not address compromised alertness on school days
  - Does not reverse performance impairments
“Weekend Oversleep”

- Leads to “circadian misalignment”
  - Exacerbation circadian phase delay
  - Shift melatonin onset
- Prevents sufficient build-up of sleep drive
  - Difficulty falling asleep Sunday night
- Result: permanent state of “social jet lag”
  - Adjustment takes 1 day/time zone crossed
  - Effects persist up to 3 days
  - Associated daytime sleepiness, poor academic performance, depressed mood
Adolescent Sleep: The Bottom Line

- For optimal health, safety and achievement the average middle and high school student needs: 8-10 hours of sleep*

- In Massachusetts:
  - At Algonquin Regional High School, 52% of students surveyed got < 6 hours of sleep/school night (2014)
  - 82% of Masconomet Regional students surveyed get ≤7 hrs of sleep (2016):
    - 41% ≤6hrs
    - 18.2% recommended 8-10 hrs

*2016 AASM recommendations based on 10 month review by 13 sleep experts of published scientific evidence addressing the relationship between sleep duration and health (total of 864 scientific articles)
Distribution of Sleep Durations among 12,050 High School Students: US, 2013

Data Source: CDC. National Youth Risk Behavior Survey (YRBS) 2013
Percent of High School Students who Report Sleeping $\geq 8$ hours/school nights, by Grade: United States, 2007-2013

Data Source: CDC. National Youth Risk Behavior Surveys (YRBS) 2007-2013
Effects on Performance, Health and Safety
Mortality Rates Among Adolescents Aged 15–19 Years, by Selected Leading Cause of Death 2010

- All Causes: 69.6
- Unintentional Injury: Male 28.3, Female 12.4
- Homicide: Male 14.0, Female 2.3
- Suicide: Male 11.7, Female 3.1
- Cancer: Male 3.2, Female 2.2
- Heart Disease: Male 2.1, Female 0.9

Rate Per 100,000 (Rank)

Sleep and Behavioral Self-Regulation

• Experimental sleep restriction has selective effects on the prefrontal cortex (PFC) and “executive functions”
  • Flexibility
  • Planning
  • Problem-solving
  • Decision-making
  • Divergent thinking
  • Cognitive set shifting
  • Judgment, motivation
  • Monitoring, modifying and inhibiting behavior
  • Modulation of emotions
• Rapid development in adolescence
Sleep and Emotional Regulation

- Sleep impacts response to positive and negative stimuli:
  - Increased response of the “emotional brain” (limbic system/striatum)
  - Weaker PFC connectivity
  - Heightened emotional response with less regulatory control
Sleep and Mood

- Adolescents who are sleep deprived are much more likely to report depression, and more likely to have suicidal thoughts
- Youth Risk Survey (2010-12)
  - 40% of teens getting less than 6 hours of sleep report depression symptoms (sadness, hopelessness)
Sleep and Risk Taking Behaviors

• Selective areas of the brain (striatum) are important for reward-related function
  • Positive emotions
  • Motivation
  • Response to reward

• These undergo structural/functional changes in adolescence

• Studies suggest insufficient sleep linked to changes in reward-related decision making
  • Perceive less negative consequences, take greater risks
Sleep and Risk-Taking Behaviors

- Sleep duration is a significant negative predictor for alcohol-related problems such as binge drinking, driving while drunk, and engaging in activates while drinking that one later regretted.
- Adolescents who obtain the least amount of sleep on school nights report the highest prevalence of alcohol use.
Sleep-Starved?

