Got Sleep?
Consequences of Sleep Deprivation

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Stanford Sleepiness Scale

Rate your level of alertness

Feeling active, vital, alert or wide awake	1
Functioning at a high level, not at peak, able to concentrate	2
Awake but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream like thoughts	7
Asleep	X

Effects of Sleep Deprivation

- Extent of the problem
- Safety issues
- Health effects
- Cognitive impairment

Normal Sleep Requirement

- Adults 7-8 hours
- Varies with age in children
  - Newborns 16-20 hours
  - Infants 13-15 hours
  - Toddlers 12 hours
  - Preschool 11-12 hours
  - School age 10-11 hours
  - Adolescents 9 hours

Sleep Deprivation/Loss

- Major symptom is excessive daytime sleepiness (EDS)
- Prevalent problem, increasing with age
- At least 18% adults report insufficient sleep
- Increasing percentage of adults sleeping less than 6 hours/night over past 20 years

Sleep Deprivation/Loss

- CDC report 2005, slept ≤ 6 hours/night
- Changes over 20 year period
- Men and women age 30-44 years
  - Men ↑26% to 32%, women ↑22% to 29%
- Men and women age 45-64 years
  - Men ↑23% to 33%, women ↑23% to 32%
- Adolescents –need 9+ hours of sleep
  - 26% slept ≤ 6.5 hours on school night

National Sleep Foundation 2006 *Sleep in America* Poll

- 20% of adolescents get 9 hours sleep/school nights
- Average 6th grader sleeps 8.4 hours on school nights
- > 50% of adolescents report feeling tired or sleepy during the day
- 9 out of 10 parents believe their adolescent is getting enough sleep at least a few nights/week=awareness gap

National Sleep Foundation 2006 *Sleep in America* Poll

- 25% of HS students fall asleep once/week in class
- 22% fall asleep doing homework
- 14% arrive late or miss school
- Teens with 9+ hours of sleep report more positive mood
- 15% of 10th to 12th grader drivers drive *drowsy at least* once a week
- 14% of adults drive *drowsy* once a week

Safety Issues

- Serious accidents after insufficient sleep
- Exxon Valdez
  - Extensive oil spill into Prince William Sound
  - Environmental damages, $2 billion clean-up
  - Third mate had slept only 6 hours in previous 48→→severely sleep deprived

