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The Science of Performance at Work

Industry leading fatigue modeling software

Fatigue in a Shiftwork Setting

Presented by: Dr. Jaime K. Devine

What is Fatigue?

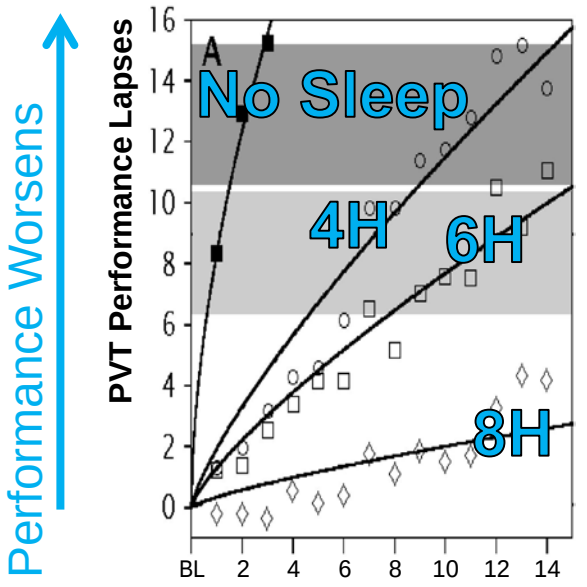
- No one single definition for fatigue
- Fatigue affects people differently
- Fatigue increases the risk of hazard exposure
  - Impaired judgement and ability to think
  - Difficulty concentrating
  - Lower motivation
  - Slower reaction times
  - Increased risk-taking behavior
  - Reduced strength and physical stamina

Subjective vs. Objective Fatigue

Most people underestimate their level of fatigue and how they are impaired by it.

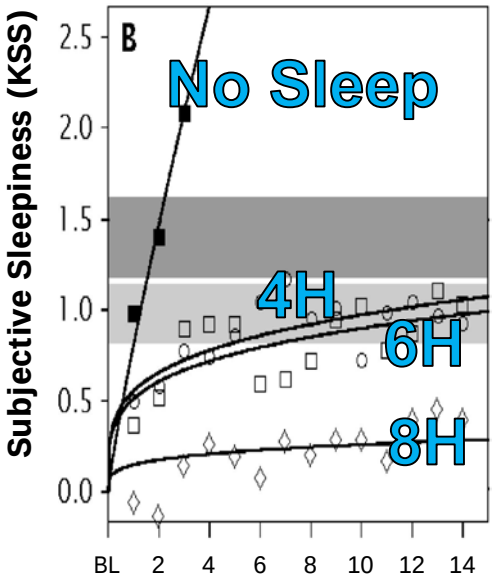
- Subjective Fatigue = feeling
- Objective Fatigue = assessment of performance
- Over days of chronic sleep loss:
  - Performance is impaired with days of sleep loss.
  - Subjective reports underestimate impairment measured in objective testing.

