NorthShore University HealthSystem

Sleep Well Elite Athlete: The Impact of Sleep Deprivation on Sports Performance

Lori Lovitz, DO

November 8, 2020

Healthcare for what's ❯ next.

DISCLOSURES

- I do not receive any payments or endorsements from commercial organizations or pharmaceutical companies
- More research is available on high school and college athletes, some including professional athletes. But for many of the other studies we can only extrapolate these results.

MY BACKGROUND

- Lori Lovitz, DO
- Clinical Assistant Professor, Pritzker University School of Medicine
- Neurology and Sleep Disorders
- Fellowship trained in Sleep Medicine as well as Clinical Neurophysiology
- Full Time Clinician at NorthShore University HealthSystem for 10 years (since 2010)

LEARNING OBJECTIVES

- Comprehend how sleep loss affects athletic performance
- Identify sleep issues specific to athletes and exacerbated by COVID-related stress
- Describe interventions for sleep optimization to improve athletic performance

ABSTRACT SUMMARY

- For the elite athlete, adequate sleep is needed to properly recovery from challenging training sessions and tough competitions. Not only do evidence-based studies show quality sleep results in improved performance and more wins, but it also may play a role in injury prevention and illness in athletes. Additionally, sufficient sleep builds the immune system and has been shown to better time, accuracy, and endurance.

- That said, most athletes fail to consistently sleep the recommended 7-10 hours per day. An estimated 38-57% of elite athletes are sleep deprived especially among females in aesthetic sports such as ice-skating, gymnastics, and dance. Many note symptoms of insomnia.

- With sleep deprivation, a variety of changes can occur that lead to suboptimal performance both physically and cognitively. It has been noted that athletes struggle with sleep due to training, competition schedules, traveling, and other factors. And like the general population, athletes likely are experiencing heightened anxiety related to the COVID emergency, either for fear of personal medical and financial risk or because their home environment and sleep conditions could have changed drastically. This stress works against a quick recovery.

- And, stress plays hand in hand with sleep deprivation. Research shows going without proper rest leads to the production of cortisol, the stress hormone, and the reduction of glycogen and carbohydrates, which are needed when exerting energy. This all works against a quick recovery.

- This lecture will note interventions for sleep optimization to improve athletic performance. It will include research that suggests clinicians monitor an athlete's sleep pattern, quality, and duration. Also detailed will be ways to promote proper sleep, including proper scheduling, stress management, and sleep hygiene.

GENERAL SLEEP REQUIREMENTS

- Adults 7-9 hours
- Adolescents 8-10 hours
- Will vary widely from person to person
- Sleep continuity and efficiency important
- Athletes may need 9-10 hours, but average less than 8 hours
  - Increased sleep duration and quality associated with better performance

TRENDS OF SLEEP IN ATHLETES

- Middle and high school athletes who slept less than 8 hours per night on average were 70% more likely to report an injury
- Combo of less sleep and increased training load is associated with the greatest risk of injury
- Sleep deprivation associated with impairments in reaction time and cognitive function and higher levels of fatigue
- Top placing teams had reported longer sleep duration and better sleep quality ratings

ALL INFLUENCED BY SLEEP DEPRIVATION

- Decision making
- Reaction time
- Fine motor coordination
- Imprinting memories and skills that were practiced
- MVA crash rate
- Risk of depression and anxiety
- Decreased immune function
- Impaired glucose control
- Weight gain

ROLE OF SLEEP IN RECOVERY

- Sleep is required for
  - cellular homeostasis and function
  - Endocrine and immune function which is vital for recovery
- Recovery is impaired by sleep restriction

EFFECTS OF SLEEP DEBT AND PERFORMANCE: AEROBIC VS ANAEROBIC

TABLE 1] Sleep and Performance

Study	Participants	Sleep Protocol	Performance Test	Findings
Aerobic				
Chase et al, 2017[72]	Recreational cyclists (N = 7)	Early waking SR (2.4 ± 0.2 h)	3 km cycle TT following an evening with heavy exercise	SR group: ↑3 km TT time
Oliver et al, 2009[70]	Recreational athletes (N = 11)	30 h of sleep deprivation	Submaximal treadmill run (60% VO_{2max}) and self-paced run	↓Distance covered
Azboy and Kaygisiz, 2009[69]	Male runners and volleyball players	25-30 h sleep deprivation	Time to exhaustion cycling	↓Time to exhaustion
Mougin et al, 1991[71]	Cyclists (N = 7)	3 h SR for 1 wk	20 min 75% VO_{2max} + ergometer time to exhaustion	↑Heart rate ↑V_E ↑Blood lactate levels
Anaerobic				
Blumert et al, 2007[67]	Collegiate weight lifters (N = 9)	24 h sleep deprivation	Maximal weight-lifting protocol	No significant change ↓Cortisol concentration ↓Vigor ↑Fatigue
Taheri and Arabameri, 2012[74]	Physical education students (N = 18)	1 night sleep deprivation	Wingate test Reaction time test	No change in anaerobic performance ↑Reaction time
Reilly and Piercy, 1994[75]	Physically active males (N = 8)	3 h SR for 3 nights	Submaximal lifts: bicep curls, bench press, leg press, and dead lift Maximal lift	↓All submaximal lifts ↓Maximal lifts but not bicep curl
Abedelmalek et al, 2013[76]	Football players (N = 12)	1 night 4 h of sleep	Wingate test	↓Peak and mean power at 6:00 PM
Skein et al, 2011[73]	Male team sport athletes (N = 10)	30 h sleep deprivation	Intermittent sprint protocol	↑Sprint time ↓Distance covered ↓Muscle glycogen
HajSalem et al, 2013[77]	Judokas (N = 21)	Partial sleep deprivation	Wingate test	↓Peak and mean power No significant change in hand grip

WINGATE ANAEROBIC TEST

Figure 1. Test configuration for the Wingate Anaerobic test.

