The Effects of Sleep Deprivation and Implications for Residency Training

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Overview

• Mechanisms regulating sleep
• Consequences of sleep deprivation
• Sleep deprivation during residency training
Definition of Sleep

“A normal reversible, recurring behavioral state of disengagement and unresponsiveness to the environment that is characterized by typical changes in the electroencephalogram (EEG)”

“Essential physiological need state that must be satisfied to ensure survival”
Sleep Stages and Normal Sleep

• NREM sleep
  - Stage 1: 3-8%
  - Stage 2: 45-55%
  - Stage 3/4 (slow wave sleep): 15-20%
• REM sleep: 20-25%
Mechanisms Regulating Sleep

- Homeostatic sleep drive
- Circadian rhythm
- Autonomic nervous system balance
Homeostatic Sleep Drive

- The pressure or drive for sleep increases proportionately to the time since last sleep
- Sleep deprivation increases desire for sleep
- Results in progressively increasing sleep propensity and concomitant degradations in alertness and performance
Circadian Rhythm

• Approximately 24-hour cycle of sleep and wakefulness
• Biological clock regulating sleep and wake is located in the suprachiasmatic nucleus (SCN) in the hypothalamus
• SCN is regulated by zeitgebers: sunlight and eating times
Autonomic Nervous System Balance and Sleep

• Factors that increase sympathetic nervous system activity inhibit sleep
  - Caffeine
  - Other stimulant drugs
  - Emotional upset
  - Physical activity
Normal Sleep Duration?

- Variable with age and for each individual person
- Young adults would spontaneously sleep an average of 8.5 h/night if given the opportunity
- Adult residents sleep ~ 2 h/night less than this amount
- Several epidemiologic studies support an ideal of 7-8 h of sleep per night

Sleep Deprivation

- Difficult to define for a given individual but can be a quantitative, qualitative, or timing issue
- Characterized as cumulative partial sleep deprivation vs. acute total sleep deprivation
- Both types of sleep deprivation have similar effects but cumulative partial sleep deprivation harder to recognize
- Exacerbates pre-existing sleep disorders, present in ~10% of population
Consequences of Sleep Deprivation

- Dose response sleep restriction study randomized 48 healthy adults to 4h, 6h, 8h sleep doses for 14 straight days or no sleep for 3 days
- Chronic restriction to 4-6 hrs resulted in significant cumulative dose-dependent deficits in cognitive performance on all tasks
- Subjective sleepiness ratings showed acute response to sleep restriction but only small further increases on subsequent days

Sleep. 2003 Mar 15;26(2):117-26
Consequences of Sleep Deprivation

- Regardless of mode of sleep deprivation, lapses in behavioral alertness linearly related to cumulative duration of wakefulness more than 15.84 hrs.
- Chronic restriction of sleep to 6h or less/night produced cognitive performance deficits equivalent to 2 nights of total sleep deprivation.

Sleep. 2003 Mar 15;26(2):117-26
C – Chronic sleep deprivation

Psychomotor performance lapses (#)

Study days

4 h TIB

6 h TIB

8 h TIB

No sleep

BL 2 4 6 8 10 12 14

Sleep. 2003 Mar 15;26(2):117-26
Effects of 48 hrs of continual wakefulness on mean cognitive throughput, as measured by a simple 4 minute addition test

Sleep. 1999 Jun; S94-S95
Consequences of Sleep Deprivation

• Significant changes in cognitive functioning: short term memory problems, impaired attention, and alteration of mental status resembling depression/anxiety
• Measurable neuropsychological deficits in motor skills, attention, and information processing
• Second leading cause of car accidents
• Poorer quality of life
Consequences of Sleep Deprivation

- Depression of ventilatory responses to hypercapnia and hypoxia in normal subjects
- Decrease in respiratory muscle endurance
- Impaired immune function with ↑TNF-α/IL-6 and ↓antibody production to vaccinations
- Possible increased risk of certain cancers