Objective



Days of Sleep Restriction

Subjective

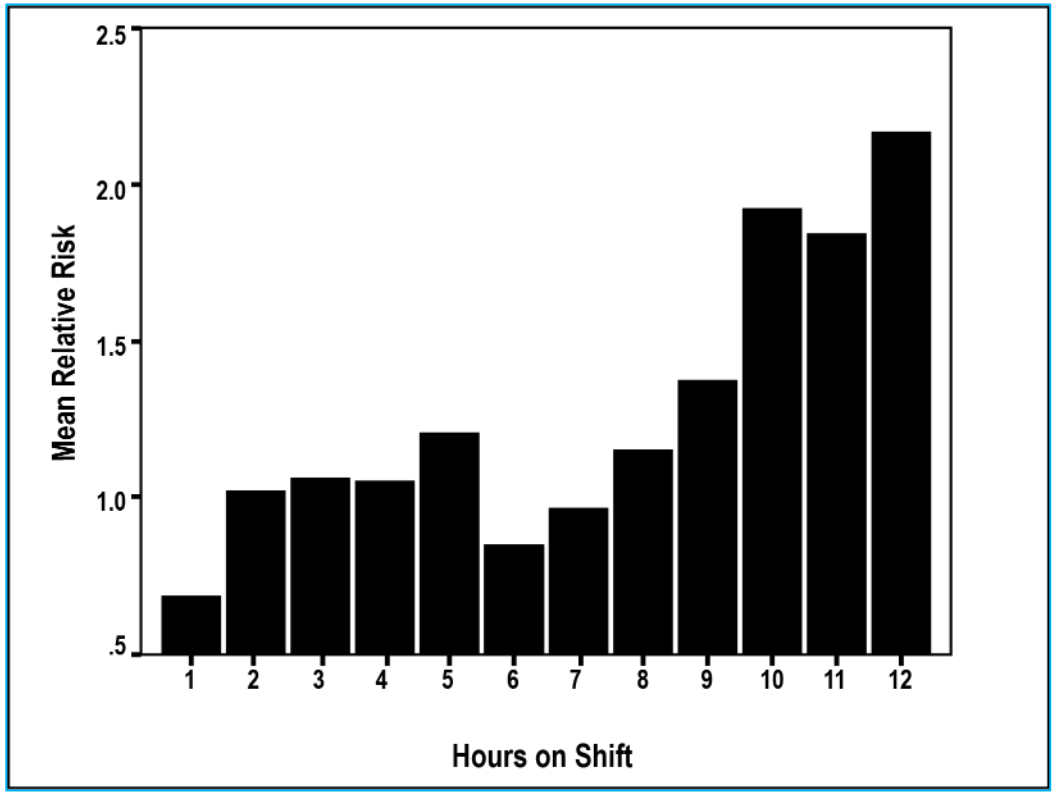


Days of Sleep Restriction

Fatigue as a Safety Risk

Work Schedule

Folkard and Tucker, 2003



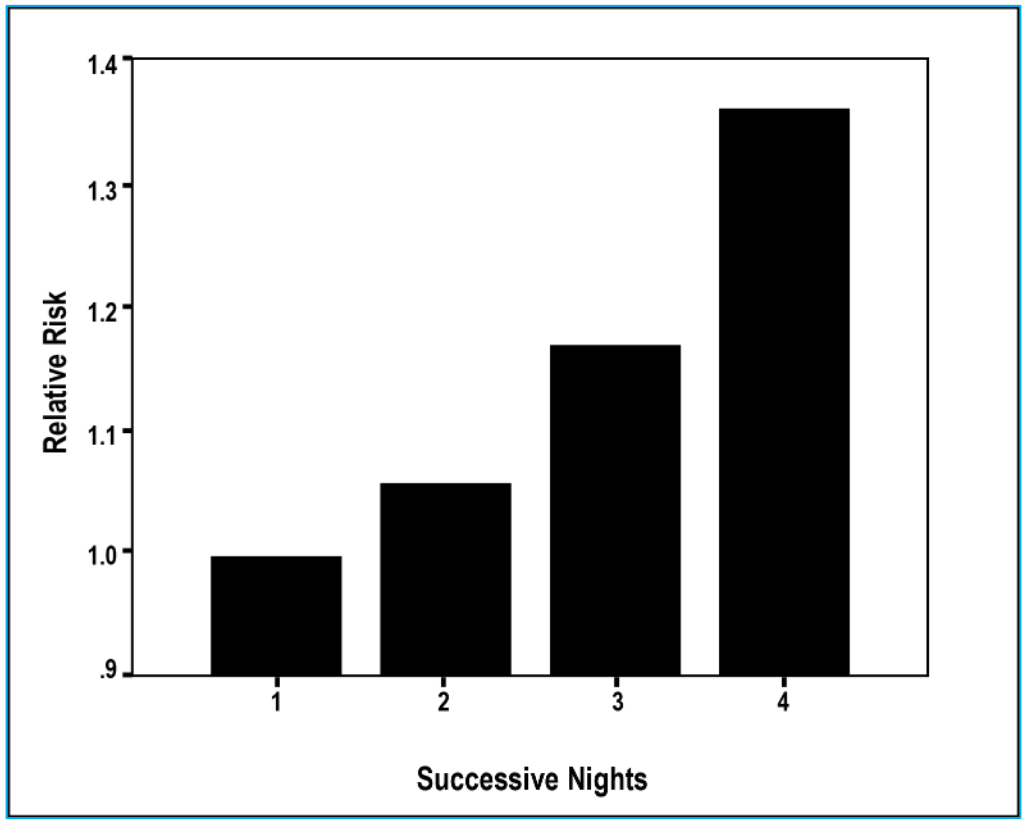
Risk of Accidents

- The risk of an accident or incident increases dramatically in shifts longer than nine hours.
- Risk increases in an approximately exponential fashion with time on shift.
- In the twelfth hour of a shift the risk is more than double during the first eight hours.

Fatigue as a Safety Risk

Time of Day

Folkard and Tucker, 2003



Successive Night Shifts

- The risk of an accident or incident increases with successive night shift periods.
- When compared to successive day shifts:
  - Risk increases 2% on average on second night shift .
  - Risk increases 7% on average on third night shift.
  - Risk increases 17% on average on fourth night shift.
- Fatigue related impairment increases between midnight and 0600 hours.
- Sleepiness is greatest between 0200 – 0600 hours.

