



A Perfect Storm: Sleep in Adolescents



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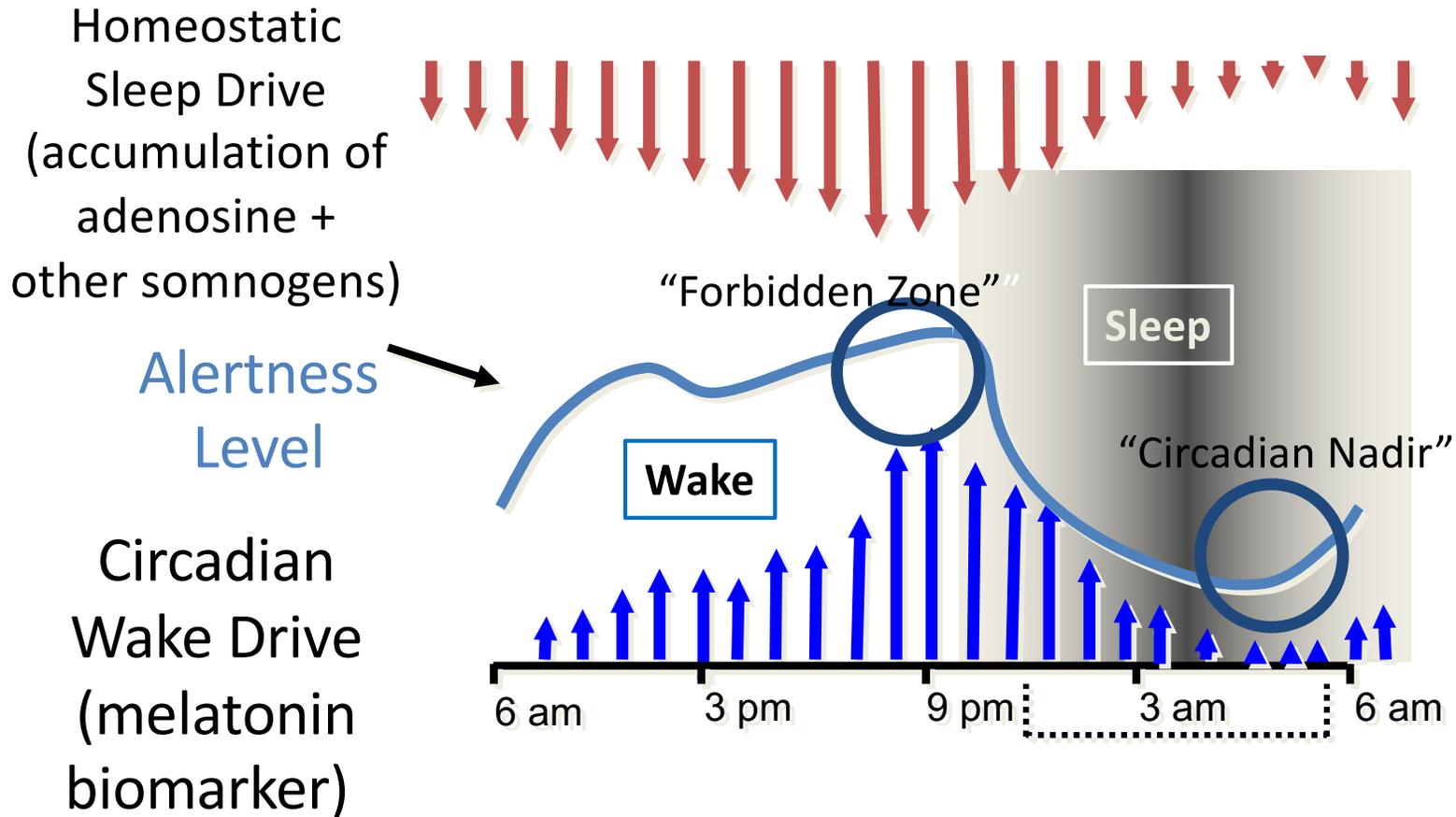
Myths and Misconceptions

- 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/week
- Kids need to learn to get up early; that's real life and no harm done