ENDURANCE VS ANAEROBIC EXERCISE

- Endurance
  - Sleep deprivation inhibits performance possibly due to perceived exhaustion (mental fatigue plus muscle fatigue)
  - 30h sleep deprivation showed decreased distance covered on treadmill but no difference in thermoregulatory function or oxygen consumption
  - Pre-exercise muscle glycogen stores decrease after sleep deprivation
- Anaerobic power
  - Wingate Testing – inconsistent results
    - Mean and peak power outputs decrease significantly after 36 hr sleep deprivation as well as after night of sleep restriction
    - Not decreased in student athlete or highly trained athlete

SLEEP DEBT AND PERFORMANCE: SPORT SPECIFIC AND COGNITIVE

Sport-specific				
Reyner and Horne 2013[78]	Tennis players Study 1: N = 16 Study 2: N = 12	2-2.5 h SR	40 serves	↓Serving accuracy
Schwartz and Simon, 2015[79]	College tennis players (N = 1)	1 week sleep efficiency (+2 h)	Serving accuracy	↑35.7% to 41.8%
Neurocognitive				
Hurdiel et al, 2014[81]	Sailors (N = 12)	SR during 3 races (22 ± 30 min, 92 ± 34 min, 172 ± 122 min)	Reaction time	↓Reaction time
Jarraya et al, 2013[82]	Handball players (N = 12)	SR (4-5 h for 2 nights)	Reaction time Stroop test Barrage test	↑Reaction time ↓Selective attention ↓Visual spatial
McClure et al, 2014[83]	Nonconcussed athletes (N = 3,686; 3,305 high school, 381 college)	Retrospective sleep categories < 7 h 7-9 h ≥ 9 h	ImPACT	< 7 h/night = ↓Reaction time ↓Verbal memory ↓Visual memory No difference in processing speed

TABLE 1] *(Continued)*

Study	Participants	Sleep Protocol	Performance Test	Findings
Rossa et al 2014[84]	Young adults (N = 19)	SR (bedtime prior to 10:30 PM, woken up at 4:00 AM)	PPVT PBART PVT Go/No-go Task PANAS	↑Risk taking ↓PVT ↓Positive affect No change in negative affect No significant reaction to Go/No-go

ImPACT = immediate postconcussive assessment and cognitive testing; PANAS = positive negative affective schedule; PBART = balloon analog risk tasking; PPVT = perceptual vigilance task; PVT = psychomotor vigilance task; SR = sleep restriction; TT = time trial; V_E = ventilation; VO_{2max} = maximal oxygen uptake.

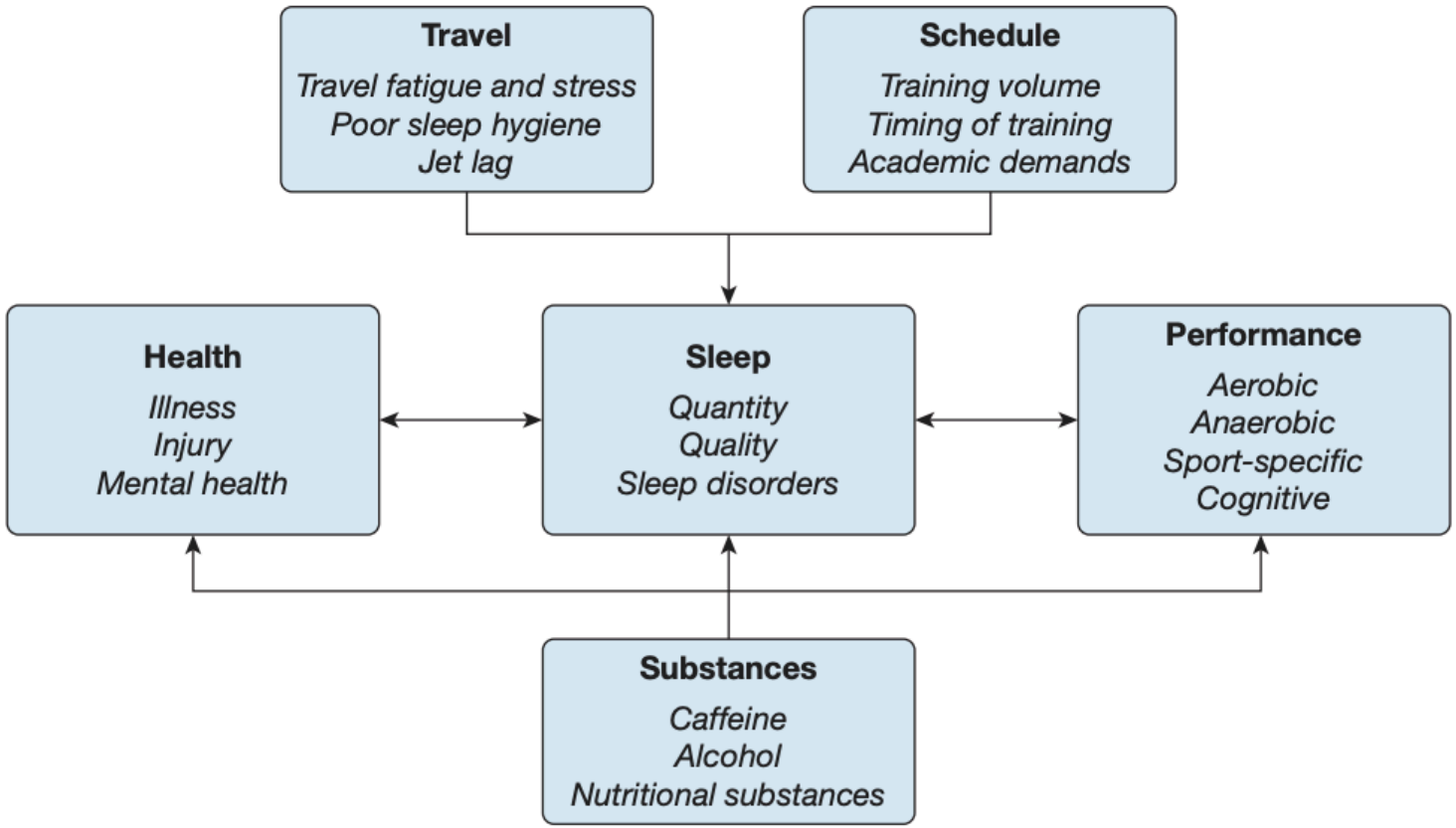
SLEEP DEBT AND PERFORMANCE

- Less affected by sleep loss
  - Sprint
  - Short bursts – weight lifting
    - 24 hour sleep loss – no significant change
    - 3 day of sleep restriction to 3 hrs – decreased amount of weight lifted
- More affected by sleep loss
  - Accuracy or reaction time (dart throwing, tennis serving)
  - Improved by sleep extension