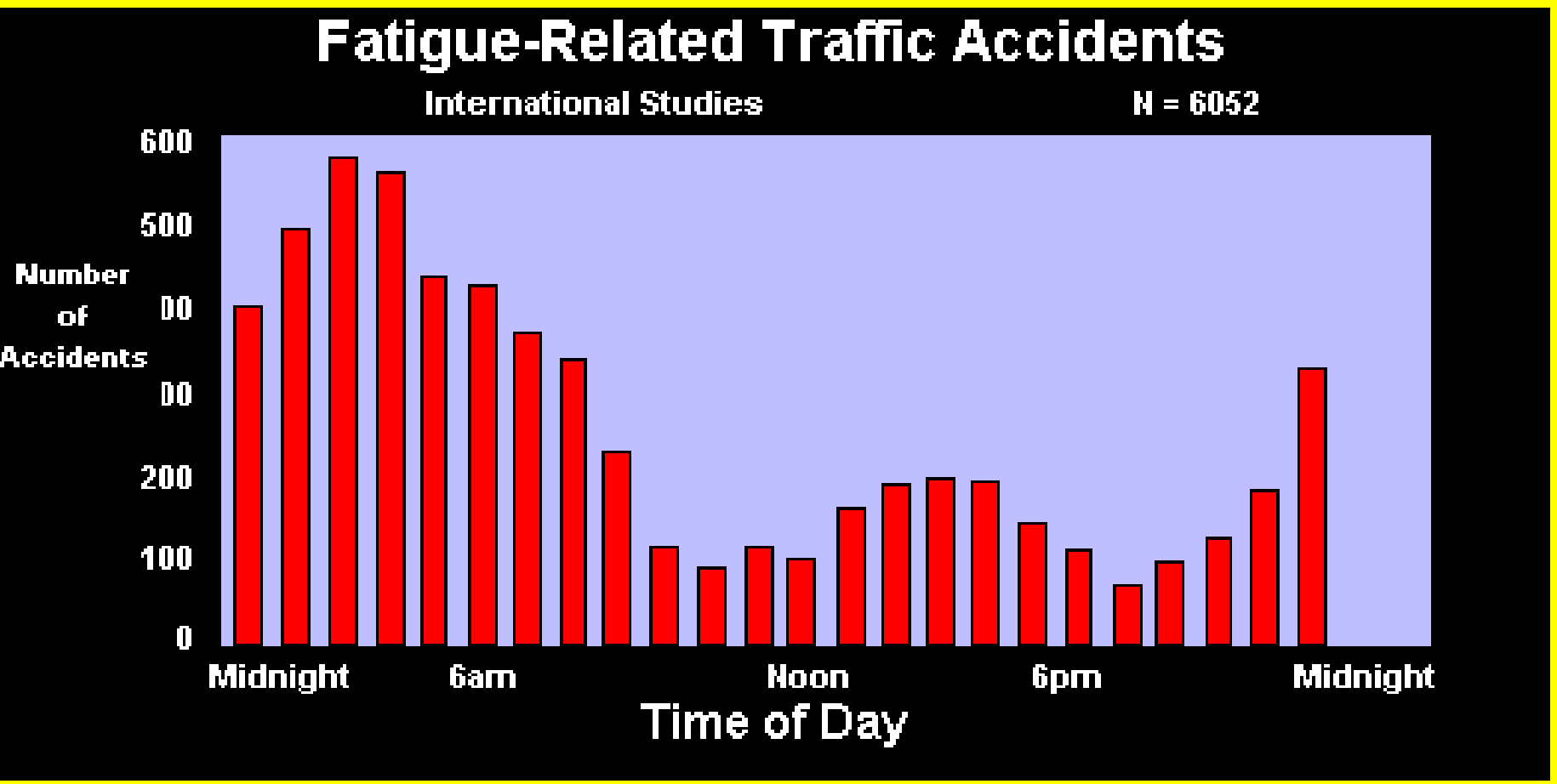
Safety Issues

- Space shuttle Challenger
- Presidential commission
- Key launch managers slept only 2 hours night before and on duty at 1 am
- Critical management decisions affected by excessive work hours

Safety Issues

- NHTSA- 100,000 accidents are caused by driver fatigue with 1500 deaths 71,000 injured
- Increased risk of vehicular crashes
  - Those with untreated OSA
  - Persons with < 6 hours sleep/night
  - 1 in 5 serious car crashes related to sleepiness
- Increased accident frequency at times of increased sleep propensity

Motor Vehicle Crashes



Lavie et al 1986, Langlois et al, 1985

Safety Issues

- 2003 New Jersey law criminalized driving while drowsy
- “Maggies Law” for Maggie McDonnell killed in a head on collision by driver who had not slept in 30 hours
- NTSB- 57% of 4800 fatal crashes involving trucks “fatigue” related
  - Study by dePinho et al
  - 300 truck drivers, sleep time 5.6 $\pm$ 1.3 hours
  - Poor sleep in 46%, 46% ESS > 10
  - Positive correlation between ESS and previous accidents

Sleepy Drivers-What Can We Do?

- *Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes*, JCSM 2008, Danner and Phillips
- Comparison of sleep duration, MVA in the 17 and 18 yo year before and after school start times delayed one hour in 1 county
- Significant increase in avg sleep duration
  - *In all groups (p <.001)*
  - *30 minutes in HS seniors*

Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes, JCSM 2008

- Increase in those getting 8+ hours of sleep
  - 35.7% to 50% ($p < .01$)
- Weekend catch up sleep decreased
  - From 1.9 to 1.1 hours ($p < 0.001$)
- Decrease in auto crashes after stable rate
  - For 17-18 yo licensed drivers county vs state
  - Only for county where start times delayed
  - Dropped by 16.5% while rest of state increased by 7.8% ($p < .01$)