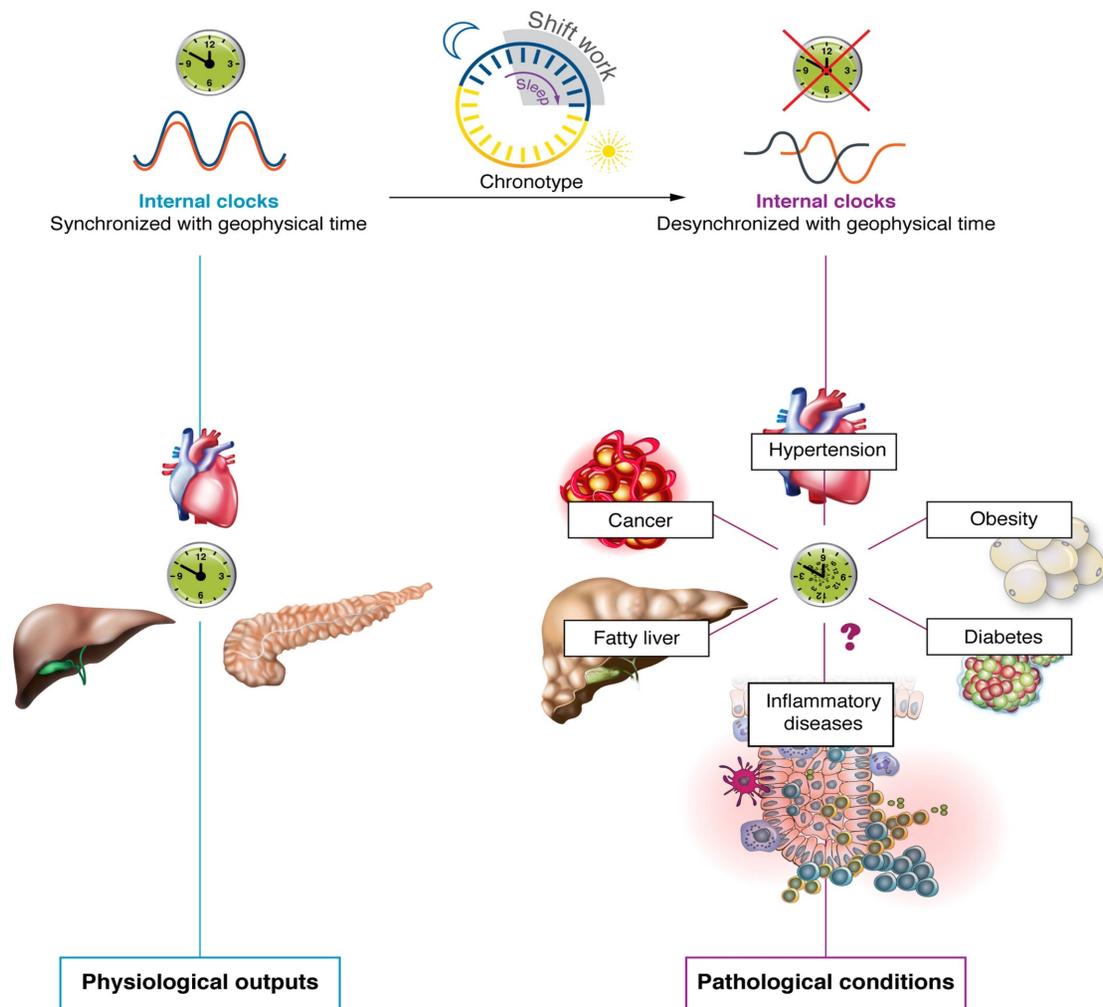
First, a few sleep basics...

“Two Process” Model of Sleep Regulation



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

What is “Deficient” Sleep?

- A concept that acknowledges that short sleep duration (compared to sleep needs) and circadian misalignment (a mismatch between biological circadian rhythms and environmental demands), while inter-related, may both contribute to behavioral and cognitive impairments and poor health outcomes
- In other words, it's not just **how much** you sleep, but **when** you sleep that's critical

Adolescent Sleep: The “Perfect Storm”?