Sleep Duration and Mortality

- Many epidemiologic studies reporting increased mortality in “short sleepers” (<7 hr/night) and “long sleepers” (>9 hr/night)
- Mortality appears to be cardiovascular and malignancy related
- Recent meta-analysis performed of 23 available studies linking sleep duration and mortality

Sleep Duration and Mortality

### Sleep Duration and Mortality

![Graph showing relative risk of mortality associated with different sleep durations.](image)

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Comparison</th>
<th>RR (95% CI)</th>
<th>% Weight</th>
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</thead>
<tbody>
<tr>
<td>Ferrie, 2007</td>
<td>&gt; 9 versus 7-7.9 h</td>
<td>1.11 (0.88, 1.40)</td>
<td>4.85</td>
</tr>
<tr>
<td>Hublin, 2007</td>
<td>&gt; 8 versus 7-8 h</td>
<td>1.21 (1.10, 1.32)</td>
<td>17.24</td>
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<tr>
<td>Lan, 2007</td>
<td>≥ 9 versus 7-7.9 h</td>
<td>1.44 (1.02, 2.03)</td>
<td>2.33</td>
</tr>
<tr>
<td>Amagai, 2004</td>
<td>&gt; 9 versus 7-7.9 h</td>
<td>1.10 (0.88, 1.38)</td>
<td>4.91</td>
</tr>
<tr>
<td>Patel, 2004</td>
<td>≥ 9 versus 7-7.9 h</td>
<td>1.24 (0.99, 1.56)</td>
<td>4.89</td>
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<tr>
<td>Tamakoshi, 2004</td>
<td>&gt; 9 versus 7-7.9 h</td>
<td>1.47 (1.25, 1.73)</td>
<td>8.20</td>
</tr>
<tr>
<td>Burazeri, 2003</td>
<td>&gt; 8 versus 6-8 h</td>
<td>1.29 (0.49, 3.36)</td>
<td>0.32</td>
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<tr>
<td>Goto, 2003</td>
<td>&gt; 8 versus 6-7.9 h</td>
<td>1.46 (1.05, 2.03)</td>
<td>2.51</td>
</tr>
<tr>
<td>Heslop, 2002</td>
<td>&gt; 8 versus 7-8 h</td>
<td>0.89 (0.56, 1.40)</td>
<td>1.35</td>
</tr>
<tr>
<td>Kripke, 2002</td>
<td>≥ 9 versus 7-7.9 h</td>
<td>1.22 (1.13, 1.31)</td>
<td>20.89</td>
</tr>
<tr>
<td>Kojima, 2000</td>
<td>≥ 9 versus 7-8.9 h</td>
<td>1.12 (0.29, 4.30)</td>
<td>0.16</td>
</tr>
<tr>
<td>Gale, 1998</td>
<td>≥ 10 versus 9-9.9 h</td>
<td>1.31 (1.10, 1.56)</td>
<td>7.43</td>
</tr>
<tr>
<td>Qureshi, 1997</td>
<td>&gt; 9 versus 6-8.9 h</td>
<td>1.30 (1.11, 1.52)</td>
<td>9.03</td>
</tr>
<tr>
<td>Ruigomez, 1995</td>
<td>&gt; 9 versus 7-9 h</td>
<td>1.37 (0.89, 2.11)</td>
<td>1.52</td>
</tr>
<tr>
<td>Tsubono, 1993</td>
<td>≥ 9 versus 7-8.9 h</td>
<td>1.58 (1.16, 2.15)</td>
<td>2.85</td>
</tr>
<tr>
<td>Kaplan, 1987</td>
<td>&gt; 8 versus 7-8 h</td>
<td>1.02 (0.87, 1.19)</td>
<td>8.90</td>
</tr>
<tr>
<td>Branch, 1984</td>
<td>&gt; 8 versus 7-8 h</td>
<td>1.08 (0.79, 1.50)</td>
<td>2.63</td>
</tr>
<tr>
<td>Overall</td>
<td>&gt; 9 versus 7-7.9 h</td>
<td>1.23 (1.17, 1.30)</td>
<td></td>
</tr>
</tbody>
</table>