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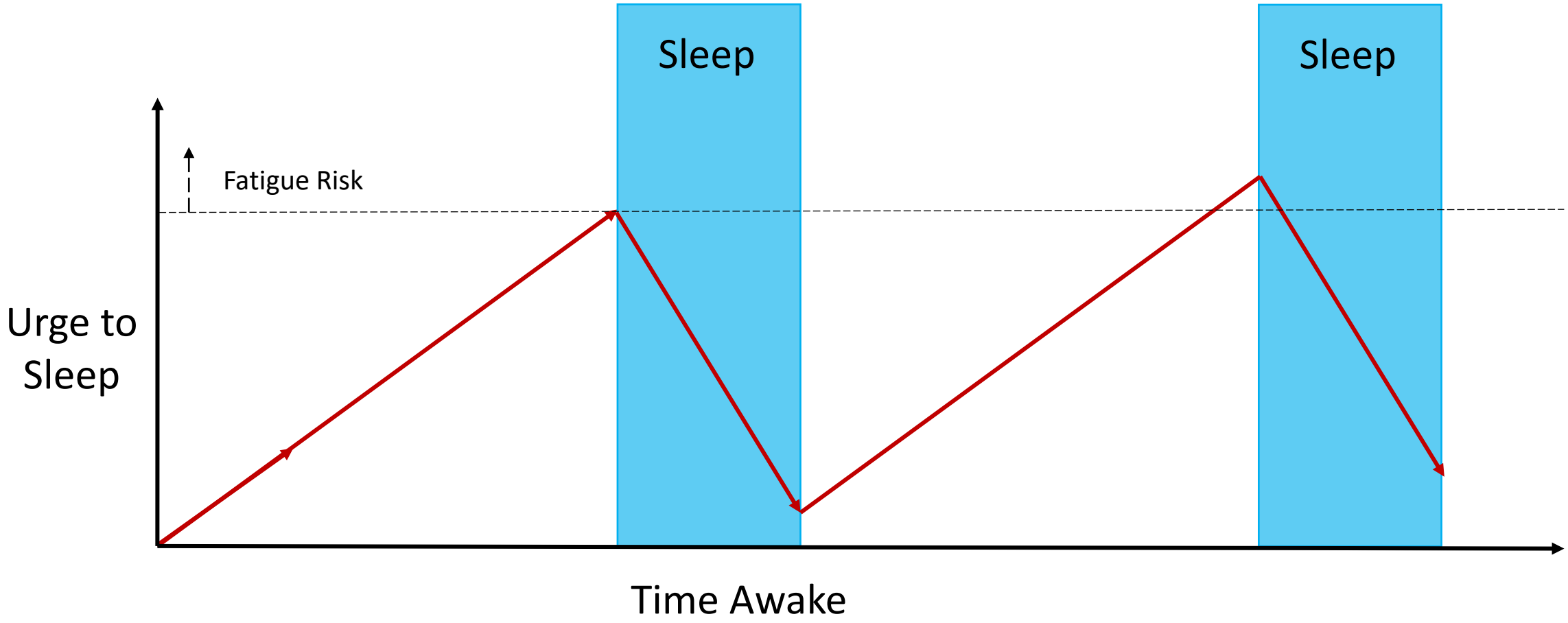
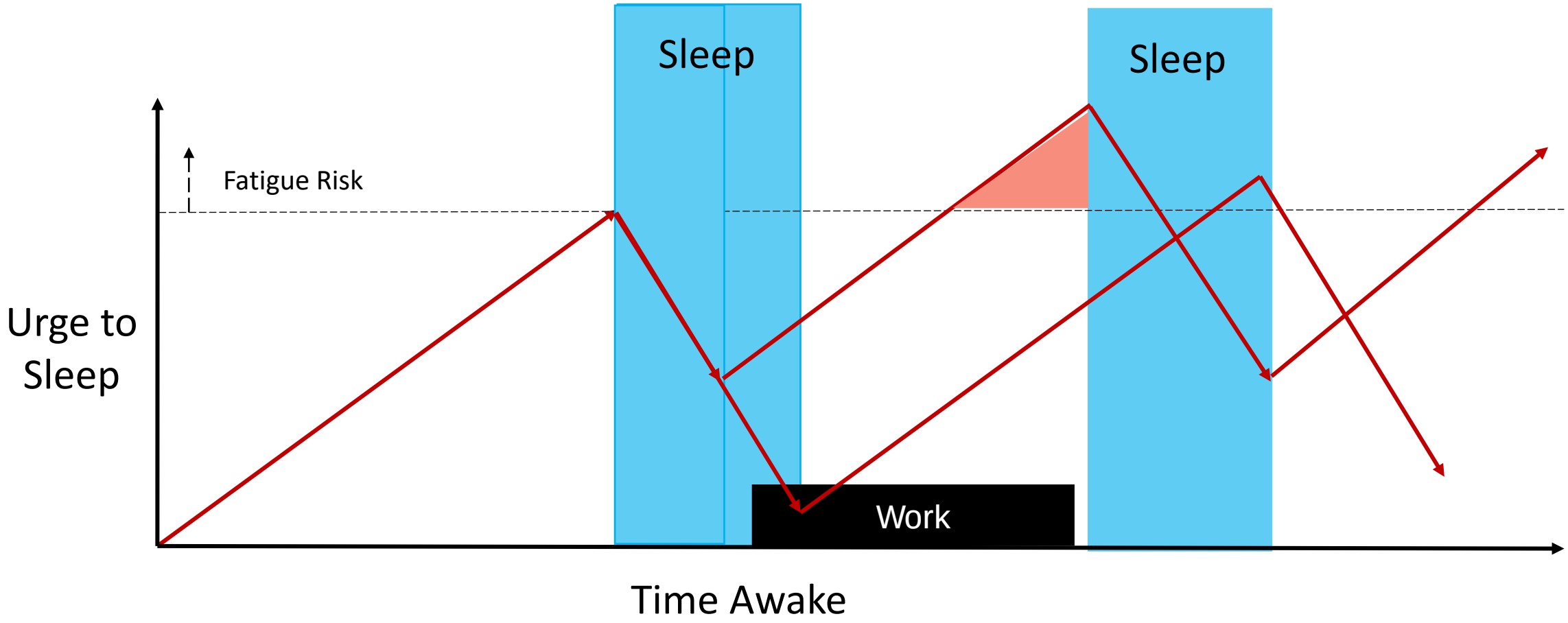
- Sleep and Sleep Debt
- Continuous Hours Awake
- Time of Day
- Circadian Misalignment
- Workload

Fatigue Factors for Shift Workers

Biological Urge to Sleep



Biological Urge to Sleep vs. Work



More Hours Working = Less Hours Sleeping

- Sleep debt accumulates over time and can only be repaid with sleep
- 40 hours per week is a normal work week in Canada, with limits after 48 hours/week
- Hours can be “averaged” across weeks for shift workers and emergency workers
- Emergency service providers are exempt from most overtime and scheduling rules

