The Biology of Teen Sleep Patterns

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Overview

• Adolescent sleep biology
• Sleep biology and early rising
• Sleep and the adolescent brain
• Consequences of too little sleep for teens
Factors Affecting Sleep Patterns

• Behavior and circumstances
e.g., life-style choices, socio-economic status, health, employment, school

• Intrinsic biological processes
  – Sleep homeostatic system (sleep “pressure”)
  – Circadian timing system

Observed features of the circadian system during adolescence
Species Manifesting Juvenile Phase Delay

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

Hagenauer et al., Devel Neurosci, 2009

Chronotype and Adolescence

- Time of midsleep on “free” days
- Later timing is marked across the 2nd decade

Roenneberg et al., Current Biol., 2004
Puberty and Melatonin Onset Phase: Hormonal Signal of Nighttime

What might underlie phase delay?

- Changes in light exposure
  - Staying up later // more late light = delay
  - Waking up later // less morning light = no advance
- Change in phase-dependent sensitivity to light exposure
- Longer internal day length
- Diminished amplitude of the melatonin rhythm
Exaggerated phase delay to light in pubertal female mice


Human Intrinsic Circadian Period—Internal Day Length

Carskadon & Acebo *Sleep*, 2005
Adolescent Melatonin Amplitude

Summary of Process C Changes

- Phase is delayed during adolescent development
  - Phase preference (chronotype) is later
  - Melatonin phase is later
- Phase-dependent light sensitivity may change
- Internal day is longer than in adults
- Amplitude of circadian nocturnal melatonin declines

- Result: late nights are favored (so, too, late mornings)
Features of Adolescent Sleep-Wake Homeostasis (Human)

The look of sleep changes

Jenni & Carskadon *Sleep*, 2004
The adolescent brain changes

Density of neuronal connections, cerebral metabolic rate, and brain wave amplitude decline during adolescence

Feinberg et al., *J Theor Biol.*, 1990

Sleep phenomenology changes; does sleep regulation?

Recovery process (dissipation)
Accumulation process
Sleep pressure dissipation does not change in adolescence

Tanner Stages 1/2  Tanner Stage 5

\[ t_d = 2.8 \text{ h} \] Decay Time Constant \( t_d = 2.7 \text{ h} \)

Across pubertal development, SWA accumulation rate slows down

Tanner Stages 1/2  Tanner Stage 5

\[ t_d = 2.8 \text{ h} \] Decay Time Constant \( t_d = 2.7 \text{ h} \)
\[ t_i = 8.9 \text{ h} \] Rise Time Constant \( t_i = 12.1 \text{ h} \)
Staying awake longer gets easier... up to a point.

Taylor et al., J Sleep Res, 2005

Model of Process S in Development

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 are easier to achieve, but the same amount of sleep is needed

Adolescent Sleep Behavior

- Bedtime becomes later
- Rise time becomes earlier (school dependent)
- Total amount of sleep is reduced
- Chronic insufficient sleep affects morning alertness most, especially when waking at an adverse circadian phase
- Evening alertness is bolstered by the clock-dependent alerting signal
Daytime sleep tendency in early-rising high school students

- 10th grade
- Start time = 0720
- Sleeping about 7 hours a night

Carskadon et al. Sleep, 1998

REM sleep tendency also affected

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

Looks like narcolepsy!

Carskadon et al. Sleep, 1998
Consequences of Clock/Homeostasis/Lifestyle Interaction

- Chronic insufficient sleep
- Variable sleep timing
- Deficits in mood, learning, impulse control, etc.
- Excessive sleepiness & possible substance use

Why should we care about short sleep? Sleep’s role in achievement and learning
Sleep Prepares for Learning

• Too little sleep impairs information *acquisition*
  – Sleepiness
  – Irritability
  – Distractibility
  – Inattention
  – Motivation
• That is, ability to *process input* is diminished

Sleep Prepares for Performance

• Too little sleep impairs information *retrieval*
  – Sleepiness
  – Irritability
  – Distractibility
  – Inattention
  – Motivation
• That is, ability to *access* learned information suffers
Caffeine or other stimulants may help, but they cannot substitute for sleep, especially because...

Sleep Enhances Learning

Information acquisition

Consolidation/stabilization/strengthening

Filtering

Information retrieval
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