Adolescent Sleep: Biological and Circadian Factors

- All adolescents experience a normal shift in circadian rhythms with age and in association with the onset of puberty → “night owls”
- This results in a biologically-based shift (delay) of up to several hours in both the natural fall sleep *and* morning wake times
- Changes in the sleep drive also make it easier for adolescents to stay up later

Adolescent Sleep: Biological and Circadian Factors

- On a practical level, due to these factors as well as the “forbidden zone”, it’s very difficult for the average adolescent to fall asleep much before 11pm on a regular basis*
 - Teens cannot “make” themselves fall asleep earlier
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- In order for high school students to obtain the recommended amount of sleep (~9 hours) at a 7:30a school start time, they would need to fall asleep by 9:30p

Adolescent Sleep: Environmental Factors

- Competing priorities for sleep: homework, activities, after-school employment, social networking
- Circadian phase delay may be further exacerbated by evening light exposure (between dusk and bedtime)
 - Suppresses brain release of melatonin
 - Greater sensitivity to evening light at puberty onset
 - Blue light from “screens” (TV, computer, e-readers)
- Consumption caffeine and other stim
 - 18-30% of teens use energy drinks
 - Daytime sleepiness major driver



“Weekend Oversleep” and “Social Jet Lag”

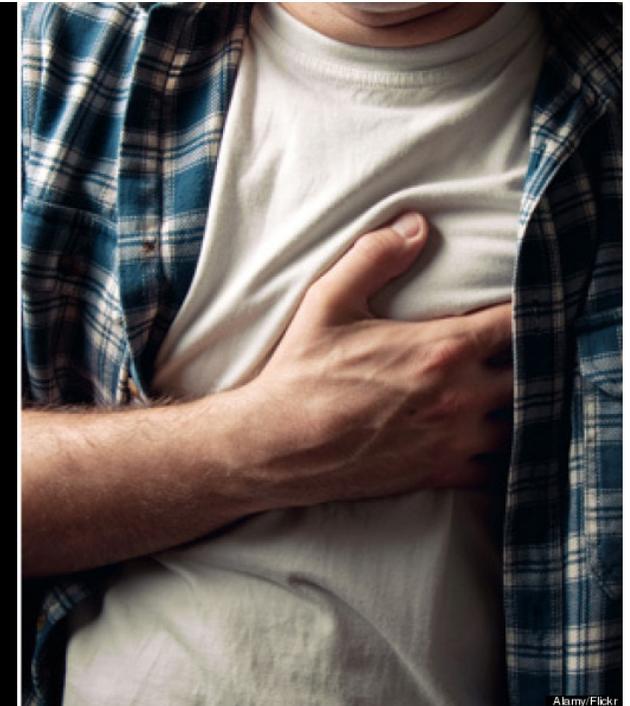
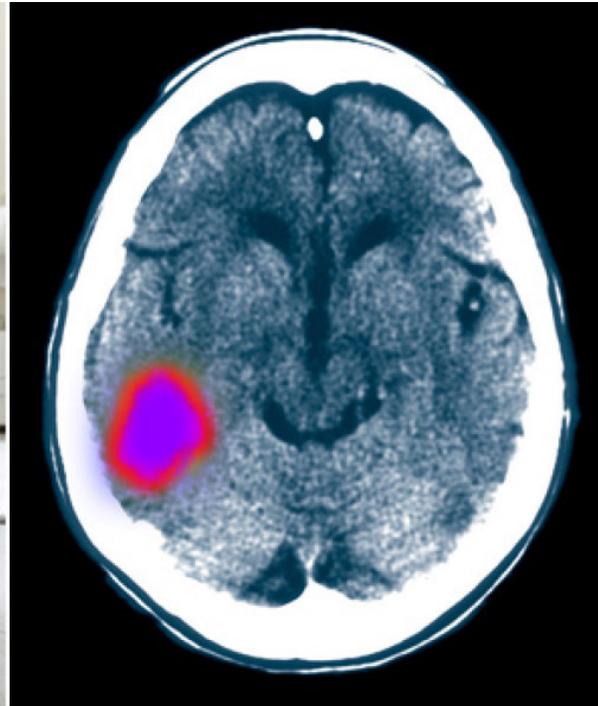
- Weekend oversleep
 - Practice of “making up” sleep
 - Marker of chronic insufficient sleep
 - But does not reverse or compensate for impairments
- Social jet lag
 - Shift in bedtime and wake times on non-school days
 - Leads to “circadian misalignment”
- Prevents sufficient build-up of sleep drive
 - Difficulty falling asleep Sunday night
- Result: permanent state of “jet lag”
 - Adjustment takes 1 day/time zone crossed
 - Effects persist up to 3 days

