

Appendix E

Facts About Sleep and Adolescents

Sleep is a basic biological need^{1, 2}. Adequate sleep is necessary for our bodies and our minds to grow and to heal.³ Research shows that on average adolescents require 9.25 hours of sleep a night for good physical and mental health.^{4, 5}

Inadequate sleep has been linked to many physical, mental and social problems:^{6, 7, 8}

- Impairment of the immune system and susceptibility to illness⁹
- Depression, anxiety and irritability¹⁰
- Impaired metabolism, diabetes, being overweight and obesity^{11, 12, 13, 14, 15}
- Acne¹⁶
- Alcohol and caffeine abuse¹⁷
- Hyperactivity¹⁸
- Poor judgment, rebelliousness, risky behavior, lack of control, trouble with relationships^{19, 20, 21}
- Lower academic performance^{22, 23}
- Decreased athletic performance and injury^{24, 25, 26}
- Car crashes due to drowsy driving^{27, 28, 29, 30}

Adolescents have different sleep patterns and needs than adults or younger children.³¹ Hormonal influences of puberty shift the adolescents' biological clocks. The secretion of melatonin, a brain hormone that causes drowsiness, begins later in adolescents, causing a "phase delay" in their sleep patterns.^{32, 33, 34, 35, 36, 37} This tendency for adolescent sleep patterns to be delayed has been reported not only in North America but also in South America, Asia, Australia, and Europe.³⁸

Despite needing 9.25 hours of sleep for good health, high school students on average get between 7 and 7.5 hours of sleep on school nights.^{39, 40} While a variety of factors may contribute to adolescents' sleep deprivation, sleep researchers point to early school start times as a major culprit.^{41, 42, 43, 44} Schedules that require teen students to wake up early in the morning run counter to their natural sleep cycle.⁴⁵

"As a result [of hormonal changes], teenagers are more likely to go to bed later than younger children and adults, and they tend to want to sleep later in the morning. This sleep-wake rhythm is contrary to the early-morning start times of many high schools and helps explain why most teenagers get an average of only 7-7.5 hours of sleep a night," according to the National Institutes of Health.⁴⁶

Jurisdictions that have later start times or have switched to later high school start times have found that teen students do get more sleep per school night on a later schedule. In Minnesota, the shift resulted in an average of an hour more sleep per school night and drop-out rates decreased significantly.⁴⁷ In Wilton, CT, where the schedule shifted by 40 minutes, it resulted in an average of 35 minutes more sleep each night.⁴⁸

Sleep and circadian rhythms play a part in how prepared we are to learn.^{49, 50, 51} “Not only is a good night’s sleep required to form new learning and memory pathways in the brain, but sleep is also necessary for those pathways to work up to speed,” according to the National Institutes of Health. “Several studies show that lack of sleep causes thinking processes to slow down. Lack of sleep also makes it harder to focus and pay attention. Lack of sleep can make you more easily confused.”⁵²

In one recent NIH study, “Volunteers had to sleep at least 6 hours to show improvement in learning, and the amount of improvement was directly tied to how much time they slept. In other words, volunteers who slept 8 hours outperformed those who slept only 6 or 7 hours.”⁵³

After a complete night’s sleep, memory is consolidated, test performance improves, problem-solving and creativity are enhanced.^{54, 55, 56, 57} Retention is even better after two nights of sleep.⁵⁸ Interrupted or incomplete sleep disrupts this process and impairs cognition.⁵⁹

Not all sleep is equal. The deepest, most healing REM (rapid eye movement) sleep is concentrated in the last hours of the normal sleep cycle. When sleep is cut off, some of its most important functions suffer.⁶⁰ “REM sleep stimulates the brain regions used in learning,” according to NIH. “One study found that REM sleep affects learning of certain mental skills. People taught a skill and then deprived of non-REM sleep could recall what they had learned after sleeping, while people deprived of REM sleep could not.”⁶¹

The body will demand the sleep it needs in one form or another. Some students will fall asleep in class, while others will experience “mini-REMs” that make them miss a few seconds of instruction at a time, possibly without even knowing it.^{62, 63}

Sleep-deprived students scored lower than their well-rested colleagues, even after catching up on lost sleep, according to a recent study from Harvard Medical School published in *Nature Neuroscience*.⁶⁴

In 2002, the U.S. Navy changed sleep times for recruits and studied the result, finding that a later schedule resulted in more sleep and better performance. The Navy first increased rack time for recruits from 6 to 8 hours. Then, the Navy shifted rack time to one hour later. The recruits both got more total sleep with the shift⁶⁵ and showed significant improvement on standardized tests as a result of the combined changes.^{66, 67} “On average test scores rose by 11 percent with the additional sleep. The odds of observing such a difference by chance is less than one in ten million,” the Navy study concluded.⁶⁸

¹ NIH, [The Need for Sleep: Wake up to the Risks of Shortened Slumber](#), *News in Health*, April 2007.