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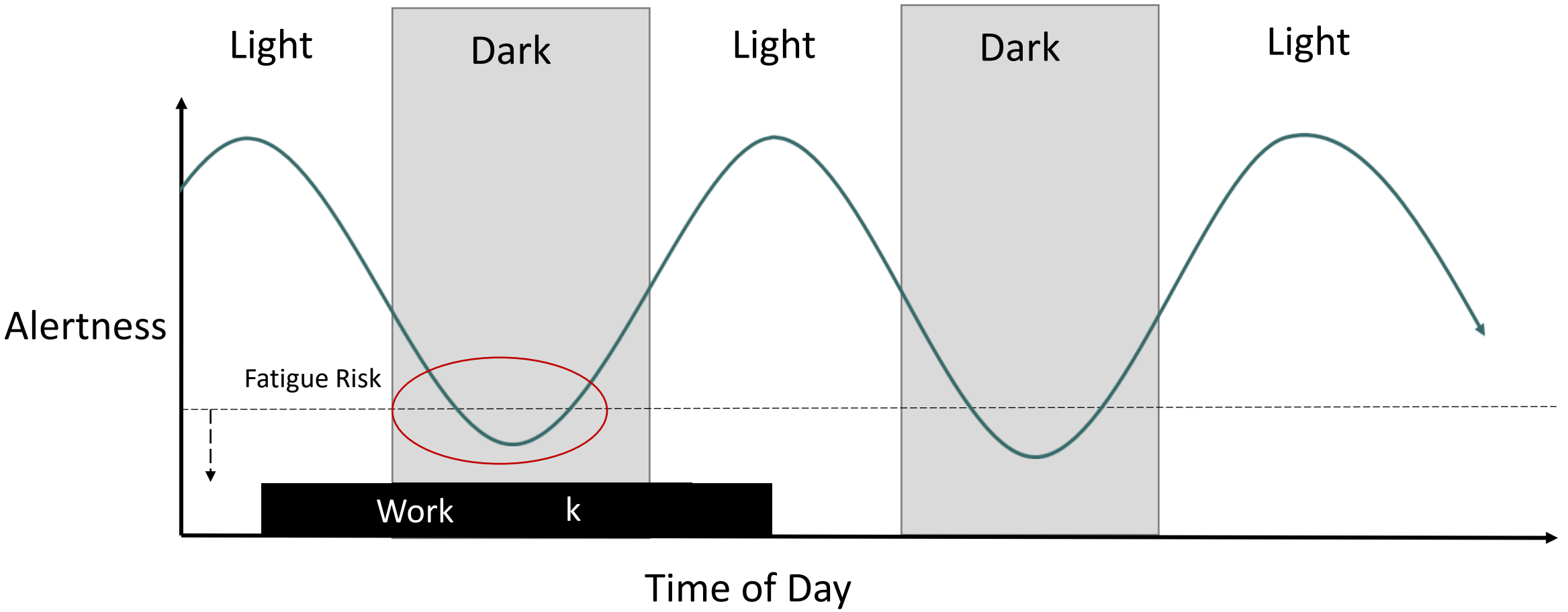
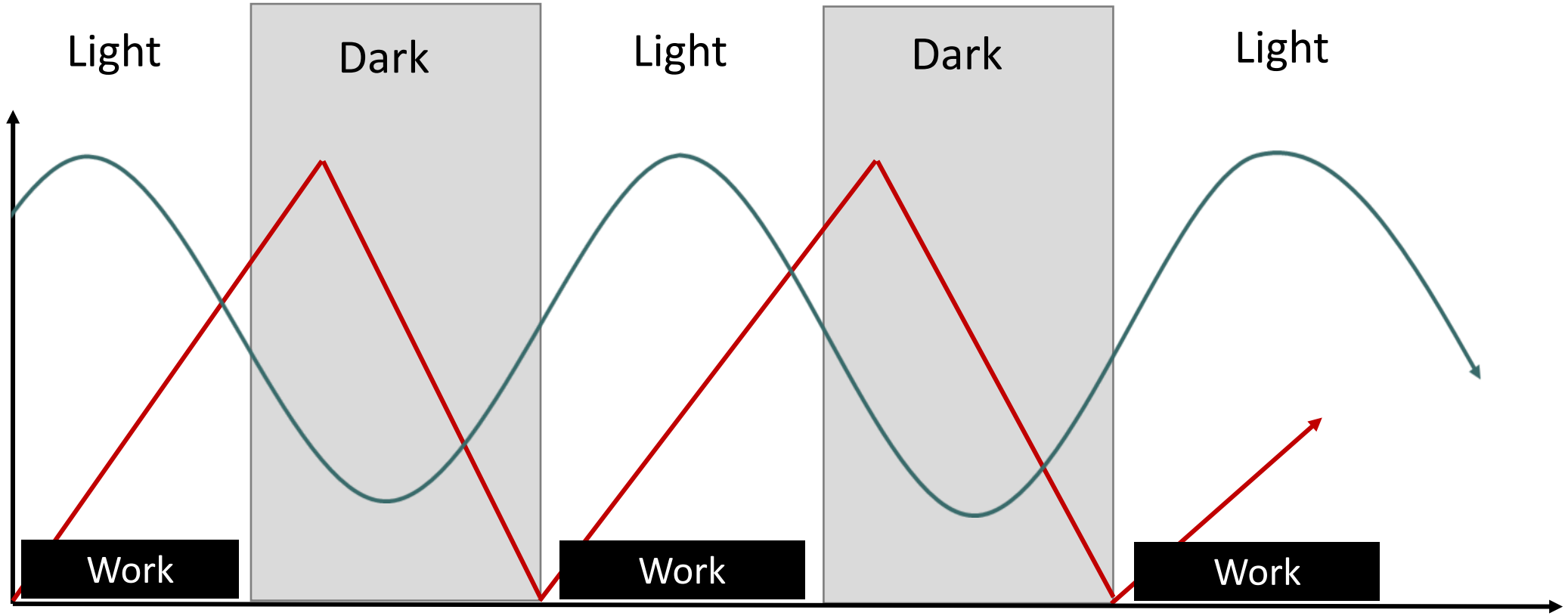
Fatigue Factors for Shift Workers