CHALLENGES TO SLEEP IN ATHLETES

- Training load and training schedule may reduce duration (early AM or late night)
- Competition related anxiety, stress, or mood changes
- Travel related, jet lag
- Academic pressures added to collegiate or youth athletes
- Higher incidence of particular sleep disorders
  - Sleep Apnea in football players
  - Restless Leg Syndrome in marathon runners

COLLEGIATE ATHLETE SLEEP HEALTH



INTERVENTIONS AND OUTCOMES

- Interventions
  - Sleep hygiene
  - Sleep extension
  - Naps
  - Melatonin
- Measurements
  - Actigraphy
  - Sleep logs
  - Performance tests
  - VO2 max

Study	Participants	Sleep Protocol	Measurement	Outcomes
Sleep hygiene				
O'Donnell and Driller, 2017[87]	Elite female netball athletes (N = 26)	1 sleep hygiene education session; 1 wk prior to and following sleep monitoring	Wrist actigraphy	↑TST ↓Wake variance and duration No change in SL, sleep efficiency, TTB, SOT, WT, or WE
Kaier et al, 2016[103]	Division I collegiate athletes (N = 104)	Brief psychoeducation sleep workshop	Self-report	51% ≥ 1 sleep behavior change ↓Daytime sleepiness ↑Daytime functioning ↑Problematic sleep hygiene ↑Knowledge of sleep
Fullagar et al, 2016[88]	Two amateur soccer teams (N = 40)	Randomized crossover design with sleep hygiene strategy or normal postgame routine	Objective sleep measures (sleep deprivation, SL, sleep efficiency, WE); Countermovement jump; yo-yo test Blood draw; Perceived recovery; stress markers	↑Sleep deprivation, WE No difference in SL or sleep efficiency No difference in physical performance, blood markers, or perceived recovery
Van Ryswyk et al, 2017[89]	Australian football league players (N = 25)	6-wk sleep program	Sleep diaries, actigraphy, self-report, PVT	↑Sleep deprivation, sleep efficiency ↑Vigor ↓Fatigue
Harada et al, 2016[91]	University soccer players in Japan (N = 84)	1 mo sleep education	Sleep diaries Self-report questionnaires	↑Sleep quality, mental health and performance ↓Irritation
Fowler et al, 2015[102]	Physically active male subjects (N = 13)	Randomized crossover design 24 h simulated travel with and without sleep hygiene + artificial bright light	Actigraphy Oxygen saturation	Intervention group ↓Travel fatigue sleep deprivation ↑Approached significance No change in performance
Caia et al, 2018[90]	Professional rugby athletes (N = 24)	Two 30 min sleep hygiene education seminars	Sleep diaries Actigraphy	Session 1: earlier bedtime, ↑TTB, ↑sleep deprivation Session 2: ↑time in bed, ↓sleep efficiency
Sleep extension				
Mah et al, 2011[92]	Division I MBB players (N = 11)	5-7 sleep extension (10 h/night)	Actigraphy, sleep logs, RT, basketball performance	↑Objective sleep deprivation, free throw accuracy ↓Sprint time, RT, ESS
Schwartz and Simon, 2015[79]	Division III tennis players (N = 12)	1 wk sleep extension (9 h/night including naps)	Self-reported sleep (ESS, Stanford Sleepiness Scale)	↑Sleep deprivation ↑Serving accuracy

SLEEP EXTENSION EFFECTS

- College basketball players prescribed sleep extension to 10 hr/night for 5-7 weeks.
  - Showed to have improvements in sprint time
  - Improved free throws-2-point and 3 point shots
- Similar studies in tennis players showed improvements in serve accuracy

SLEEP HYGIENE

- Consistent bedtimes and wake times
- Allow for 7-8 hours of sleep
- Avoid bright lights, electronics, stimulation within 2 hours of bedtime and throughout night
- Avoid rigorous exercise or heavy meals within 2 hours of bedtime
- Avoid cigarette smoking or late day caffeine
- Sleep in a cool, dark, and quiet environment
- Avoid daytime naps, or keep under an hour and earlier in day
- Avoid recreational drugs and alcohol

SCREENING FOR SLEEP PROBLEMS

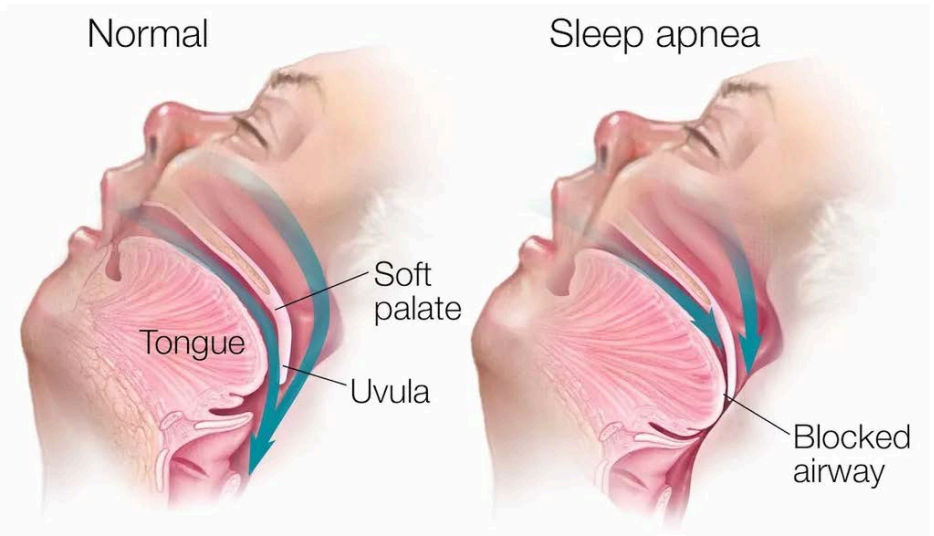
- For those with sleep disruption, insomnia, or sleepiness
  - Start documenting on sleep log
  - Can use electronic tracking device
  - Start by practicing good sleep hygiene strategies
- If still no improvement, consider a primary sleep disorder