- Multiple studies suggest shorter sleep amounts associated increased risk of obesity
- Sleep duration and timing affect:
  - Hunger
  - Food intake: increased amount, more calories, more fat
  - Eating patterns (skipping breakfast, increased night eating)
  - Physical activity
  - Cardiovascular function
  - Insulin metabolism and increased diabetes risk
- Sleep apnea more common in obese children, further compromising cardiovascular and metabolic health
Sleep and Safety: Accidental Injuries

- Drowsy driving:
  - Drivers 16-25 years are involved in more than 50% of the 100,000 police-reported fatigue-related traffic crashes each year
  - National poll: 68% of HS seniors have driven while drowsy; 15% at least 1x/wk
  - Sleep loss impairments are equal or greater than those due to alcohol intoxication (ie, 3-4 beers)
- Sleep loss is associated with an increased risk of pedestrian injuries in children
- Sleep loss is associated with increased sports-related injuries in high school students
- Sleep loss is associated with almost 3x risk in adolescents of work-related injury requiring medical care
AAP Recommendation: Delay School Start Time until 8:30 am or Later

Let Them Sleep: AAP Recommends Delaying Start Times of Middle and High Schools to Combat Teen Sleep Deprivation

8/25/2014

For Release: August 25, 2014

Studies show that adolescents who don’t get enough sleep often suffer physical and mental health problems, an increased risk of automobile accidents and a decline in academic performance. But getting enough sleep each night can be hard for teens whose natural sleep cycles make it difficult for them to fall asleep before 11 p.m. – and who face a first-period class at 7:30 a.m. or earlier the next day.

Brief History of SSTC

- Minnesota pioneers
  - 1996: Edina MN changed high school start times from 7:20am to 8:30am
  - 1997: Minneapolis changed high school start times from 7:15am to 8:40am; N>18,000 students
- Since late 1990’s, ~1000 high schools in >100 districts in 43 states report school start time delays; almost no schools have returned to the original bell times
Brief History of School Start Times

• BUT less than 1 in 5 middle and high schools in the US (N=40,000) start at the recommended 8:30am or later*

• In MA, average SST in 2015 for public middle and high schools was 7:37am (from 7:53am 2011-12) and only 2 schools (1%) of start at 8:30am or later*

  • >80% start before 8am

• Students in earlier starting schools more likely to belong to an ethnic minority, be eligible for free lunches and have less educated parents

*MMWR 2015
Outcomes: Sleep*

- Bedtimes remain the same or in some studies actually shift earlier
- Students obtain significantly more sleep
  - More morning sleep
  - The later the start time, the greater the sleep amounts
  - But even a 30 minute delay results in improvements
- Students report less daytime sleepiness (falling asleep in class, doing homework)
- \( \geq 8:30 \text{am} \) the sleep and circadian “sweet spot”?  

Review of 38 reports examining the association between school start times, sleep, and behavioral, health and academic outcomes among adolescent students
Outcomes: School Performance*

• Attendance improves
• Tardiness rates drop
• Drop-out rates decline
• Standardized test scores improve
  • In one study SAT scores for the top 10% of students increased by more than 200 points
• Grades improve
  • 5/6 schools showed significant increase in GPA pre-post in English, math, science and SS
• Disadvantaged students may benefit more
  • Larger effects of start times at lower end grade distribution**
  • Effects of 1\textsuperscript{st} period classes larger for black students***

Outcomes: Health & Safety

• Delayed SST are associated with improvements in:
  • Mood (fewer report feeling unhappy, depressed)
  • Health (decreased health center visits)
  • Safety
    • Kentucky: 7:30 to 8:40a start time; teens involved in car crashes down by 16% (vs 9% increase in the rest of the state)
    • Virginia: Adolescent crash rates VA Beach (7:20a) vs Chesapeake (8:40a) 40% higher and peak 1 hour earlier
    • CDC study (2014): Reduction crash rates in 16-18yo by as much as 65-70% (Minnesota, Colorado, Wyoming)
Outcomes: $$$

• Brookings Institute Report: “Organizing Schools to Improve Student Achievement: Start Times, Grade Configurations, and Teacher Assignments” (2011)

• Moving school start times one hour later would have a substantial benefit: cost ratio (9:1)
  • Based on a conservative estimate of both costs per student ($0-$1950; largely related to transportation), and the increase in projected future earnings per student in present value due to test score gains (approximately $17,500)

• “A later start time of 50 minutes in our sample has the equivalent benefit as raising teacher quality by roughly one standard deviation”
Outcomes: $$$