Window of Circadian Low



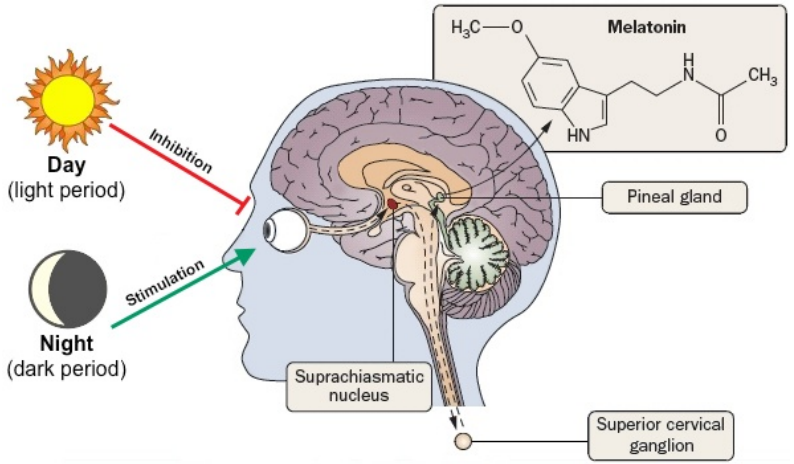
Circadian Misalignment

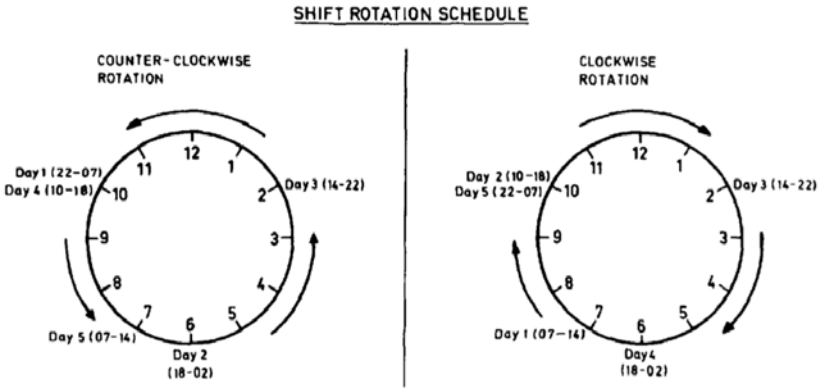
Change to Schedule and Light Exposure



Circadian Rhythm

Your brain uses information (mostly light exposure and schedule) to set the pace of the circadian rhythm





Timing is Everything

- Fatigue is worse during the Window of Circadian Low (WOCL)

- Circadian rhythms need time to adjust to a new routine
  - Shorter rotation intervals may not allow time to adjust

- Adjusting to an earlier schedule is more fatiguing than adjusting to a later schedule
  - Jet lag is worse going west (9am → 6am)
  - Counter-clockwise/Backward rotation (night to evening to morning)

Fatigue “Biohacks”

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- Sleep and Sleep Debt
- Continuous Hours Awake
- Time of Day
- Circadian Misalignment
- Workload

Fatigue Factors for Shift Workers

What is Workload?

No one single definition for workload

- NASA Task Load Index (TLX) quantifies workload as:
  - Mental demand
  - Physical demand
  - Temporal demand
  - Performance
  - Effort
  - Frustration

- SAFTE-FAST features an adjustable workload calculator
  - Can be compared against NASA TLX
- Download our Workload Calculator White Paper on our LinkedIn page
  - linkedin.com/company/safte-fast/

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- Sleep and Sleep Debt
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Ultimate Goal

Fatigue Tools

Desktop & Web Solutions

- Validated SAFTE fatigue model
- Shift Work Pattern Builder
- Pro-active forecasting & Retrospective analysis
- Safety Performance Indicators
- Reporting Tools

Wearable Tools

Zulu

- Consumer grade wearable that records sleep events as short as 20 minutes
- Ideal for data collection studies
- Off-wrist data is easily imported into SAFTE-FAST FRMS software solutions
  - Model predictive sleep against actual sleep
- On-wrist sleep scoring, Off-wrist detection
- Long battery life of up to one year
- Automatic scoring of multiple sleep periods
- Light sensor for bright light and blue light
- On-demand download to Zulu Data Extractor App

Fatigue in Surgical Residents

Multi-Phase Project modeling fatigue from residents' schedules and sleep behavior

1. Model sleep and fatigue patterns

Predicting Strategic Napping in Surgical Residents by Individual and Rotation Characteristics

Jaime K Devine, PhD[1], Lindsay P. Schwartz, PhD[1], Steven R. Hursh[1,2], PhD, Elizabeth Mosher[3], MA, Sarah Schumacher, BS[4], Lisa Boyle[4,5], MD, Jonathan E. Davis[4,5], MD, Mark Smith, MD[3], and Shimae Fitzgibbons, MD, MEd[4,5]

[1]Institutes for Behavior Resources, Baltimore, MD; [2]The Johns Hopkins University School of Medicine, Baltimore, MD; [3]MedStar Institutes for Innovation; [4]Georgetown University School of Medicine; [5]MedStar Georgetown University Hospital

Introduction

- Poor sleep in relation to work schedules has been well documented in medical residents[1].
- Strategic napping, or napping on-shift, is recommended to reduce fatigue[2]. Napping has benefits for:
  - on-call alertness[1]
  - reaction time[3]
  - performance[4]
  - overall sleep duration[1]
- The actual prevalence of strategic napping in relation to residents' workload, schedule, or demographics is largely unquantified.
- The Accreditation Council for Graduate Medical Education (ACGME) New Common Program Requirements recently removed any suggestions for strategic napping[2,5].
- Knowing if, when, and which residents utilize strategic napping can help healthcare administrators better manage resident fatigue risk.

Research Aims

- Aim 1: To measure and describe existing sleep patterns, fatigue, and incidence of strategic napping in general surgery residents by demographic and work schedule characteristics during resident rotations.
- Aim 2: To determine which individual characteristics and/or rotation-related work characteristics predict incidence of strategic napping in surgical residents.

Methods

Participants and Procedure: N=22 (ages 26-35, 10 men) surgical residents from an academic surgery program in the Washington, DC area provided schedule information, completed the Epworth Sleepiness Scale (ESS)[6], and wore sleep-tracking devices (Zulu Watch) continuously for 8 weeks.
Statistical Analysis: Service lines were condensed into five categories based on the nature of the work performed for statistical analysis. Between-group differences were examined using Student's t-tests controlling for unequal variance, one-way analysis of variance (ANOVA), and Kruskal-Wallis rank tests for variables with unequal distribution. Multiple linear regression was performed to predict percent days with on-shift napping from resident demographics (age, gender, post graduate year (PGY), sleep characteristics (ESS, total sleep time (TST), sleep efficiency (SE)), schedule characteristics (shift start time, shift length, rotation length, percent days on-shift, percent night shifts), and service line characteristics (service line category, number of service lines worked).