The Bottom Line

- These changes in sleep are in direct conflict with earlier high school start times (before 8:30am)
 - 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
 - And they are unable to meet sleep needs
 - For optimal health, safety and achievement the average middle and high school student needs 8-10 hours of sleep*

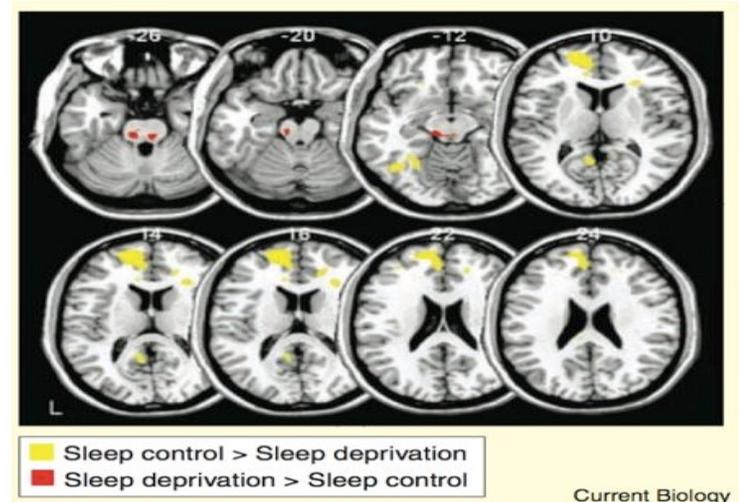
*AASM recommendations, 2016

Effects of Deficient Sleep on Health, Safety and Performance



Contributors to Health Risk Behaviors

- Multiple cross-sectional as well as longitudinal prospective studies link deficient sleep and risk behaviors
- Executive function deficits (pre-frontal cortex)
 - Impaired decision making
 - Reduced motivation
 - Poor judgement
 - Poor impulse control
 - Inattention
 - Poor inhibitory control
- Emotional dysregulation
- Impaired reward-related decision making Take more risks due to perception of reduced consequences



Sleep-Starved?

- 20.6% of adolescents 12-19yo are obese (2015-16; CDC)
- Both cross-sectional and prospective longitudinal observational studies have linked shorter sleep duration with increased obesity risk in children and adolescents (>2x) in a dose-dependent fashion
 - Evening chronotype also associated with increased obesity risk
 - Decreased sleep efficiency (TST/TIB) and regularity also risk factors
- Mechanisms:
 - Appetite regulation (gherlin, leptin)
 - Insulin resistance
 - Food intake: increased amount, more calories, more fat and carbohydrates
 - Eating patterns
 - Physical activity/sedentary behavior
 - Bedtime and sleep routines
 - Sleepiness-related impairments