The Sleep Deprivation Epidemic

- In 1960, US adults slept average of 8-8.9 h/night
- Now average sleep time 6.9 h/night and >30% of adults report sleeping <6 h/night
- In a 2008 US survey, 11% of people reported insufficient rest or sleep every day in the preceding 30 days

The Sleep Deprivation Epidemic

• Reasons for high prevalence of sleep restriction:
  - Long work hours; night shift work
  - Family responsibilities
  - Increased time watching TV and on internet
  - Insomnia

The sleep deprivation epidemic has occurred over the same time period as the obesity/diabetes epidemic!

?Coincidence?
Cardiovascular Effects of Sleep Deprivation

- Increased blood pressure
- Activation of sympathetic nervous system
- In Nurses Health Study (NHS), women sleeping <5 h/night had increased risk of coronary disease over a 10 year period
Endocrinologic Effects of Sleep Deprivation

- Deterioration of glucose tolerance
- Higher evening cortisol levels
- Appetite stimulation, weight gain, and obesity
- In NHS, women sleeping <5 h/night had 1.84 relative risk of developing symptomatic diabetes
- Sleep-disordered breathing an independent risk factor for insulin resistance
- Among patients with type 2 diabetes, subjective poor sleep quality and insufficient sleep associated with higher levels of hemoglobin A1c
Sleep Deprivation and Obesity

• Multiple cross-sectional studies have consistently shown a significant association between short sleep duration and obesity

• Lowest BMI observed in those sleeping 7-8 h/night

• A 13-yr longitudinal study found that every extra hr increase of sleep duration was associated with a 50% reduction in risk of obesity

Sleep Deprivation and Appetite Regulation

- Leptin = appetite-inhibiting hormone secreted by adipose tissue
- Ghrelin = appetite-stimulating hormone released from stomach
- Sleep deprivation leads to ↓leptin and ↑ghrelin via increased orexinergic activity

Δ in daytime levels of leptin, ghrelin, appetite and hunger from 10- to 4h bedtimes in 12 healthy lean subjects after 2d.

**FIGURE 3.** Profiles of hunger ratings, appetite ratings, and the ghrelin-to-leptin ratio during the long-sleep (10 hour) and short-sleep (4 hour) conditions in a single representative subject.

FIGURE 1. Schematic of the putative pathways leading from sleep loss to diabetes and obesity risk.

Many questions remain...

- Experimental sleep deprivation only shows short-term effects
- Epidemiologic studies often rely on subjective reports of sleep duration
- Majority of studies cross-sectional so difficult to determine direction of causality
"How can I ever become a doctor if I don't learn to go without sleep?"
“Given the uncommon stresses inherent in fulfilling the demands of their training program, residents must be allowed sufficient opportunities to meet personal and family obligations, to pursue recreational activities, and to obtain adequate rest.”

From the Association of American Medical Colleges, Compact Between Resident Physicians and Their Teachers, 2005
Recognizing Sleep Deprivation in Residency and Fellowship

- Repeatedly yawning and “nodding off” during conferences or other sedentary activities (driving)
- Loss of ability to perform usual activities quickly
- Poor memory, concentration, judgment
- Irritability, moodiness, depression
- Dozing off while writing notes/orders or while reviewing medications/labs
- Repeatedly checking your work
THE EPWORTH SLEEPINESS SCALE

How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

- 0 = no chance of dozing
- 1 = slight chance of dozing
- 2 = moderate chance of dozing
- 3 = high chance of dozing