COMMON SLEEP DISORDERS FOUND IN ATHLETES

- Obstructive sleep apnea – risk factors are large body mass index, enlarged neck circumference, male (defensive and offensive linemen and linebackers had higher rates)
  - Associated with cardiovascular disease and mortality later in life
  - Decreased attention, concentration, longer recovery time, higher risk of injury
  - Snoring can disrupt sleep of teammates when traveling
- Insomnia – risk factor is high stress, frequent travel, pain, sleeping in strange environment
  - 60% or more of athletes reported insomnia night before competition
- Circadian rhythm disorders – risk factors are frequent travel, varying practice times
- Insufficient sleep – risk factor poor sleep hygiene, busy schedules
- Hypersomnolence- higher risk in athletes with traumatic brain injury (TBI). 10x more likely in TBI than general population
- Restless Legs Syndrome – sometimes seen in marathon runners

OBSTRUCTIVE SLEEP APNEA

- Risk Factors for OSA
  - BMI > 30
  - Neck circumference > 17 inch (16 inch for women)
  - Restricted airway – high Mallampati score
- Diagnosed with a polysomnogram
- Treated with CPAP machine



NorthShore University HealthSystem

INSOMNIA TREATMENTS

- Promote good sleep hygiene
- Sleep Log
- Cognitive behavioral therapy
  - Stimulus control
  - Scheduled worry time
  - Sleep restriction
- May need more aggressive therapy with psychotherapy
- Sleep hypnotics in few cases
- Several online programs and apps to promote sleep
- Meditation, Yoga Nidra, progressive muscle relaxation

STRESS REDUCTION AND RECOVERY

- Look for root causes of the stress
- Severe emotional reactions could decrease sleep quality and recovery process
- Stress management methods
  - Meditation
  - Brain wave entrainment – future studies needed
  - Professional intervention

SLEEP HYGIENE

- Consistent bedtimes and wake times
- Allow for 7-8 hours of sleep
- Avoid bright lights, electronics, stimulation within 2 hours of bedtime and throughout night
- Avoid rigorous exercise or heavy meals within 2 hours of bedtime
- Avoid cigarette smoking or late day caffeine
- Sleep in a cool, dark, and quiet environment
- Avoid daytime naps, or keep under an hour and earlier in day
- Avoid recreational drugs and alcohol

MEDICATION AND RECOVERY

- Generally LESS effective than sleep hygiene and cognitive behavioral therapy
- Sleep Hypnotics examples
  - temazepam – medium half life benzodiapine
  - zolpidem – short half-life non-benzodiazepine
- Confirm with the World Anti-Doping Agency – (some banned in Rio 2016)
- Risks
  - Hangover effect
  - Reduced coordination and reaction time 10 hr after dose
  - Risk of tolerance and dependence
- Benefits
  - Subjective improvement of sleep quality
  - Best if short term treatment
- Melatonin
  - Can be naturally found in some foods such as tart cherry juice
  - Taken as supplement
  - Can be beneficial or detrimental depending on the timing of the dose
  - May also be controversial per the World Anti-Doping Agency