- RAND Corporation report (2017)*
  - Potential *significant economic gains of a state-wide shift in start times to >8:30am* related to improved academic performance of students resulting in increased lifetime earning potential and reduced car crashes
  - Economic gain [modeled across 47 US states] estimated annual gain of ~ $9.3 billion
    - Roughly the annual revenue of MLB
  - Report estimates that MA would see one of the highest cost-benefit ratios in the nation
    - *At minimum breaking even after just 2 years*
    - Achieving a cost-benefit ratio of 4.5 after 10 years, meaning that *for every dollar spent, the return is more than four-fold the cost*

Challenges to Change

- COST $$$
- Curtailed time for athletic practices and interference with scheduling of games
- Reduced after-school employment hours for students
- Challenges in providing childcare for younger siblings
- Adjustments in family schedules
- Need to make alternative transportation arrangements
- Potential safety issues and impact on sleep duration in younger children if elementary school schedules are “flipped” with those of middle/high school students
Elementary School Start Times

- Sleep needs: 9-12 hrs*
- Circadian preference (chronotype): owl vs lark**
- School, activities, electronic media, later bedtimes, earlier rise times, irregular sleep/wake schedules contribute to deficient sleep
- However, as opposed to adolescents, they are biologically, environmentally and socially more amenable to manipulation of bedtimes (ie, to move sleep onset earlier) if required
- Is there a sweet spot?
  - Data is mixed but suggest 7:30-9am
  - Earlier start times more impact on academics, behavior
  - Issues of civil twilight, safety concerns

*AASM 2016

**But most school-aged (pre-pubertal) children have a “morningness preference”
Elementary School Start Times: The “Flip”

- Impact of School Start Time Changes:
  - HS students delayed from 7:30am to 8:15am
  - Students in grades 3-5 advanced from a start time of 8:20am to 7:45am
  - HS students got 35 minutes more sleep
  - 3rd graders also got more sleep (+24 minutes) after the change
  - Sleep duration changes in 4-5th graders negligible
  - No differences in behavior measures post-change

<table>
<thead>
<tr>
<th>Grade</th>
<th>SST 1 BT/WT (SD HH:MM)</th>
<th>SST 2 BT/WT (SD HH:MM)</th>
<th>Sleep Duration Difference (Min)</th>
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<tbody>
<tr>
<td>3</td>
<td>8:37p/6:49a (10:11)</td>
<td>8:22p/6:57a (10:35)</td>
<td>+24*</td>
</tr>
<tr>
<td>4</td>
<td>8:52p/6:56a (10:03)</td>
<td>8:22p/6:22a (9:59)</td>
<td>-4</td>
</tr>
<tr>
<td>5</td>
<td>9:10p/6:59a (9:49)</td>
<td>8:43p/6:23a (9:40)</td>
<td>-9</td>
</tr>
<tr>
<td>10</td>
<td>(7:42)</td>
<td>(8:17)</td>
<td>+35**</td>
</tr>
</tbody>
</table>

*Largely accounted for by earlier bedtimes
**Completely accounted for by later rise times; 0 min difference bedtimes

*Appleman et al. School start time changes and sleep patterns in elementary school students. Sleep Health, 1(2) (2015), 109-114.*
Lessons Learned

- District superintendent support and leadership critical
- School board involvement key
- School leadership (ie, principals) and teacher support vital
- Importance of middle/elementary school principal, teacher, parent involvement
- Importance of student engagement
- Critical role of community *education*
  - Health, safety *and* academics
- Critical role of community *engagement*
  - Identification and involvement of key stakeholders
Lessons Learned

- Critical to allow adequate time for families to become informed and make sufficient plans prior to implementation
- Each community faces different, unique challenges
  - But you don’t have to “reinvent the wheel”
- Not all students will benefit equally
  - The goal is to provide “the greatest good for the greatest number of students”
- Anticipation often worse than reality (impact on athletics, teacher retention, after-school programs, childcare issues)
- Initial challenges reduced over time
What is your vote?

Thanks for your attention!