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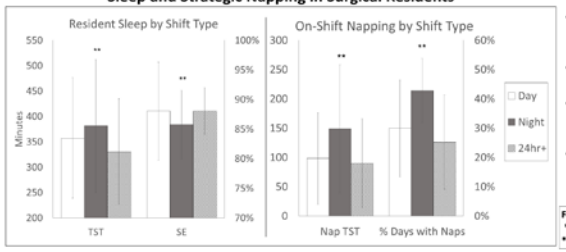
Results

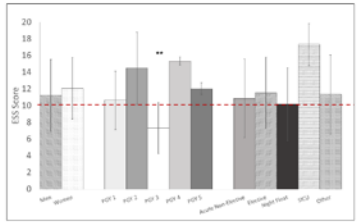
Sleep and Strategic Napping in Surgical Residents



- Residents had an average TST around 6 hours and SE of 87%.
- Residents napped on-shift 32% of their working days.
- 95% of residents napped at least once on-shift during the study period.
- Residents working at night took naps more frequently than residents working days.

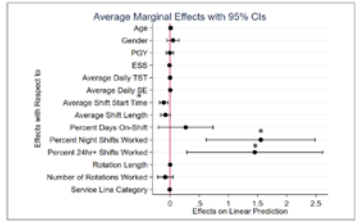
For all graphs:
*** represents significance at p≤0.05**
**** represents significance at p≤0.001**

Excessive Daytime Sleepiness



- 73% of residents had excessive daytime sleepiness (ESS >10; - -)
- Excessive sleepiness affected residents across gender, PGY, and service line categories, except residents in PGY 3 (N=4).

Predictors of Strategic Napping



- More night and 24hr+ shifts worked predicted greater likelihood of napping on shift.
- Earlier shift start time predicted less likelihood of napping on shift.

Discussion

- Residents exhibit insufficient sleep and excessive sleepiness which could represent a safety risk to themselves and/or patients.
- The majority of residents took advantage of strategic napping opportunities.
- Work schedule, especially working during the night, seems to drive on-shift napping rather than the nature of the work performed or individual resident characteristics.
- Removal of napping recommendations from the 2017 ACGME common program requirements may negatively affect strategic napping in surgical residents suffering from sleep deprivation and fatigue.

Biomathematical modeling predicts fatigue risk in general surgery residents

Lindsay P. Schwartz, PhD[1], Jaime K. Devine, PhD[1], Steven R. Hursh, PhD[1,2], Elizabeth Mosher, MA[3], Sarah Schumacher, BS[4], Lisa Boyle, MD[4,5], Jonathan E. Davis, MD[4,5], Mark Smith, MD[3], and Shimae Fitzgibbons, MD[4,5]

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Introduction

Fatigue in Medical Residents

- Fatigue impacts the safety of both resident physicians and patients by:
  - Reduced resident performance and wellbeing[1,2,3]
  - Increased patient post-operative complications[4]
  - Lower on-call alertness[6]
  - Riskier clinical decisions[7]
  - More medical errors[8,9]
- Fatigue in medical residents is a consequence of long working hours, unpredictable schedules, and limited opportunities for sleep[8,10].
- Restricting working hours and encouraging scheduled nap periods during long shifts[13,14] is recommended to reduce fatigue risk on shift, but…

Biomathematical Modelling of Fatigue

- Biomathematical models, such as the Sleep, Activity, Fatigue and Task Effectiveness model, can either predict likely sleep around a schedule, or use objectively measured sleep to predict performance (cite).
- Biomathematical fatigue modeling can help mitigate fatigue in shift scheduling but has not been utilized in the medical field.

Aims

- Aim 1: To measure and describe existing sleep patterns in general surgery residents to optimize sleep prediction in a biomathematical fatigue model.
- Aim 2: To estimate sleep as accurately as possible so that we could use the model and resident schedules to predict future performance and fatigue risk in general surgery residents.

Methods

Participants and Procedure: 22 residents based at a large, multi-hospital, general surgery residency program wore wrist actigraph devices for 8 weeks and completed subjective sleep assessments. Sleep intervals (bedtime and wake time) and shift schedules (start and stop times) for each resident were then input into the SAFTE to assess predicted cognitive performance.

Data analysis: Sleep data was summed for 24-hour periods (12:00-12:00) to produce average time in bed (TIB: sleep interval), total sleep time (TST: sleep interval – time awake), sleep efficiency (SE: total sleep time/time in bed), and the number of sleep episodes per day.
The SAFTE-FAST® Console (Fatigue Avoidance Scheduling Tool, Institutes for Behavior Resources, Baltimore MD), a software scheduling program using the SAFTE model, was used to analyze schedules and predict fatigue risk. Performance was compared to an "effectiveness" level of 77%, which is equivalent to a BAC of 0.05g/dL and is validated against psychovigilance motor task performance. The percent of time below the 77% criterion level (% BCL) was also calculated. Sleep debt, measured as a "reservoir" level, was assessed at 75% – an eight-hour sleep debt.

Analysis and Results

Residents slept on average between once and twice per day (1.76±1.24 times; range 0-7) and received on average slightly over 6 hours (370±129 minutes) of sleep within a 24-hour period. Total sleep time was significantly shorter on 24+ hour shifts than on shorter day or night shifts ($p<.001$). Sleep efficiency (SE) was in the normal range for healthy adults (87.13%±7.55%). Residents napped on 32% of their workdays, with naps averaging 2 hours. Based on these results, sleep prediction parameters were adjusted (for example, predicted bedtimes were changed) so resident sleep could be better estimated. Figure 1 shows the percent of sleep events that occurred in each half-hour of the day, as predicted by the SAFTE model and as measured by actigraphs. The average percent difference in predicted and actual sleep was 33.3%.