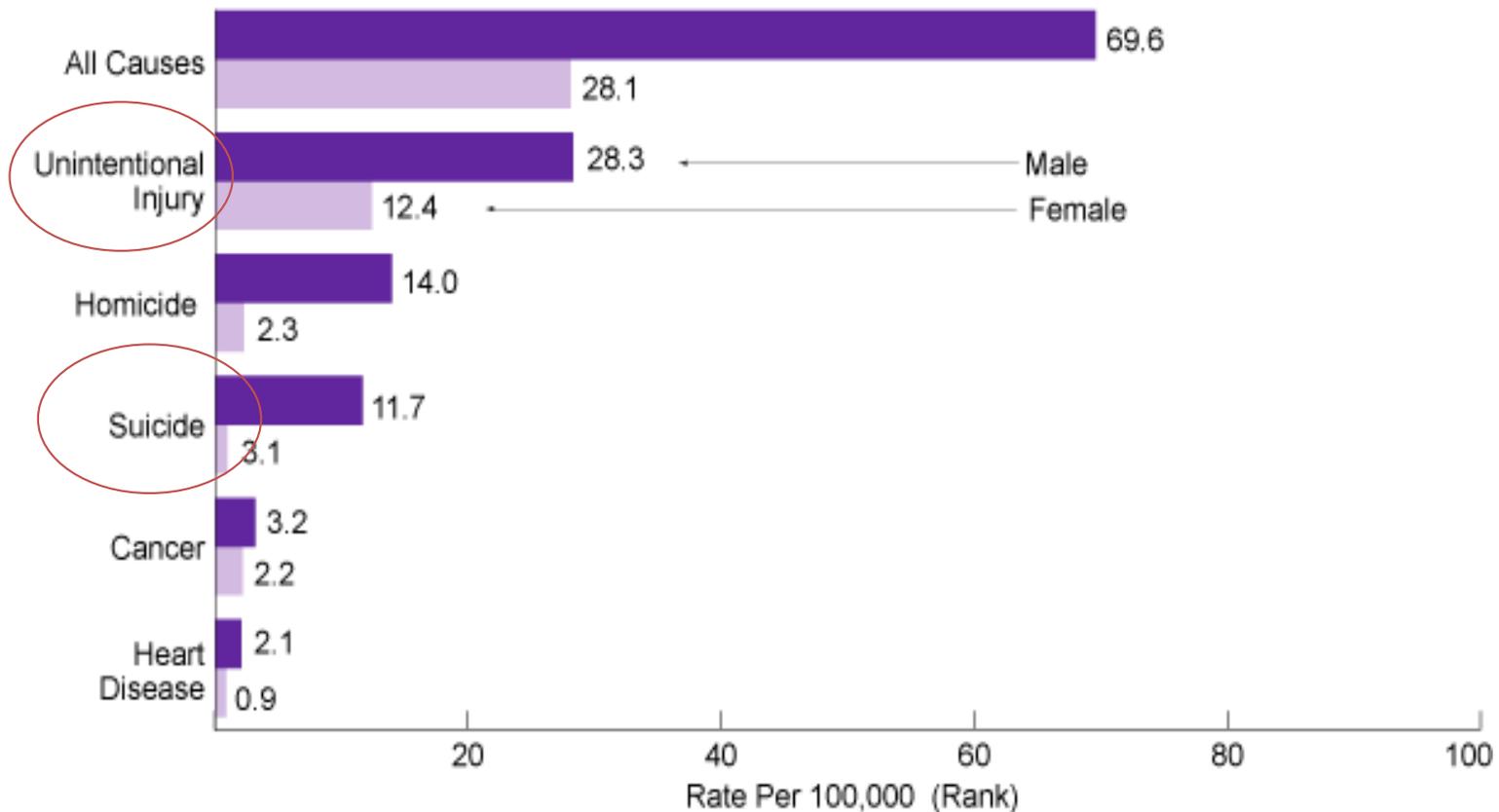
Metabolic and Cardiovascular Health

- Short sleep duration associated with increased cardiometabolic risk
 - Insulin resistance, type II diabetes, dyslipidemia, hypertension
- Eveningness chronotype/circadian misalignment associated with Type II diabetes risk (adults)
- Both deficient sleep and obesity have direct detrimental impact on cardiovascular health, metabolic function and systemic inflammation

Sleep and Medical Conditions

- Immune function
 - Complex bidirectional relationship between sleep and immune response mediators (inflammatory markers):
 - Short sleep associated with susceptibility to and slowed recovery from infection
 - Shorter TST in adolescents associated with increased frequency of common infectious diseases
 - Short sleep duration associated with poorer antibody response to vaccines (eg, influenza, Hep B)

Mortality Rates Among Adolescents Aged 15–19 Years, by Selected Leading Cause and Sex, 2010



Source: Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999-2010. CDC WONDER Online Database, compiled from Compressed Mortality File 1999-2010 Series 20 No. 20, 2012. Retrieved from: <http://wonder.cdc.gov/ucd-icd10.html>. Accessed: November 15, 2012.