Safety Issues

- Libby Zion Case-1984
- 19 y.o. college student died at NYC hospital of undiagnosed treatable infection
- Grand jury ruled death
  - Due to undiagnosed but treatable infection
  - Inadequate resident supervision and fatigue
  - New York state law-reduce resident work hours
  - Other states, ACGME followed

Safety Issues

- Resident work hours and medical errors
- Sleep deprived surgical residents
  - Up to 2X number of surgical errors in surgery simulation-Grantcharov et al, Eastridge et al
- ACGME survey of 5600 medical residents
  - Residents working > 80 hours were 50% more likely to make a significant medical error-Baldwin and Daughtery

Safety Issues

- Harvard Work Hours, Health and Safety Study
  - Traditional schedule ~ 80 hours/week
  - Intervention schedule
    - No 24 hour shifts
    - $\leq$ 63 hours/week
  - Intensive care unit
    - Most intense service unit
    - Highest error rate

Harvard Work Hours, H & S Study

- Intervention schedule
- Increased resident sleep time by 6 hours
- Rate of “attentional” failures cut by half
- Comparison of errors
  - Interns randomized to the two schedules
  - Direct observation of two physicians blinded to the schedule

Harvard Work Hours, H & S Study

Variable	Traditional	Intervention	P value
Serious medical errors	176	91	<0.001
Nonintercepted serious errors	58	26	<0.001
Intercepted serious errors	91	50	0.02
Medication	129	75	0.03
Diagnostic	24	3	<0.001

Safety Issues

- Ayas et al
- Interns sustaining percutaneous injuries
  - After extended work day vs. non-extended
  - 2737 interns surveyed
- Increased rate after extended work hours
  - Odds ratio 1.61

Health Effects

- Obesity
- Diabetes/impaired glucose tolerance
- Cardiovascular disease/hypertension
- Inflammatory/Immune systems
- Anxiety/depression