MISCELLANEOUS AIDS TO SLEEP AND RECOVERY

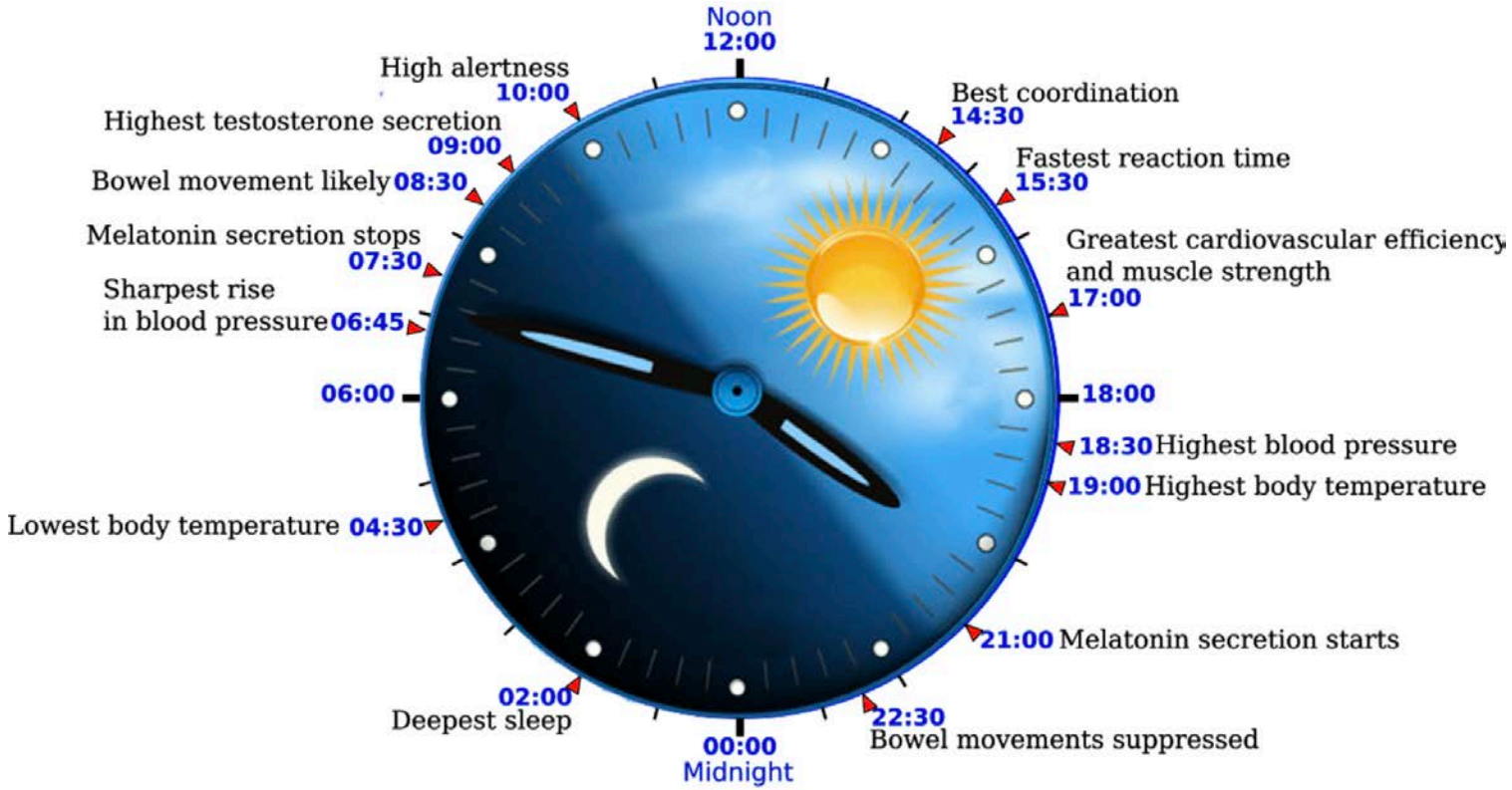
- High glycemic index carbohydrate within 1 hour post-match
- High protein immediately prior to sleep
- Tart cherry juice taken in AM and before dinner (or tryptophan-rich foods)
- Reduction of muscle soreness
  - Vitamin D supplements
  - Cold water immersion closer to bedtime is controversial due to the effects of the sympathetic nervous system
  - Cooling the core while heating the extremities
  - Avoid compression garments
- Sleep hygiene recommendations

Table 1 Potential sleep hygiene strategies for promoting sleep quantity and/or quality after night soccer match

Use glasses fitted with short-wavelength filters after the match (e.g., in the airport, travelling from airport) [51]
Consume high-electrolyte fluids such as milk rather than low-sodium fluids (e.g., water) between cessation of match and bedtime [82, 85]
Consume a high glycemic index meal [89]
Consume protein immediately prior to sleep (e.g., milk) [94]
Consume Montmorency tart cherry juice concentrate and/or tryptophan-containing foods (e.g., turkey, pumpkin seeds) [98, 100]
Use recovery strategies aimed at reducing muscle soreness (e.g., cold water immersion, contrast water therapy, compression garments, massage)
Create a low-light and cool (18–19 °C) sleep environment, avoid all electronic stimulants (i.e., television, mobile phones, computers) in the hour prior to sleep [123, 125]
Eliminate the bedroom clock [61]
Explore the use of brainwave entrainment and meditation [9, 69]
Use acute dawn-simulation therapy during the last 30 min prior to waking (especially for late chronotypes) [46]
Have a regular bedtime/wake time and avoid sleeping too late in the morning off days [21, 34]
Nap briefly (i.e., 5–30 min) and appropriately (close to the early afternoon and not during the morning or evening) [37, 38, 40]
Engage in active daytime behaviors (e.g., light exercise) and bright morning light exposure during off days [42, 43]