<table>
<thead>
<tr>
<th>SITUATION</th>
<th>CHANCE OF DOZING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting and reading</td>
<td></td>
</tr>
<tr>
<td>Watching TV</td>
<td></td>
</tr>
<tr>
<td>Sitting inactive in a public place (e.g. a theater or a meeting)</td>
<td></td>
</tr>
<tr>
<td>As a passenger in a car for an hour without a break</td>
<td></td>
</tr>
<tr>
<td>Lying down to rest in the afternoon when circumstances permit</td>
<td></td>
</tr>
<tr>
<td>Sitting and talking to someone</td>
<td></td>
</tr>
<tr>
<td>Sitting quietly after a lunch without alcohol</td>
<td></td>
</tr>
<tr>
<td>In a car, while stopped for a few minutes in traffic</td>
<td></td>
</tr>
</tbody>
</table>

Total Score=
Figure 5. The figure shows the effect of 24–30 hours of acute sleep loss on various types of performance based on a meta-analysis of 60 sleep-deprivation studies of physicians (top panel) and nonphysicians (bottom panel). The average effect sizes are shown for each performance type and are corrected for measurement error and standard error of the corrected effect sizes. Following 24–30 hours on duty, physicians’ clinical performance deteriorated by ~1.5 standard deviations as compared to when ‘rested’ (top panel). As most of these data were collected under ‘field’ conditions, however, physicians in the ‘rested’ condition were unlikely to be non-fatigued, which may explain the greater effect of sleep deprivation observed under more highly controlled laboratory conditions (bottom panel).
Circadian Misalignment and Resident Schedules

- SCN acts as endogenous circadian pacemaker to drive alertness during day and sleepiness at night
- Rapid changes in work schedules from days to nights and vice versa cause a permanent state of “jet lag”
- Prolonged wakefulness (>16 hr) + circadian misalignment likely responsible for fatigue-related errors or accidents, which often occur at night

Sleep Inertia and the Pager

• Sleep inertia refers to the cognitive impairment present immediately on awakening from sleep
• The first 15-30 min after waking are a vulnerable period and performance decrements can exceed those after 24 hrs of continuous wakefulness
• Highlights risk of residents committing fatigue-related errors when woken from sleep by a page

Sleep inertia during 1st 4 hrs of wakefulness after an 8 hr sleep – takes 2+ hrs to reach maximal performance; highest risk of fatigue-related error in 1st 30 min after awakening

Cognitive performance worst immediately after waking and more impaired than following 24 hrs of continuous wakefulness

JAMA. 2006 Jan 11;295(2):163-4
Consequences of Sleep Deprivation for Residents

Negative Effects of Sleep Loss and Fatigue on Resident Physicians

Impaired Ability to Attend, Learn, Remember and Problem Solve
Concentration, Complex Learning, Memory and Executive Functions

Reduced Job Performance and Professionalism
Interactions with Patients and their Families, Empathy, Motor Skills, Efficiency, Accuracy and Medical Error Rates

Diminished Quality of Life, Health, and Well-Being
Mood, Psychological Health, Relationships with Spouse, Family and Friends, Motor Vehicle and other accidents

Consequences of Sleep Deprivation for Residents

- GW Small first described features of a stress syndrome common among graduate physicians:
  - Episodic cognitive impairment
  - Chronic anger
  - Pervasive cynicism
  - Family discord
- More recent data stresses prevalence of anxiety, depression, obsessive-compulsive trends, hostility, and alcohol/substance abuse

Consequences of Sleep Deprivation for Residents

- Residents who average ≤5 hrs of sleep/night report more:
  - Serious accidents and injuries
  - Conflict with other professional staff
  - Alcohol use
  - Medication use for the purpose of staying awake
  - Noticeable weight changes
  - Working in an “impaired condition”
  - Medical errors
Consequences of Sleep Deprivation for Residents

- Physicians in-training working traditional schedules with recurrent 24 hr shifts:
  - Make more medical and diagnostic errors
  - Have more attentional failures
  - Suffer more needlestick injuries
  - Increase their risk of a motor vehicle crash
  - Experience a deterioration in performance on both clinical and nonclinical tasks, similar to having blood alcohol level of 0.05-0.10%