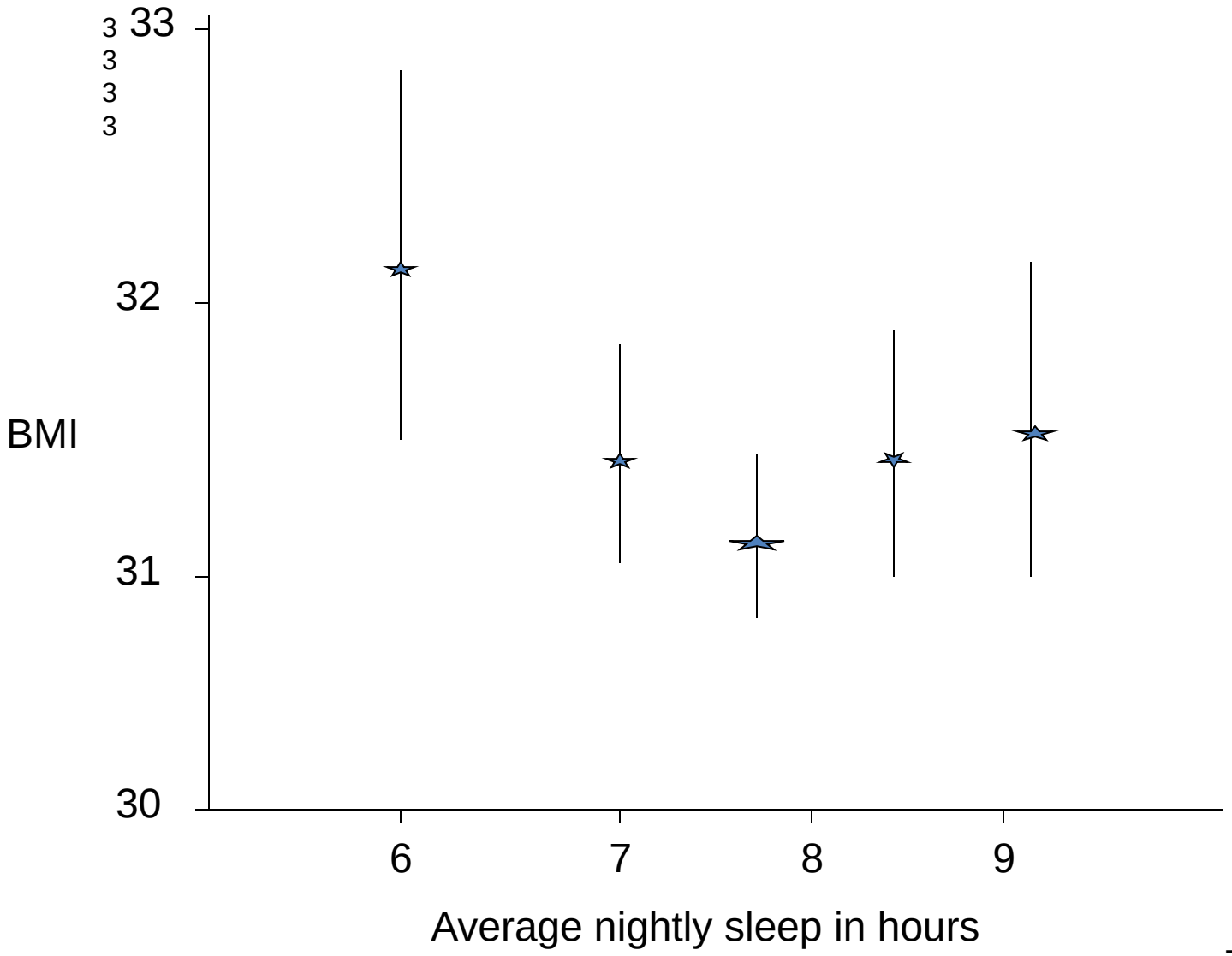
Sleep Deprivation and Obesity

- Dose response relationship between sleep loss and obesity for sleep time <7 hours
- Shorter sleep time, greater BMI
- 13 year prospective cohort of 500 adults
  - By age 27 years, those with < 6 hours sleep
  - 7.5 x more likely to have ↑ BMI
  - Controlled for exercise, family hx, demographics (Hasler, et al)

Sleep Deprivation and Obesity

- Relationship of sleep duration and BMI in 1000 adults Taheri et al
- U-shaped curve
- Lowest BMI in those who slept 7.7 hours
- Higher BMI for SPT longer and shorter

BMI VS SLEEP PERIOD TIME



Taheri et al

Sleep Deprivation and Obesity

- Hairston, et al found increased visceral and SQ adipose tissue by CT scan in those < 40 years of age sleeping ≤ 5 hours vs. 6-7 hours
  - BMI, Abd CT at 5 year intervals
  - Adjusted for age, gender, race, baseline, activity, calorie intake, smoking status and education

Sleep Deprivation and Obesity

- Physiologic mechanisms behind obesity & ↓TST
  - Many authors have “weighed in” on this
- Decreased sleep time
  - Lower leptin levels-appetite suppression
  - Higher ghrelin levels-appetite stimulation
  - Increased opportunity to eat
    - Hyperphagia in sleep deprived animals
    - Increased intake of high fat/carbohydrate foods
  - Fatigue→→decreased physical activity
  - Altered thermo-regulation

Sleep Deprivation and Obesity

- Australian study in 6000 15 year olds
  - Males with ≤ 8 hours of sleep 3.1 times greater chance of overweight compared with those with ≥ 10 hours of sleep
- Knutson – study in > 4000 17 year olds
  - Overweigh risk ↑10% for each hour in sleep decrease
  - Only among boys
- Many studies suggest boys more susceptible than girls

Sleep Deprivation and Diabetes

- Sleep Heart Health Study
  - Community based cohort, 1486 adults
- Those sleeping $\leq$ 5 hours 2.5 x more likely to have diabetes compared to those sleeping 7-8 hours/night
- Sleeping 6 hours/night→1.7 x more likely
- Increase in impaired glucose tolerance in both groups