NorthShore University HealthSystem

CIRCADIAN RHYTHM BASICS

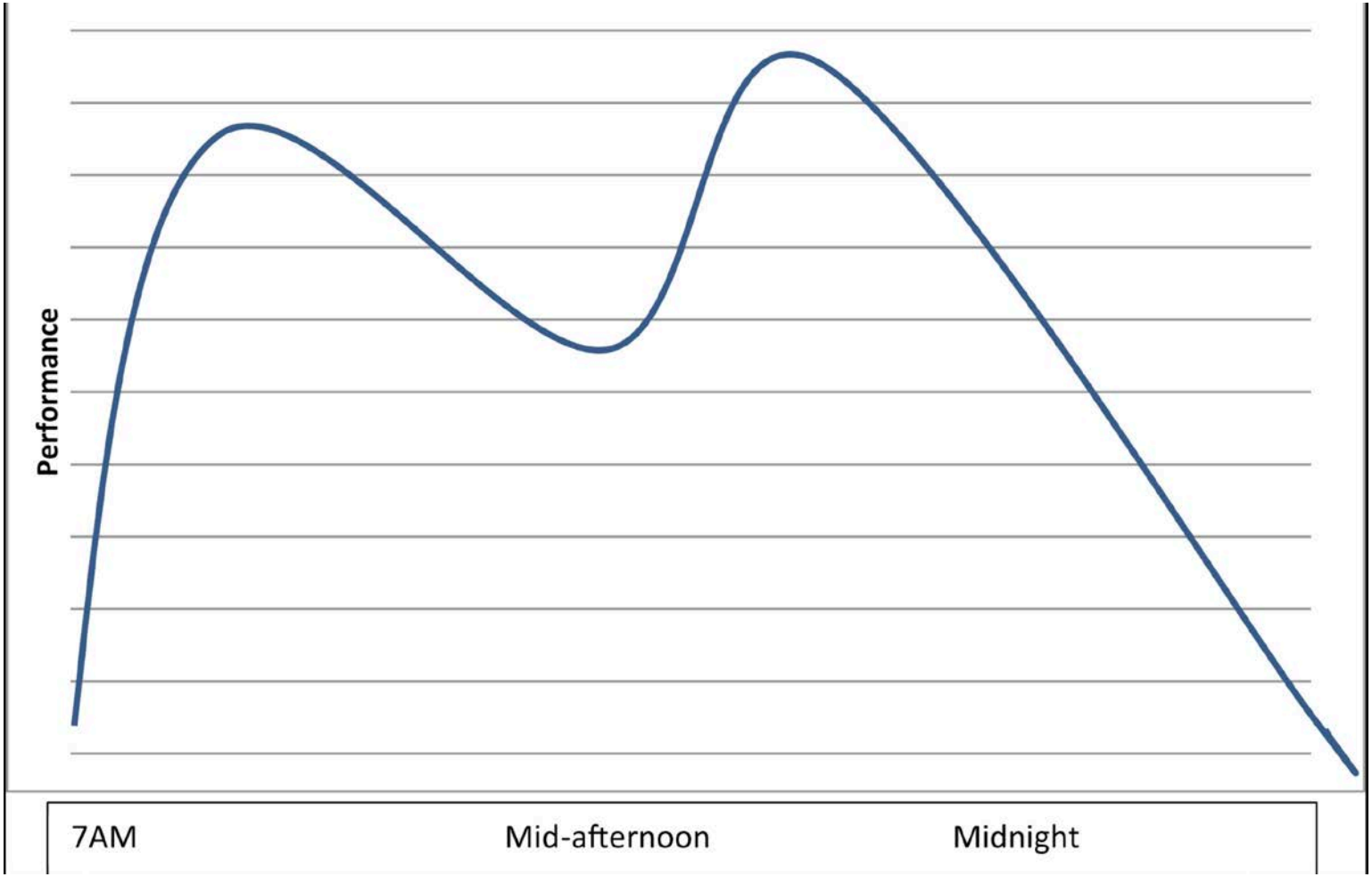


- Our bodies evolved to follow 24-hr light-dark cycle over thousands of years
- Artificial light can influence this master clock

CIRCADIAN EFFECTS ON ATHLETES

- Alertness, concentration, strength, and coordination seem to peak in early evening time
  - Most world records in swimming and running are set during this time
  - Swimming, tennis serves, badminton serves
  - Endurance peaks in late afternoon or early evening
- Less optimal in the early afternoon and immediately before and after bedtime

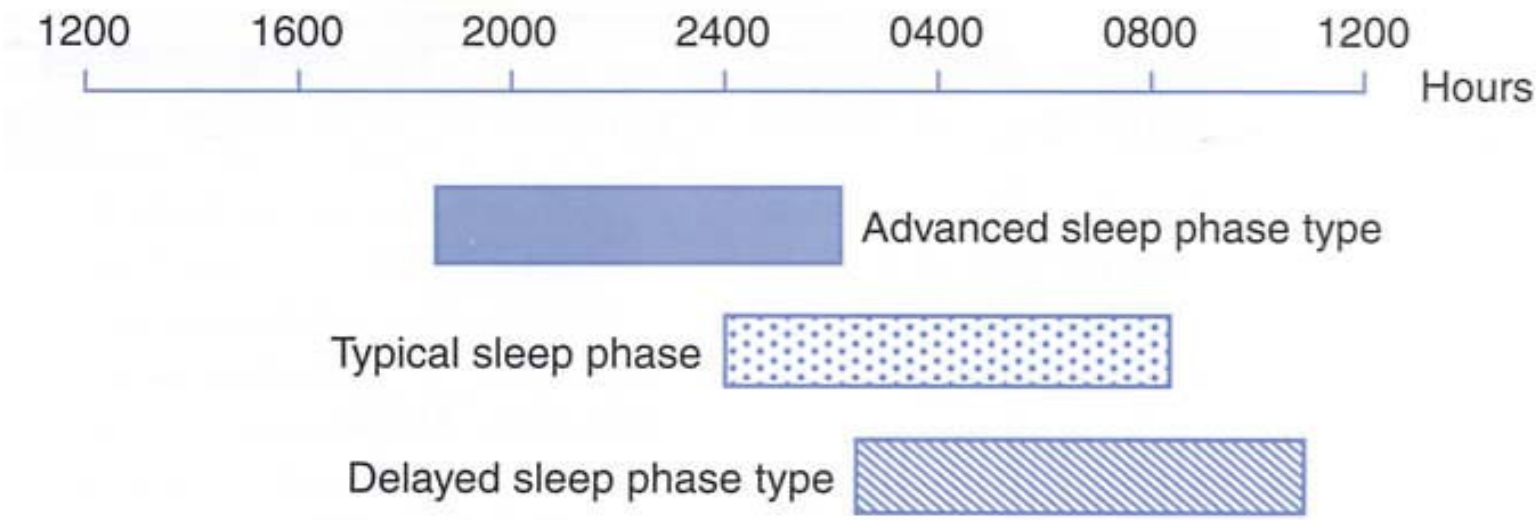
PERFORMANCE AND TIME OF DAY



CIRCADIAN RHYTHMS

- Travel across multiple time zones –worse performance
- Advantage of west coast teams playing Monday night football against east coast team since game ends after east coaster's habitual bedtime
- Individual differences if someone is morning lark vs night owl

SLEEP PHASE DISORDERS

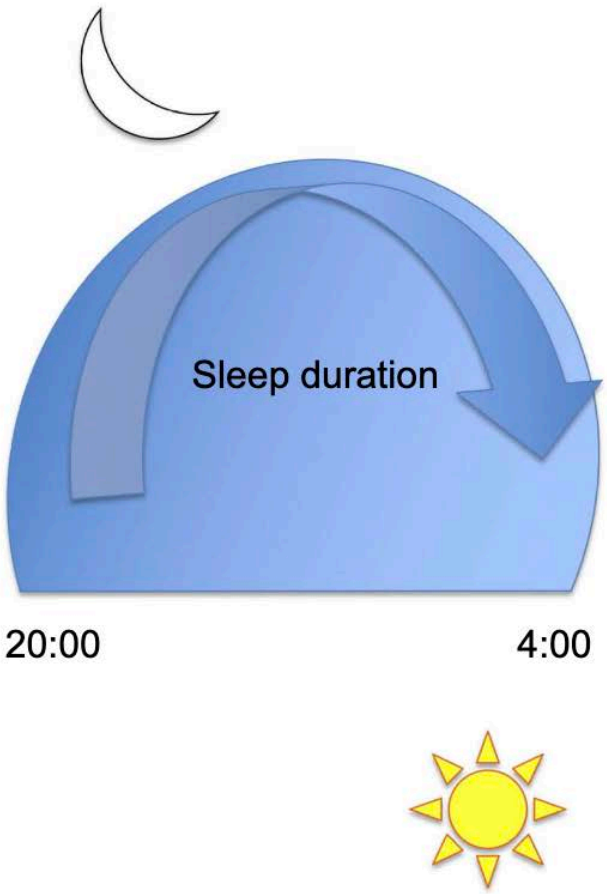


Look for individual player's sleep patterns. It may be beneficial or detrimental to the final performance