² Institute of Medicine, Committee on Sleep Medicine and Research, *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Need*, Harvey R. Colten and Bruce M. Altevogt, editors, The National Academies Press, 2006.

³ Harvard Medical School Division of Sleep Medicine website: <http://healthysleep.med.harvard.edu/> (accessed 2.18.08.)

⁴ Wolfson, AR and Carskadon, MA, Sleep Schedules and Daytime Functioning in Adolescents. *Child Development*. 69(4):875-887.

⁵ IOM, p. 142

⁶ NIH, [The Need for Sleep: Wake up to the Risks of Shortened Slumber](#), *News in Health*, April 2007.

⁷ IOM (hypertension, diabetes, obesity, depression, heart attack, stroke) p. 55 immune system, anxiety, alcohol use (p. 59), alcohol use and suicide in adolescents (p. 63)

-
- ⁸ Harvard: [Healthy Sleep: Sleep and Disease Risk](#) (accessed 2.18.2008); [Healthy Sleep: Consequences of Insufficient Sleep](#) (accessed 2.18.2008).
- ⁹ Emsellem, *Snooze . . . or Lose! 10 “No-War” Ways to Improve Your Teen’s Sleep Habits*, 2006; Joseph Henry Press, Washington, DC, p. 25.
- ¹⁰ IOM, p. 63.
- ¹¹ Spiegel, et. al, Impact of sleep debt on metabolic and endocrine function. *Lancet*, 1999; 354(9188):1435-9.
- ¹² Knutson, et.al., Role of Sleep Duration and Quality in the Risk and Severity of Type 2 Diabetes Mellitus. *Archives of Internal Medicine*, 2006; vol. 166, p. 1768-1774.
- ¹³ Tasali, et. al., [Slow-wave Sleep and the Risk of Type 2 Diabetes in Humans](#). *Proceedings of the National Academy of Sciences*. 2008, 105 (3):1044-1049.
- ¹⁴ Spiegel, et. al, Sleep Loss: A Novel Risk Factor for Insulin Resistance and Type 2 Diabetes. *J. Appl Physiol*. 2005, 99(5):2008-19.
- ¹⁵ Spiegel, et.al. (2004). Brief Communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann. Int. Med*, Vol. 141, p. 846-850.
- ¹⁶ Emsellem, *Snooze . . . or Lose! 10 “No-War” Ways to Improve Your Teen’s Sleep Habits*, 2006, p. 41.
- ¹⁷ IOM, p. 59
- ¹⁸ Emsellem, p. 185.
- ¹⁹ Emsellem, p. 44-45.
- ²⁰ O’Brien, EM and Mindell, JA, Sleep and risk-taking behavior in adolescents. *Behav Sleep Med*. 2005;3(3):113-33.
- ²¹ Carskadon MA, et. al. Regulation of adolescent sleep: implications for behavior. *Annals of the New York Academy of Sciences*. 2004 Jun;1021:276-91.
- ²² IOM, p. 142-3.
- ²³ Shin, et. al., Sleep habits, excessive daytime sleepiness and school performance in high school students. *Psychiatry Clin Neurosci*. 2003; 57(4):451-3.
- ²⁴ Lamberg, Clinical & Research News: [Sleep May Be Athletes’ Best Performance Booster](#), *Psychiatric News*, 2005, Volume 40 Number 16, p. 21.
- ²⁵ Reilly, T and Edwards, B., Altered Sleep-Wake Cycles and Physical Performance in Athletes, *Physiology and Behavior*, 90, 2007.
- ²⁶ Carskadon, MA., Sleep and Circadian Rhythms in Children and Adolescents: Relevance for Athletic Performance of Young People. *Clinical Sports Medicine*. 2005, 24(2): 319-28.
- ²⁷ IOM, 147-149
- ²⁸ Harvard, [Healthy Sleep: Sleep, Performance and Public Safety](#) (accessed 2.19.08).
- ²⁹ Video interview at above website of Charles A. Czeisler, MD, director, Division of Sleep Medicine, Harvard Medical School, cites statistics showing 1 in 5 motor vehicle crashes result from drowsy driving, the same number as alcohol and drug-related crashes
- ³⁰ Danner, FW, U. of Ky., “High School Start Times and Teen Auto Accidents,” Abstract, Associated Professional Sleep Societies, Seattle 2002. http://www.journalsleep.org/PDF/Oral_Split/Oral_Tuesday.pdf
- ³¹ Spiegel, et.al., Leptin levels are dependent on sleep duration: relationships with sympathovagal balance, carbohydrate regulation, cortisol, and thyrotropin. *J Clin Endocrinol Metab*. 2004; 89 (11) :5762-71.
- ³² Carskadon, et.al., Association Between Puberty and Delayed Phase Preference. *Sleep*, vol.16, 1993, p. 258-62.
- ³³ Lewy and Sach, The Dim Light Melatonin Onset as a Marker for Circadian Phase Position, *Chronobiology International*, vol. 6, 1989, p. 93-102.
- ³⁴ Carskadon, et.al., An Approach to Studying Circadian Rhythms of Adolescent Humans. *Journal of Biological Rhythms*, vol. 12, 1997, p. 278-89.
- ³⁵ Carskadon, et. al., Adolescent Sleep Patterns, Circadian Timing, and Sleepiness at Transition to Early School Days, *Sleep*, 1998.
- ³⁶ Harvard, [Healthy Sleep: Changes in Sleep with Age](#) (accessed 2.19.08) Video Interview, Richard A. Ferber.
- ³⁷ IOM, p. 142
- ³⁸ Carskadon, Adolescent Sleep Patterns: Biological, Social and Psychological Influences, New York: Cambridge University Press, 2002.
- ³⁹ National Sleep Foundation, 2006, [Sleep in America Poll](#), p. 8
- ⁴⁰ IOM, p. 142
- ⁴¹ IOM, p. 266.