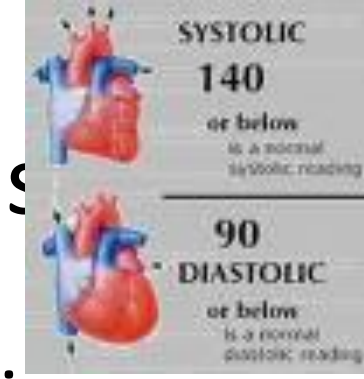
Sleep Deprivation and Diabetes

- Nurses Health Study
- Follow up over 10 years in 70,026 female nurses without diabetes
- Sleeping $\leq$ 5 hours/night 1.57 odds ratio of developing diabetes, decreased to 1.18 when adjusted for BMI

Sleep Deprivation and Diabetes

- Spiegel et al examined experimental sleep restriction in 11 healthy males
- Slept 4 hours/night for 6 nights
- Glucose clearance 40% slower with sleep loss compared to after recovery

Sleep Deprivation and Hypertens



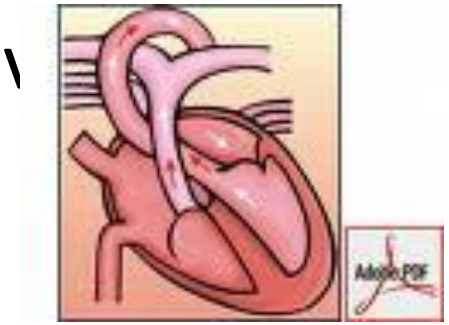
- National Health and Nutrition Examination Survey (NHANES I) group 1982-1992
- 4810 subjects
- Sleep duration $\leq$ 5 hours
  - Increased risk of hypertension
  - 2.1 odds ratio in ages 32-59 years

Sleep Deprivation and MI

- Nurses Health Study
- No coronary heart disease at baseline
- 10 year follow-up
- In those with $\leq$ 5 hours sleep/night
  - Increased likihood fatal & non-fatal MI
  - Risk increased 45%
  - Adjusted for age, BMI, smoking, snoring
  - Increased risk if $\geq$ 9 hours sleep/night as well

Sleep Deprivation and MI

- Epidemiologic study by Liu et al
- Two to three fold increase in cardiov events
  - Average sleep ≤ 5 hours/night
  - Chronic sleep deprivation of ≤ 5 hours/night twice per week
- Proposed mechanism activation of inflammatory process(es) with sleep loss



Sleep Deprivation and Mortality

- Increase in age-specific mortality
- Kripke et al, Tamakoshi et al, Patel et al
- 83,000 to 1.1 million subjects
- Surveys about sleep duration, 6-14 year follow-up
- Increased deaths short and long sleepers compared to 7 hour sleepers
- Sleeping $\leq$ 5 hours→15% ↑mortality from all causes

Sleep Deprivation and Other Health Issues

- Spiegel et al examined chronic sleep restriction on antibody response
- 6 nights ↓ sleep period to 4 hours
- Decreased antibody response to influenza vaccination by 50% (Compared to subjects with usual sleep duration)

Sleep Deprivation and Other Health Issues

- Decreased febrile response to endotoxin in sleep restriction reported by Balachandran et al
- Vgontzas et al found increased secretion of IL-6 and TNFα after 1 week of sleep restriction

Sleep Deprivation and Mood

- Adults with chronic sleep deprivation
  - ↑anxiety, depressive symptoms, distress and ETOH use
- Study of 2200 middle school students over 3 year period found sleep deprivation associated with ↑depressive symptoms, ↓ self esteem
- Study of 3000 adolescents, those with inadequate sleep had ↑behavior problems, depressed mood, anxiety, ETOH use

eep Deprivation and Performance Deficits

- Involuntary micro sleeps
- Unstable attention of intensive performance tasks→↑errors of commission/omission
- Cognitive slowing in tasks with no time limit
- Increased cognitive errors with time limited tasks