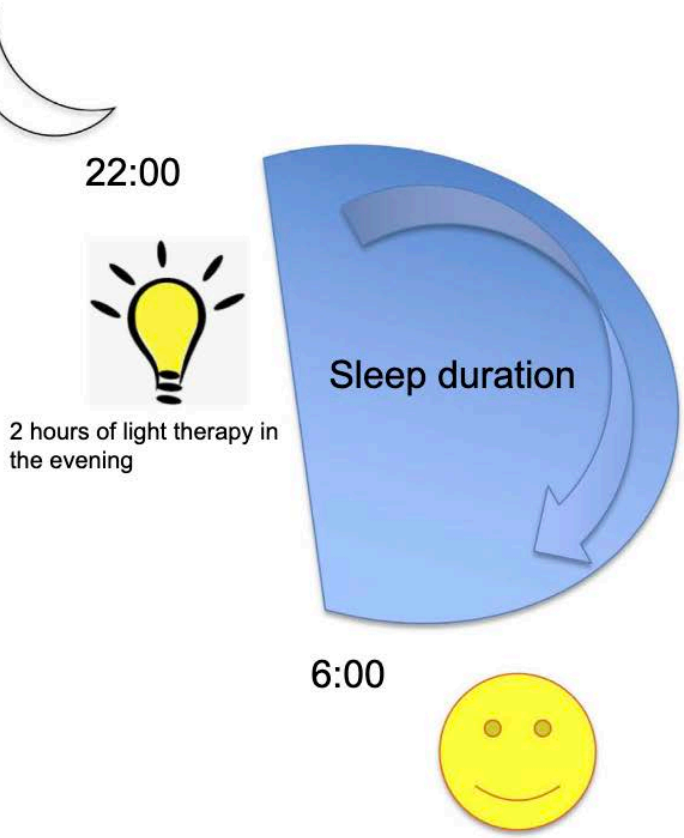
MANAGING CIRCADIAN RHYTHMS

- May take 1 day per time zone crossed to acclimate, consider extra time to adjust
- Shifting an individual's circadian rhythm
  - To shift earlier: bright light exposure in the early morning hours and melatonin given in early evening around dinner time
  - To shift later: evening light exposure (no evening melatonin)
- Consider keeping home sleep schedule if short trip
- Hypnotics best avoided, but may be useful in certain situations short term
- Make sure meetings and activities occur during periods of time associated with greatest alertness