-
- ⁴² Wolfson and Carskadon, A Survey of Factors Influencing High School Start Times, *NASSP Bulletin*, Vol. 89, No. 642, 2005.
- ⁴³ Harvard, [Healthy Sleep: Matt's Story: Rethinking School Start Times](#) (accessed 2.19.08).
- ⁴⁴ National Sleep Foundation: [A Look at the School Start Times Debate](#) (Accessed February 19, 2008).
- ⁴⁵ Carskadon, MA, Wolfson AR, Acebo C, Tzischinsky O, Seifer R, "Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days," *Sleep*, 1998 Dec. 15; 21 (8): 871-81.
- ⁴⁶ U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, National Institutes of Health, National Heart, Lung, and Blood Institute, *Your Guide to Healthy Sleep*, NIH Publication No. 06-5271, November 2005.
- ⁴⁷ Wahlstrom, [Changing Times: Findings From the First Longitudinal Study of Later High School Start Times](#), *NASSP Bulletin*, Vol. 86, No. 633, 2002.
- ⁴⁸ National Sleep Foundation, [Changing School Start Times: Wilton, Connecticut](#) (accessed February 19, 2008).
- ⁴⁹ Walker, Matthew P., et al, Harvard Medical School, Sleep-Dependent Learning and Memory Consolidation. *Neuron*, Volume 44, Issue 1, 2004, p.121-133.
- ⁵⁰ Harvard, [Healthy Sleep: Sleep, Learning, and Memory](#) (accessed February 19, 2008).
- ⁵¹ Stickgold, R. and M. Walker, Sleep-dependent memory consolidation and reconsolidation, *Sleep Medicine*, 2007; 8 (4): 331-343.
- ⁵² *Your Guide to Healthy Sleep*, NIH
- ⁵³ Ibid.
- ⁵⁴ Walker, Matthew P., et al, Harvard Medical School, Sleep-Dependent Learning and Memory Consolidation. *Neuron*, Volume 44, Issue 1, Sept. 2004, Pages 121-133.
- ⁵⁵ Stickgold, R. and M. Walker, Sleep-dependent memory consolidation and reconsolidation, *Sleep Medicine*, 2007; 8(4): 331-343.
- ⁵⁶ Jeffrey M. Ellenbogen, Peter T. Hu, Jessica D. Payne, Debra Titone, and Matthew P. Walker, "Human relational memory requires time and sleep," *Proc Natl Acad Sci U S A*. 2007 May 1; 104(18): 7723-7728.
- ⁵⁷ Beth Israel Deconess Medical Center, April 2007, [To Understand the Big Picture, Give it Time -- And Sleep](#) (Accessed February 19, 2008).
- ⁵⁸ Stickgold, Robert, et. al, Visual Discrimination Learning Requires Sleep After Training. *Nature Neuroscience*, 2000; Vol. 3, p. 1237-8.
- ⁵⁹ Harvard, [Healthy Sleep: Sleep, Learning, and Memory](#). (accessed, February 19, 2008).
- ⁶⁰ *Your Guide to Healthy Sleep*, NIH.
- ⁶¹ Ibid.
- ⁶² Emsellem, Helene A., MD., Snooze or Lose! 10 No-War Ways to Improve Your Teen's Sleep Habits, Joseph Henry Press, 2006, p. 58.
- ⁶³ IOM, p. 138.
- ⁶⁴ Stickgold, Robert, et. al, "Visual Discrimination Learning Requires Sleep After Training." *Nature Neuroscience*, 2000; Vol. 3, p. 1237-8.
- ⁶⁵ Baldus, Brian R., "Sleep Patterns in U.S. Navy Recruits: An Assessment of the Impact of Changing Sleep Regimens," Sept. 2002.
- ⁶⁶ Ibid.
- ⁶⁷ Andrews, Charles H., "The Relationship between Sleep Regimen and Performance in United States Navy Recruits," Sept. 2004.
- ⁶⁸ Ibid.