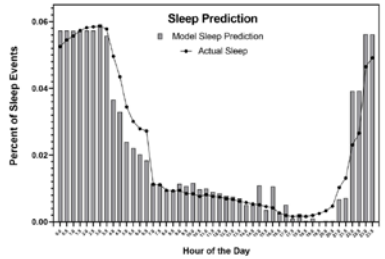

Figure 1. Percent of Sleep Events by Hour

Modeling results showed that as shift lengths increased, effectiveness scores decreased, and the time spent below criterion (77) increased. Shift lengths 16 hours or less in duration had significantly higher effectiveness scores and lower % below criterion than shifts longer than 16 hrs.

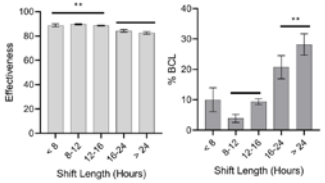

Figure 2. Left: Effectiveness by Shift Length; Right: % BCL by Shift Length

Additionally, 7.39% of shifts were below the effectiveness criterion and 35.3% of shifts were below the reservoir criterion. These results are displayed in Figure 2.

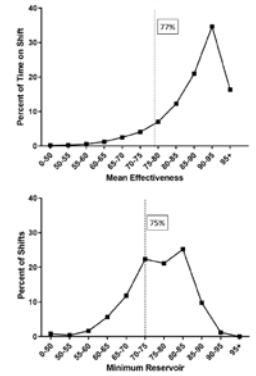

Figure 3. Top: The Percent of Time on Shift in Average Effectiveness Bins; Bottom: Percent of Shifts in Minimum Reservoir Bins

Discussion

- Despite adherence to national standards (cite), surgical residents' sleep patterns and shift schedules create an elevated level of fatigue risk.
- Residents do not appear to compensate for long work hours by increasing sleep duration.
- A biomathematical fatigue model is capable of predicting resident sleep patterns and performance when creating shift schedules.

Conclusion

- Biomathematical modeling can assist in minimizing fatigue risk and maximizing performance in medical professionals.

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Fatigue in Surgical Residents

Multi-Phase Project modeling fatigue from residents' schedules and sleep behavior

2. Identify schedule factors which contributed to potential fatigue hazard

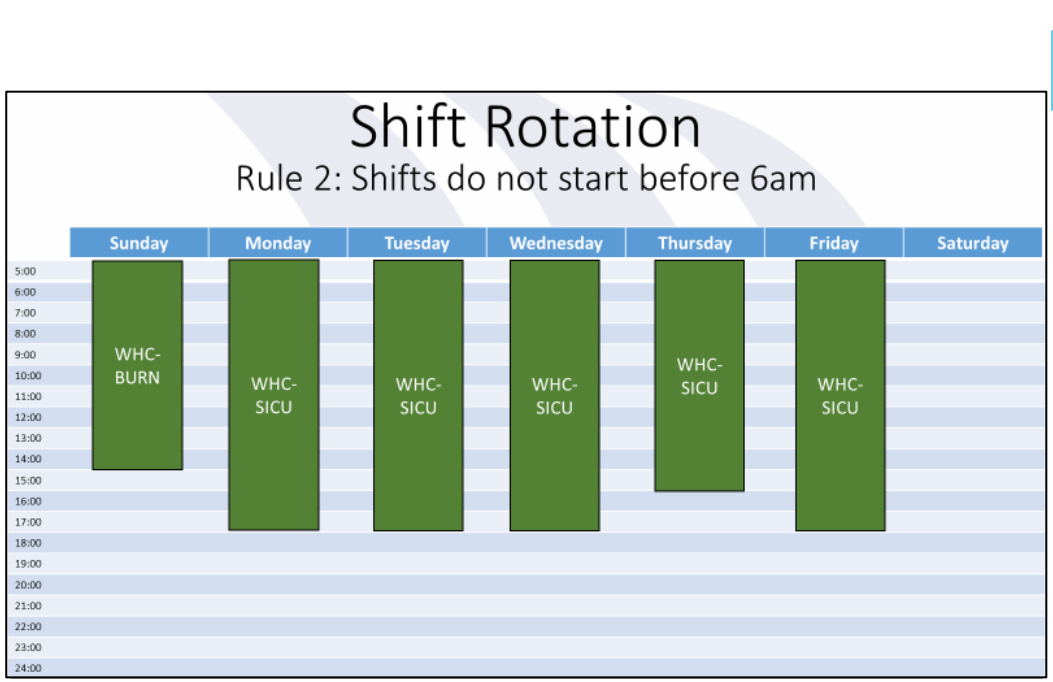
- Scheduling
  - Duty Hours
  - Start Times