Sleep Deprivation and Performance Deficits

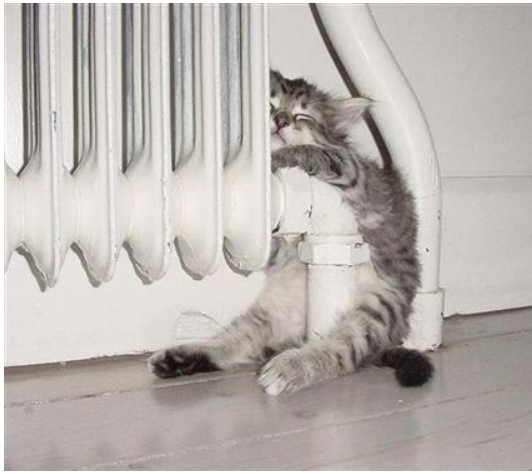
- Decrease in short term memory recall
- Reduced learning of cognitive tasks
- Worsened performance with prolonged task duration
- Increased compensatory efforts

Working Memory Capacity is Decreased in Sleep-Deprived Internal Medicine Residents- Gohar, Adams, Gertner, et al.JCSM, 2009

- 39 residents completed study, Q 4 day call
  - Sleep questionnaire, sleep logs, actigraphy
  - Tests of WMC, math problems
  - Self rating of sleepiness
  - Comparison of call and non-call months

Working Memory Capacity is Decreased in Sleep-Deprived Internal Medicine Residents- Gohar, Adams, Gertner, et al.JCSM, 2009

- Average sleep times
  - Logs showed more hours than acitgraphy
  - Non call months stable sleep duration at 7.25 hours
  - On call months variable sleep duration mean+=6.39 h
    - Mean on call sleep 3.7 hours,
    - Mean sleep post call was 10.1 hours



Working Memory Capacity is Decreased in Sleep-Deprived Internal Medicine Residents- Gohar, Adams, Gertner, et al.JCSM, 2009

- ↑Self rated sleepiness at time of test
  - Lower WMC scores, more math errors
  - More accuracy and speed errors
  - Not specifically correlated with hours sleep
  - Ten residents "resistant" with better WMC scores on call months
- Full recovery of WMC didn't occur until 4th post call day
- No evaluation of impact on patient care