Sleep Deprivation and Performance

- 20 interns studied in ICU/CCU during both traditional and intervention schedule
- Intervention interns worked 19.5 hrs/wk less, slept 5.8 hrs/wk more, and slept more in the 24 hrs preceding each work hr
- Duration of sleep
  - 6.6 +/- 0.8 hrs/day during traditional schedule
  - 7.4 +/- 0.9 hrs/day during intervention schedule

Sleep Deprivation and Performance

• Interns had <1/2 the rate of attentional failures during on-call nights on intervention schedule
• Interns made significantly more medical errors on traditional schedule:
  - 35.9% more serious medical errors
  - 56.6% more unintercepted serious errors
  - 20.8% more serious medication errors
  - 5.6 times the number of serious diagnostic errors
• No differences in adverse event rates between groups

Medical Errors Reported by Residents Relative to the Number of Extended-Duration Work Shifts (> 24 hours) per Month

A - Medical errors

B - Adverse outcome

C - Fatality
Sleep Deprivation and Performance

• Dozens of studies in residents showing poorer performance in
  – ICU simulation sessions
  – Surgical simulation sessions
  – Tests of simple neurobehavioral performance
Risk of Motor Vehicle Crashes (MVCs)

- Prospective nationwide web-based survey in 2002-3
- 2737 interns (79% medical specialties, 69% car commuters) completed monthly surveys re: work hrs, extended work shifts, MVCs, near-miss incidents, and incidents involving involuntary sleeping
- Average weekly work hrs: 70.7 +/- 26.0 hrs
- Average monthly no. of extended shifts: 3.9 +/- 3.4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Extended Work Shifts (≥24 hr)</th>
<th>Nonextended Work Shifts (&lt;24 hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crashes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. reported</td>
<td>58</td>
<td>73</td>
</tr>
<tr>
<td>No. of commutes</td>
<td>54,121</td>
<td>180,289</td>
</tr>
<tr>
<td>Rate (per 1000 commutes)</td>
<td>1.07</td>
<td>0.40</td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td>2.3 (1.6–3.3)</td>
<td>1.0</td>
</tr>
<tr>
<td>Near-miss incidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. reported</td>
<td>1,971</td>
<td>1,156</td>
</tr>
<tr>
<td>No. of commutes</td>
<td>54,121</td>
<td>180,289</td>
</tr>
<tr>
<td>Rate (per 1000 commutes)</td>
<td>36.42</td>
<td>6.41</td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td>5.9 (5.4–6.3)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*A within-person case-crossover analysis was used to assess the risks of motor vehicle crashes and near-miss incidents among interns during commutes after extended shifts as compared with nonextended shifts. A two-by-two table was constructed for each intern who reported either a crash or a near-miss incident, consisting of the number of crashes or near-miss incidents after an extended shift, the number of crashes or near-miss incidents after a nonextended shift, the number of extended shifts that did not precede a crash or a near-miss incident, and the number of nonextended shifts that did not precede a crash or a near-miss incident. CI denotes confidence interval.
<table>
<thead>
<tr>
<th>Question</th>
<th>0 Extended Work Shifts</th>
<th>1–4 Extended Work Shifts</th>
<th>≥5 Extended Work Shifts</th>
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<tbody>
<tr>
<td></td>
<td>No. of Person-Months</td>
<td>No. of Person-Months</td>
<td>No. of Person-Months</td>
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<tr>
<td>Did you nod off or fall asleep</td>
<td>3035</td>
<td>199</td>
<td>3068</td>
</tr>
<tr>
<td>while driving?</td>
<td></td>
<td></td>
<td>3068</td>
</tr>
<tr>
<td>Did you nod off or fall asleep</td>
<td>3039</td>
<td>311</td>
<td>3078</td>
</tr>
<tr>
<td>while stopped in traffic?</td>
<td></td>
<td></td>
<td>3078</td>
</tr>
</tbody>
</table>