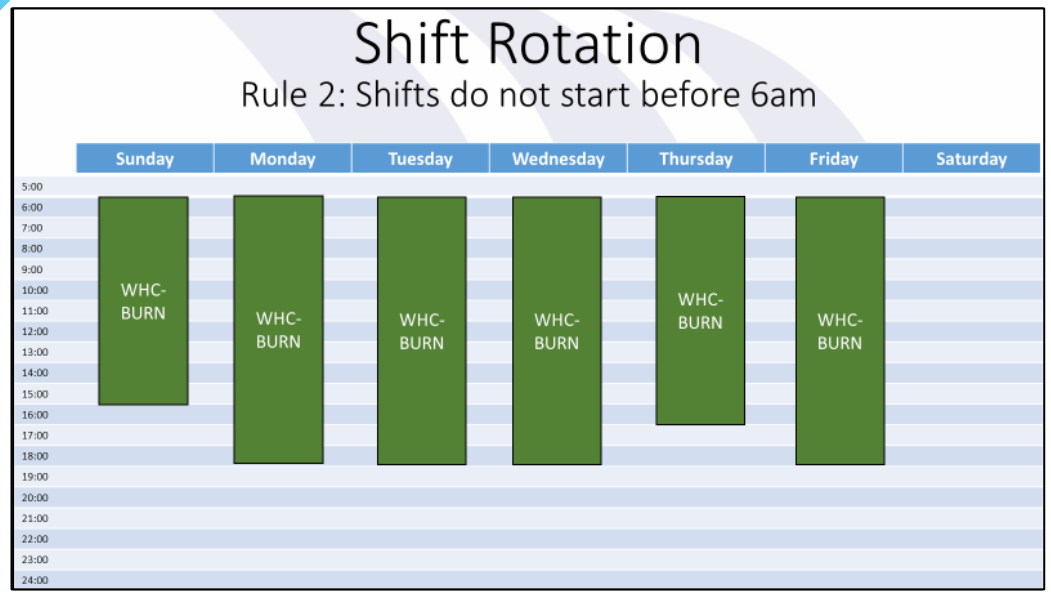
- Rotation attributes (Each rotation was assigned a fatigue risk ranking based on predictive factors)
  - Low Risk
  - Moderate Risk
  - High Risk

Fatigue in Surgical Residents

Multi-Phase Project modeling fatigue from residents' schedules and sleep behavior

3. Propose fatigue mitigation strategies





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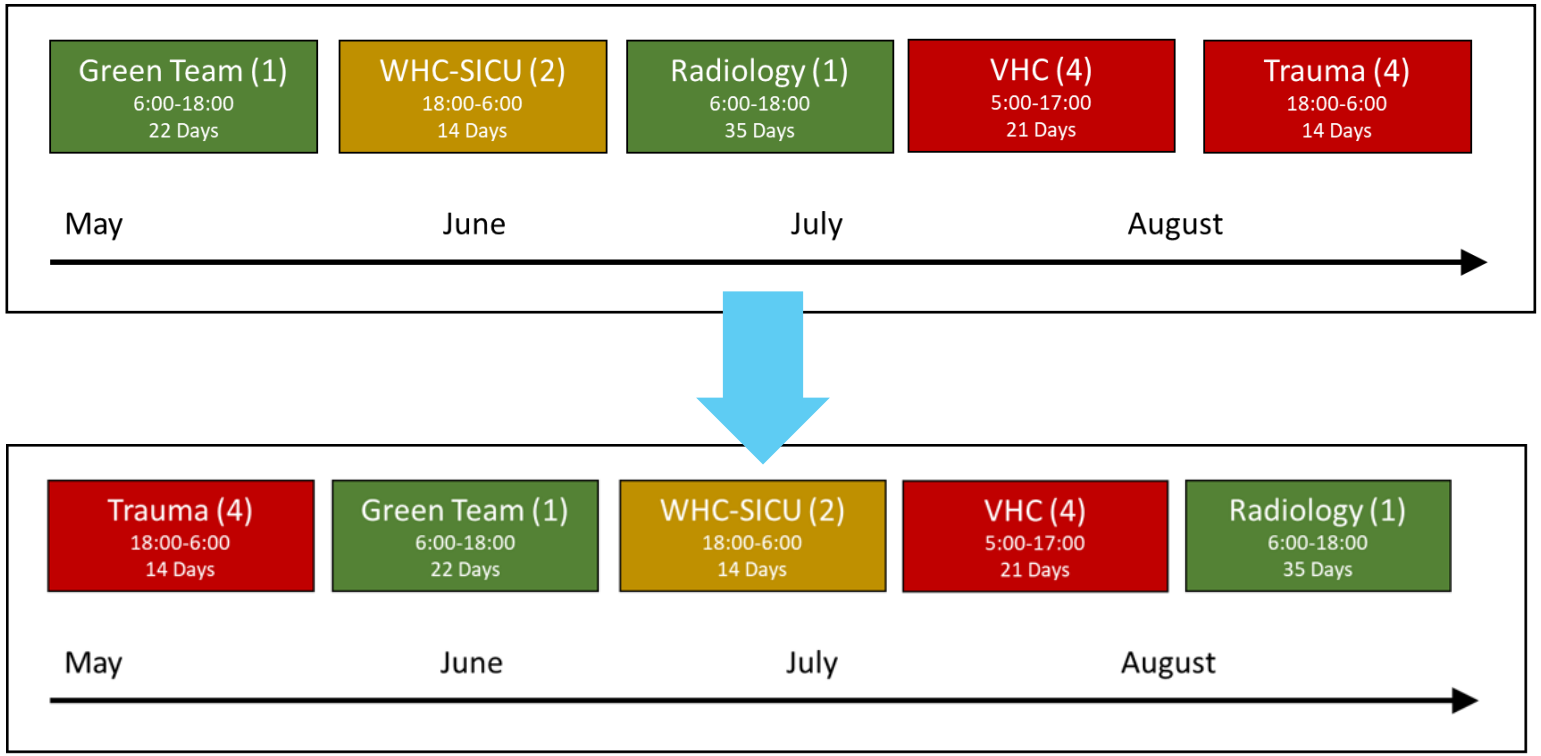
3. Propose fatigue mitigation strategies



Fatigue in Surgical Residents

Multi-Phase Project modeling fatigue from residents' schedules and sleep behavior

4. Test the efficacy of fatigue mitigation strategies

Take-Aways

- Fatigue constitutes a safety risk
- Multiple factors contribute to fatigue in shift working populations
- Regulations do not address the wide scope of fatigue factors
- Fatigue can be managed through multiple means, not just by limiting hours worked
- Mitigation strategies are most successful when tailored to the industry’s needs

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