Depression Symptoms and Risky Behaviors

- In a sample of HS students (N>10,000), 38% overall with insufficient sleep
 - ≤ 6 hours; 19% 8th graders/42% 10th graders/56% 12th graders
- 10% overall with optimal sleep
 - ≥ 9 hours; 19% 8th graders/6% 10th graders/3% 12th graders
- 40% of teens getting 6 or less hours of sleep report depression symptoms (sadness, hopelessness)
- Almost 3 times as many students getting less than 6 hours of sleep report alcohol use in the past 30 days compared to those getting 9+ hours

Substance/Alcohol Use

- Adolescent SU:
 - 11% of 12-17yo used illicit drug in past month; 15% of 16-17yo (CDC 2017)
 - 10% of 12-17yo used alcohol in past month; 19% 16-17yo (CDC 2017)
 - 11% binge drinking
 - 18% smoked cigarettes in the past month; 7% 16-17yo (CDC 2017)
- In comparison: YRBS study (2015)
 - HS students: average WD sleep duration 6.5 hrs; 77% reported <7hrs sleep; 20% < 5 hrs
 - 37% of those getting 7 hrs of sleep reported tobacco/alcohol/marijuana use (vs 14% with 9 hrs)

Safety Issues: Drowsy Driving and MIVAs

- Two-thirds of accidental injury fatalities in adolescents are related to road crashes (CDC 2012)
- AAA study (2015) found that 16.3% of 16-18 year olds reported driving while “so tired you had a hard time keeping your eyes open” at least once in the past 30 days¹
- 48% of adolescent drivers reported drowsy driving; every hour less sleep on school-nights compared to a sleep duration of ≥ 8 hrs was associated with an increased risk of drowsy driving²

Safety Issues: Risk Behaviors

- Survey of >50,000 US high school students: injury risk behaviors significantly more frequent in students sleeping < 7 vs 9hrs¹
 - Infrequent bicycle helmet use
 - Infrequent seatbelt use
 - Texting while driving
 - Rode with drinking driver
 - Drinking and driving (increased 8 vs 9 hrs)

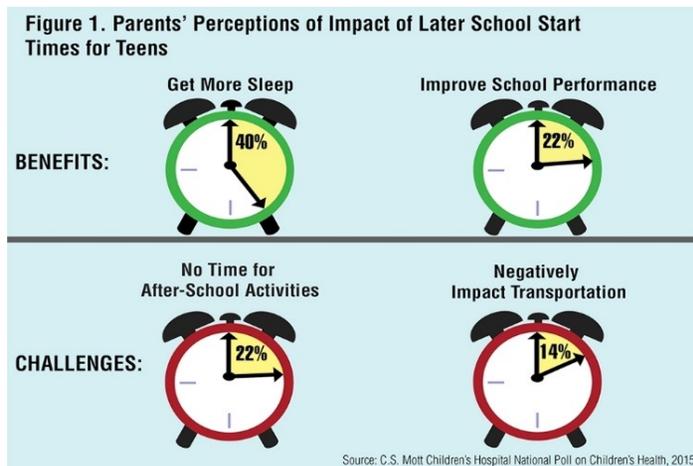
¹CDC MMWR 4/8/16

Safety Issues: Risk Behaviors

- Sleep loss also associated with:
 - An increased risk of pedestrian injuries in children (2014) and more risk-taking behaviors crossing streets in adolescents (2013)
 - Increased sports-related and musculoskeletal injuries in adolescents (2014)
 - Increased training time associated with less sleep (2019)
 - An almost 3x risk in adolescents of work-related injury requiring medical care (2015)
 - 2-5x risk of in-school/out of school repeated injuries (2015)



What is the Role of School Start Times?



Analyses of Student Self-Reported Data in US Schools That Changed to Later School Start Times

- Significant changes ($p < 0.05$):
 - Later rise time
 - Longer sleep durations
 - Less weekend catch-up sleep
 - Decline in Epworth scores and less daytime sleepiness
 - Greater sleep satisfaction
 - Less depressed mood
 - More time doing homework

Outcomes: Sleep

- Bedtimes remain similar or shift slightly later (or in some cases are earlier), which is offset by morning wake time delay
- Students obtain significantly more sleep
 - More morning sleep
 - The later the start time, the greater the sleep amounts
- Students report less daytime sleepiness (falling asleep in class, doing homework)
- ≥8:30am the sleep and circadian “sweet spot”?

