What is Going on with Sleep in Adolescent Development…and Why it is a Problem
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Overview
• Adolescence & Puberty Defined
• Sleep phenomenology
• Sleep regulation
  – Process S (sleep homeostasis)
  – Process C (circadian rhythms)
• Lifestyles of the 21st century
• Public policy
  – School start time example

What is adolescence?
• Ages vary by culture
• WHO: 10-19 years; 10-14 = early adolescence; 15-19 = late adolescence

What about puberty?
• Time when the reproductive organs become functional and the secondary sexual characteristics appear
• Tanner staging can be used to scale puberty
• Tanner stage and age are highly correlated
• In early adolescence, if girls show finding at a younger age than boys, pubertal maturation may be relevant
The central question

Why do adolescents (once such champion sleepers, so eager to start the day) struggle to wake up in the morning and struggle against going to sleep in the evening?

Adolescent Brain Changes

- Density of neuronal connections, blood glucose metabolism, and brain wave amplitude are stable in adulthood
- All decline during adolescence…a lot!

The “look” of sleep changes

Tarokh & Carskadon, Sleep in press.

Change is Asymmetrical

Feinberg et al., *J Theor Biol.*, 1990
Sleep phenomenology changes across adolescence, but how does sleep regulation change developmentally and how does this play out behaviorally?

Two-Process Model of Sleep Regulation (Borbély, 1982)

- **Process C:** Circadian Rhythm
- **Process S:** Sleep/Wake Homeostasis (sleep pressure)

**Measures of Process S**

- Slow wave (NREM stages 3+4) sleep [qualitative: deep sleep]
- Slow-wave activity (SWA) in sleep [quantitative: slow EEG waves]
- Sleep propensity (speed of falling asleep)

Image downloaded from Scholarpedia after Borbély
Changes of Slow Wave Sleep and Slow Brain Waves of Sleep

Dynamics of Sleep Pressure: Building Up and Letting Go

Summary of Process S Change

- Recovery sleep process does not change across adolescence
  - Need for sleep is stable
- Accumulation of sleep pressure slows
  - Staying awake longer is easier
- Result: late nights
Circadian Regulation Changes: Measures to Assess Process C

- **Phase preference**—when do you prefer to be active, sleeping, etc?
- **Phase** of circadian rhythms—what time is it in your brain?
- **Period** of the circadian timing system—what is the internal day length?
- **Phase response to light**—does light work the same in adolescents?

**Phase Preference and Adolescence**

- Time of midsleep on “free” days
- European sample
- Developmental changes occurred at a younger age in girls than boys

**Animals with Adolescent Phase Delay**

- Homo sapiens (humans)
- Macca mulatta (Rhesus monkeys)
- Octodon degus (degu)
- Rattus norvegicus (laboratory rat)
- Mus musculus (laboratory mouse)
- Psammomys obesus (fat sand rat)

**Melatonin Phase and Puberty in Humans**

Hagenauer et al., *Devel Neurosci*, 2009

Ronneberg, *Current Biol.*, 2004

Carskadon & Acebo NYAS, 2004
Activity offset delays in pubertal Macaques

- Puberty: phase delay in the daily offset of activity
- If puberty is inhibited by zinc deprivation, the phase delay does not occur.

Exaggerated phase delay to light in pubertal female mice

Circadian Rhythms Summary

- Phase delays during adolescence
  - Phase preference is later
  - Melatonin phase is later
- Intrinsic period may lengthen
- Phase-dependent light sensitivity may change
- Result: late nights

Internal Day Length in Humans

Golub et al., In: Adolescent development..., 2002

Carskadon & Acebo, Sleep (APSS) 2005

Hagenauer et al., Devel Neurosci, 2009; after Weinert & Kompaurova, Zoology, 1998
Other factors co-opt the biology…

- Academic obligations
- Social opportunities
- Substance use, including caffeine
- Psychological stressors
- Societal messages
- Stimulating activities (“screens”) in the evening
- Parental control vs. autonomy (Gangwisch et al., Sleep, 2010)
- School start time

Bottom Line for Sleep

School Start Time

School Transition Project — A “real-life” example

9th Grade
8:25 am

10th Grade
7:20 am

Carskadon et al., 1998
Measured sleepiness in high school students

- 10th grade
- Start time = 0720
- No schedule manipulation
- Sleeping about 7 hours a night

REM tendency also affected

REM occurred in 12 of 25 subjects—most in the morning

Summary

- Long days
- Slower build-up of sleep pressure
- Later circadian phase
- Early school start time
- Same “need” for sleep/sleep recovery

Consequences of Insufficient & Ill-timed Sleep

- Excessive sleepiness
- Impaired learning
- Impaired behavior regulation
- Increased risk taking
- Poor mood, depression
- Appetite and metabolic changes; possible association with weight gain, obesity, diabetes risk
- Stimulant use