Sleep Deprivation and Performance Deficits

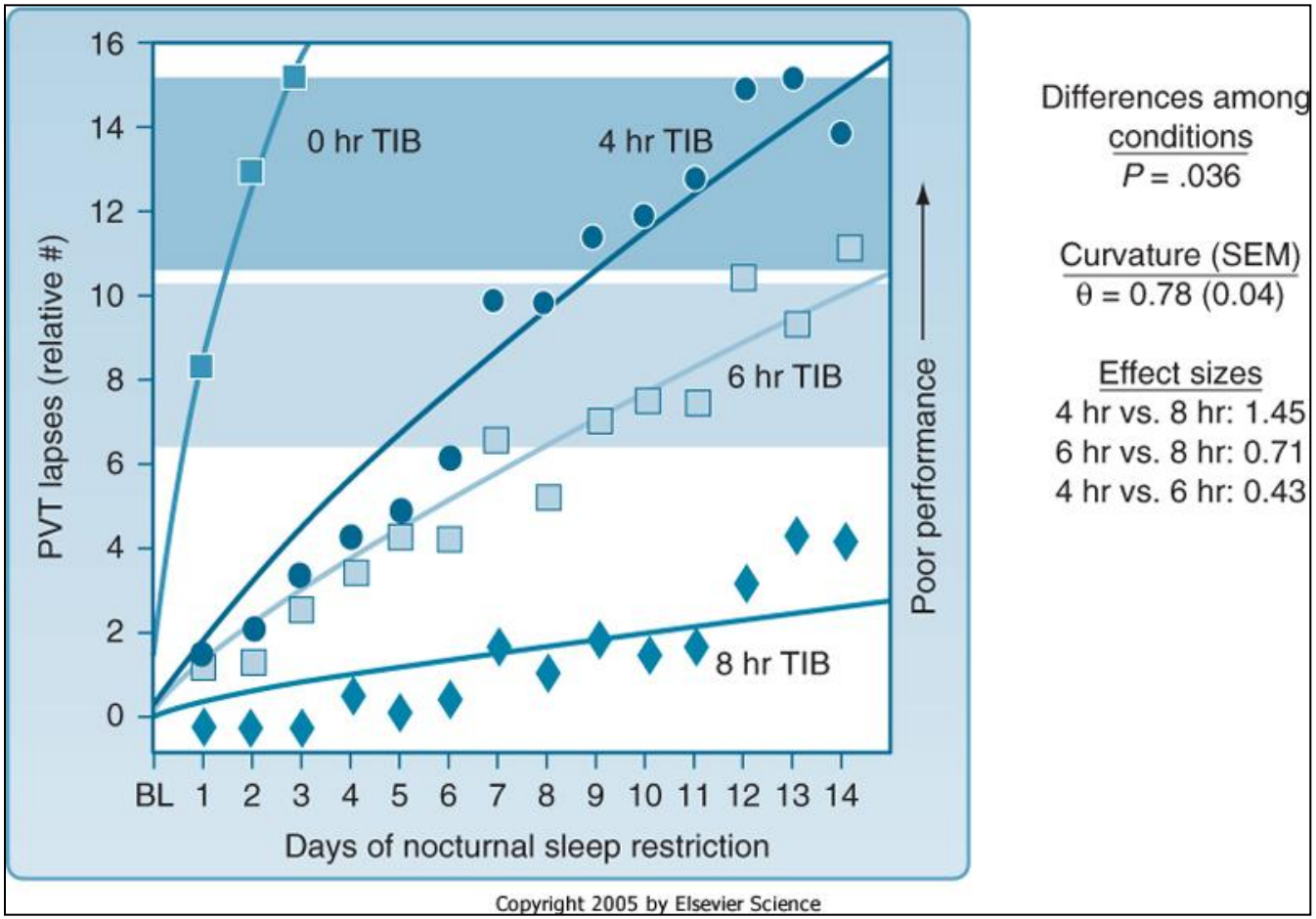
- Truck drivers randomized to 7 nights of sleep restriction-3,5,7,or 9 hours TIB
- 3 and 5 hour subjects
  - ↓ performance across 7 days
  - ↑ reaction time, lapses
- 7 hour subjects
  - ↑ reaction time, no lapses

Sleep Deprivation and Performance Deficits

- 9 hour group
  - Stable performance
- No accumulation beyond 6 days

Sleep Deprivation and Performance Deficits

- Sleep restriction 4,6,8 for 14 nights
- Deficits worsened for entire period
- Compared to subjects with 4 days of total sleep deprivation
- Those in 4 and 6 hour groups had similar deficits to subjects awake for 24-48 hours
- Subjects unaware of deficits by self ratings



Sleep Deprivation and Performance Deficits

- Herscovitch examined subjective evaluation of sleepiness
- Stanford Sleepiness Scale ratings for 5 nights of sleep restriction
- Scores increased over the 5 nights
- Subjective ratings underestimated the extent of dysfunction

Ethanol and Sleep Loss: A "Dose" Comparison of Impairing Effects

Roehrs et al; Sleep2003;26(8):981-5.

- Comparison of ETOH intake and sleep restriction in 32 healthy volunteers
  - Sleep loss of 0, 2,4 6, 8 hours
  - ETOH doses 0,0.3, 0.6, 0.9 gm/kg
- Dose response
  - Decrease in sleep latency
  - Slowed reaction time
  - Poorer tracking
  - Reduced memory recall

Sedative Effects of Sleep Loss and ETOH

Sleep loss in hours	ETOH dose in g/kg	Number of beers	% Breath ETOH Concentration
8	2.16	10-11	0.19 %
6	1.07	7-8	0.10 %
4	1.0	5-6	0.095 %
2	0.5	2-3	0.045 %

Ethanol and Sleep Loss: A "Dose" Comparison of Impairing Effects

Roehrs et al; Sleep2003;26(8):981-5.