Outcomes: School Performance

- Increased attendance rates
- Decline in absenteeism rates
- Decline in tardiness rates
- Decreased drop-out rates
- Increased graduation rates
- 1st period grades improved
- Increase in GPA
- Higher standardized test scores

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; similar results follow up study
 - CDC study (2014): Reduction crash rates in 16-18yo by as much as 65-70% (Minnesota, Colorado, Wyoming)
 - FCPS (2013-16): Significant decrease in crash rates in FC and a slight increase in the rest of VA; amounting to approximately 126 fewer crashes

Economic Benefits

- Recent macroeconomic modeling of US state-wide change from current SST to 8:30am vs status quo suggested that benefits of later start times far out-weigh immediate costs (\$150 per student/yr + \$110,000 for infrastructure); includes grades 6-12
 - Based on projected student lifetime earnings: increase HS graduation rates, university attendance PLUS reduction in adolescent car crashes
 - During the 15 year period examined by the study, the average annual gain to the U.S. economy would about \$9.3 billion/yr*
 - Some states would “break even” after just 2 years (like MA)
- This study suggests that delaying school start times to 8:30am is a cost-effective, population-level strategy which could have a significant impact on public health and the U.S. economy

The Impact of the Pandemic: What We Know*

- Virtual learning schedules:
- Sleep schedules (Bedtime/Wake time) shift later
- However, almost all studies report increased sleep duration as a result of later wake times
- Many studies demonstrate less daytime sleepiness
- Regularity of sleep patterns (“social jetlag”) improves
- Emerging evidence supports later school start times

*So far...

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 due to later wake times
- 3rd graders also got more sleep (+24 minutes) after the change
- Sleep duration changes in 4-5th graders negligible
- Significantly shorter sleep durations associated with having TV or cell phone in the bedroom, having screen time before bed
- Students who reported reading a book before going to bed slept 15-22 min more per night

GRADE	SST 1 BT/WT Sleep Time	SST 2 BT/WT Sleep Time	Sleep Duration Difference (Min)
3	8:37p/6:49a (10:11)	8:22p/6:57a (10:35)	+24*
4	8:52p/6:56a (10:03)	8:22p/6:22a (9:59)	-4
5	9:10p/6:59a (9:49)	8:43p/6:23a (9:40)	-9

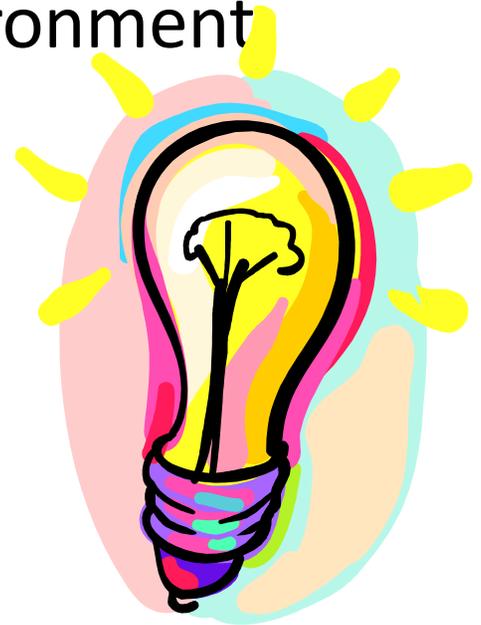
*Largely accounted for
by earlier bedtimes

What Can Schools Do?

- Set healthy school start times
- Include sleep as part of student health education, biology classes
- Help students manage their schedules so that they have time for adequate sleep
- Decrease homework burden
- Buffer early start times by setting limits on evening activities at school as well as early morning/ late evening athletic practices.
- Work with employers to decrease adolescents' work hours
- Include drowsy driving in driver ed

What Can Parents Do?

- Know the signs of deficient sleep in teens
- Enforce appropriate sleep schedules
- Set limits on after-school activities and jobs
- Keep track of caffeine use
- Monitor drowsy driving: “No ZZZs? No keys!”
- Provide a “sleep-friendly” home environment
- Be a good sleep role model
- Make sleep a priority!





Thank you!
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