* Data are from interns’ monthly reports on extended shifts. The number of person-months varies because nonresponses were eliminated from the analysis. Rates represent the proportion of months in which participants reported one or more incidents of nodding off or falling asleep, regardless of how many incidents were reported. CI denotes confidence interval.
Risk of Motor Vehicle Crashes

- In summary, the odds that interns will have a MVC on the commute after an extended work shift is more than double the odds after a nonextended shift.
- Near-miss incidents more than 5X as likely to occur after an extended work shift.
- Every extended work shift scheduled in a mo. increased the monthly risk of a MVC by 9.1%.

Risk of Motor Vehicle Crashes

- May have legal implications i.e. drivers can be convicted of vehicular homicide for driving when impaired by sleepiness
- NJ has added to reckless driving definition: “driving after having been without sleep for a period in excess of 24 consecutive hours”
- An employer’s responsibility for fatigue-related MVCs can continue after an employee has left work

UCLA Data

- 2007 UCLA graduate medical education survey of 744 residents (78% of housestaff):
  - 19.5% responded “yes” to “have you fallen asleep while driving as a result of work-related fatigue in the past year?”
  - <50% of residents reported that they would take a nap at the hospital prior to driving home if they were feeling very fatigued after a shift
Risk of Percutaneous Injuries (PIs)

• PIs more frequent from 6:30-17:30 after working overnight (1.31/1000) compared with same times on previous day (0.76/1000) - OR 1.61
• Extended work injuries occurred after mean of 29.1 consecutive work hrs vs. 6.1 hrs
• Injuries more frequent at night (1.48/1000 vs. 0.70/1000, OR 2.04)
• Primary reasons attributed by residents were lapse in concentration (64%) and fatigue (31%)

JAMA. 2006 Sep 6;296(9):1055-62
C - Percutaneous injuries

Rate/1000 opportunities

Extended | Nonextended
Attempts to Fix the Problem

• Some departments offer round-trip cab vouchers to residents on request

• A lecture on SAFER (Sleep, Alertness, and Fatigue Education in Residency) program had no beneficial effect on intern sleep

• A nap intervention for interns 2 wks/mo. (leading to 41 more min of sleep/on-call night) reduced subjective post-call fatigue but no other outcomes evaluated

Arch Intern Med. 2007 Sep 10;167(16):1738-44
Fixing the Problem?

- Resident education/fatigue management programs (now required by ACGME)
- Minimizing and taking extra caution during post-call procedures or operations
- Encouraging pre-call naps prior to night shifts
- Carpool – don’t drive when tired!
- Wise use of caffeine – prophylactically (i.e. 30 minutes prior to drive home) rather than regularly
- Minimizing moonlighting
Fixing the Problem?

• Recognizing any medical condition that may impair sleep
• Making sleep a priority during any time off
• Further reduction of work hrs (European healthcare workers limited by law to 13 consecutive hrs of work and 48-56 hrs work/wk)
• Scientifically designed work schedules
New 2011 ACGME Duty Hour Rules

• Duty hours not to exceed 80 per week
• Shifts no longer than 16 hrs for interns
• Shifts no longer than 24 hrs for residents
• +6 hrs allowed for “continuity of care”
• Recommend “alertness-management strategies" and "strategic naps "especially after 16 hrs of continuous duty and between 10 p.m. and 8 a.m
• Costly implementation

http://acgme-2010standards.org/proposed-standards.html
ACGME work-hour changes…
what we know so far…

- Several (but not all) studies indicate improvements in quality and safety in patient care
- Surveys of trainees reveal improved quality of life and less fatigue but varied effects on perceived patient care and learning
- Surveys of program directors and faculty largely negative regarding education in residency, poor continuity of care, and increased workload for faculty
- In other words, the jury is still out….  

Sleep. 2010 Aug 1;33(8):1043-53
THE END