- Sleep loss as potent as ETOH in impairing performance
- Sleep loss more potent in sedative effects
- Similar deficits in psychomotor tasks
- Williamson et al –similar findings
  - 17-19 hours without sleep
  - Performance similar to BAC 0.05%

Sleep Deprivation and Performance Deficits

- Killgore et al studied 34 healthy volunteers
- Iowa Gambling Task
  - Simulates real world decision making with element of uncertainty
- Baseline and after 49.5 hours sleep deprivation
  - Increased risk taking post sleep loss
  - Worsened as game progressed
  - More risks in older subjects

The Effects of 53 hours of Sleep Deprivation on Moral Judgment, Kilgore, Kilgore, Day, et al JCSM 2007

- 29 healthy volunteers, active military
- Ages 20-35 years, healthy, awake 53.5 h
- Compared responses pre and post
  - 60 practical dilemmas –moral and non-moral
  - To determine if course of action suggested was appropriate or inappropriate
- Sleep deprivation resulted in significantly longer response times to moral personal dilemmas but not other dilemmas

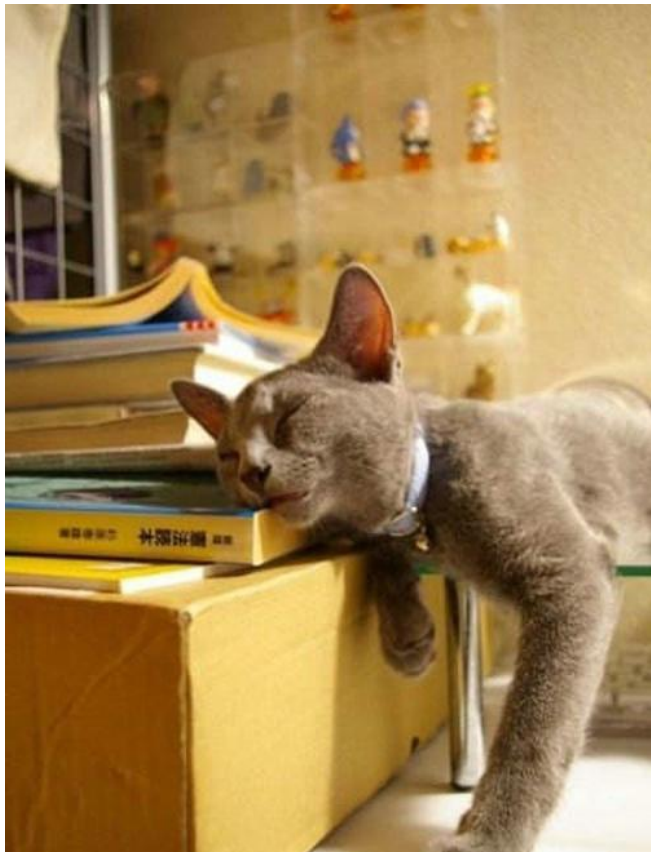
Sleep Deprivation and Performance Deficits

- Randazzo et al studied 16 children ages 10-14 years, with 11 and 5 hours TIB
- Sleep restricted group
  - Shortened sleep latency
  - Decreased verbal creativity
  - Decreased learning of abstract concepts
  - ↓ higher cognitive functions
  - No difference in rote memory, less complex cognitive function

$$S(q) = -\frac{e^2 \hbar^2 k_B T}{m^2 c} \sum_{n=-\infty}^{n=\infty} \oint k^2 \sin^2 \theta [\ldots]$$

Sleep Deprivation and Performance Deficits

- Fallone et al studied teacher ratings in children with sleep restriction for 1 week
- 74 children ages 6-12 years, no history of behavior or academic problems
- Sleep restriction resulted in
  - Increased academic problems
  - Increased attention problems
  - No increase in hyperactivity score



Sleep Deprivation

- Safety issues
  - Traffic accidents, medical errors
  - Don’t drive big oil tankers
- Health problems
  - Diabetes, hypertension, MI, obesity, mortality
- Mood disorders
  - Depressive symptoms, anxiety
- Performance deficits
  - Sleepiness, ↓ psychomotor performance, ↓ higher cognitive function

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