TO DELAY SLEEP



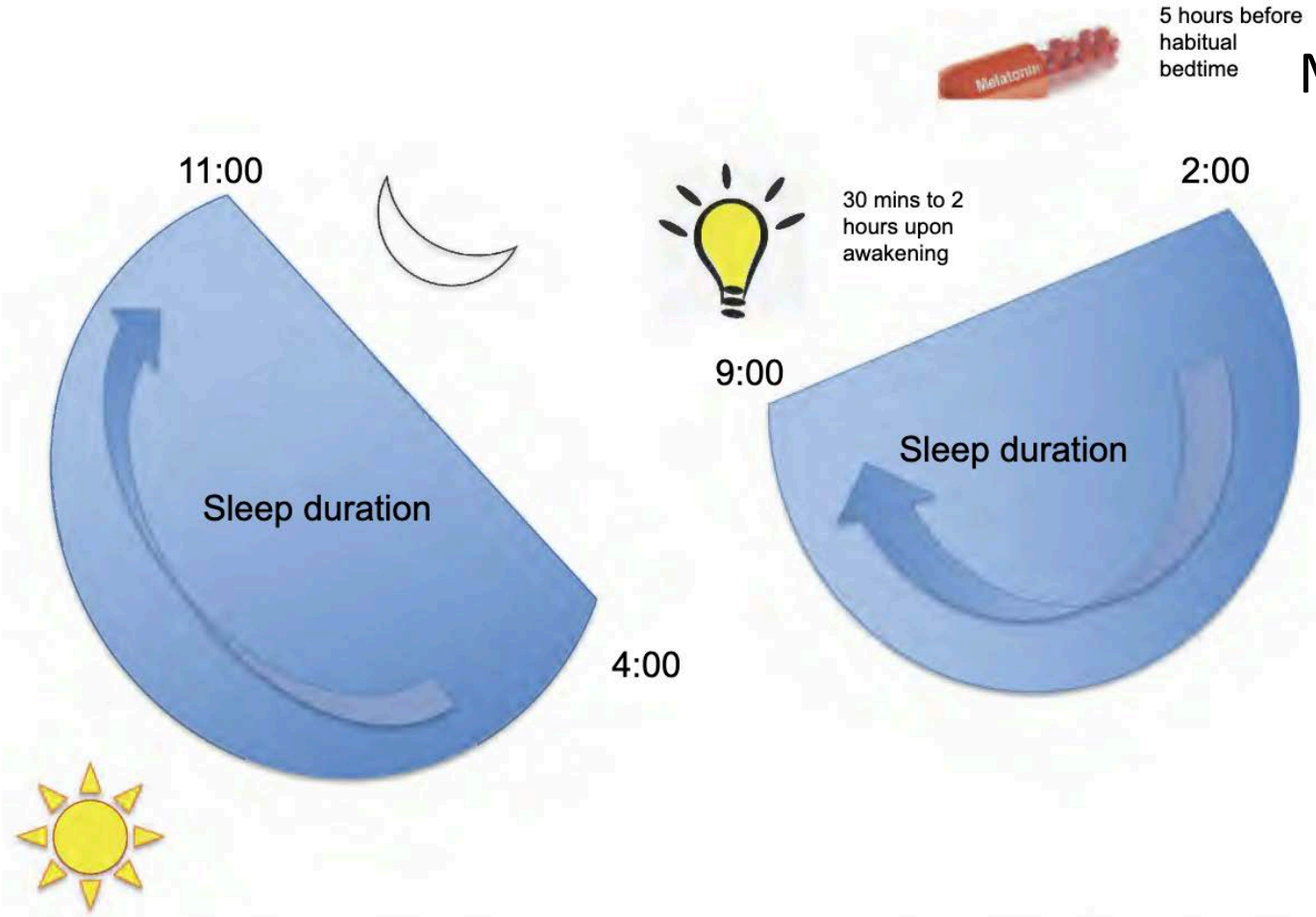
Advanced sleep wake phase disorder



Sleep schedule with treatment

NorthShore University HealthSystem

TO ADVANCE SLEEP



Delayed sleep wake phase disorder

Sleep schedule with treatment

LIGHT AS A STRATEGY FOR RECOVERY

- Light strongly influences sleep
- Staying active during off days, and maintain light exposure
- Avoiding bright light in early evening hours
- Avoiding blue light (short wavelength light 470 nm) which is more likely to suppress the evening increase in melatonin
  - Including computer screens, phone screens to check on the time, read email, etc
  - Red light (660 nm) has no effect on melatonin suppression but in some studies showed subjective improvement in sleep
- May be some implication to wearing a blue light blocking eyeglass right after an evening soccer match to improve that night's sleep
- Morning light exposure, prior to waking (gradual change from 0.001 lux to 300 lux) can improve both cognitive and physical performance by 4.7%.

TRAUMATIC BRAIN INJURY
SLEEP EFFECTS

- 50% of TBI patients report sleep disturbances
  - Hypersomnolence (28%)
  - Insomnia (29%)
  - Sleep apnea (25%)
- Possible causes
  - Diffuse axonal injury leading to impairment in axonal membrane stability and intracellular function
  - Decreased hormonal levels:
    - Decreased hypocretin or histamine- hypersomnia
    - Decreased melatonin – decreased REM sleep and disrupts circ rhythm
  - Damaged retino-hypothalamic tract – light-dark receptors for internal circadian pacemaker
  - Fatigue, depression, or anxiety could lead to insomnia
- Conversely insomnia could hinder repair of TBI

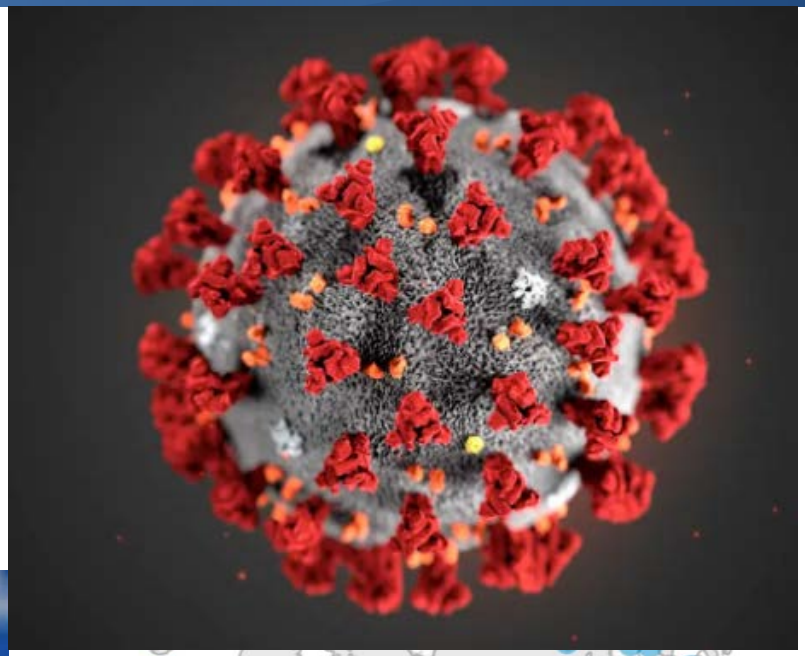
TREATMENT OF TBI

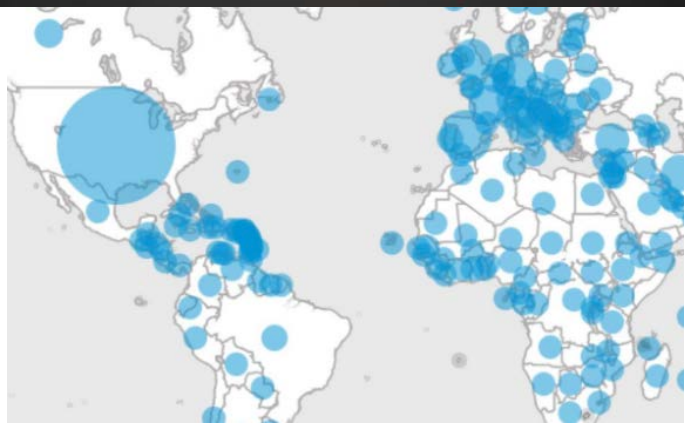
- Sleep hygiene
- Use of light to improve circadian rhythm
- Melatonin supplement useful
- May need ramelteon or other longer lasting melatonin receptor agonist

MANAGING HYPERSOMNOLENCE

- Consider modafinil or stimulants for TBI
  - may be prohibited by the sport due to risk of abuse for trying to enhance performance
  - Modafinil and methylphenidate are prohibited if used “IN-COMPETITION” per the World Anti-Doping Agency

COVID-19 PANDEMIC





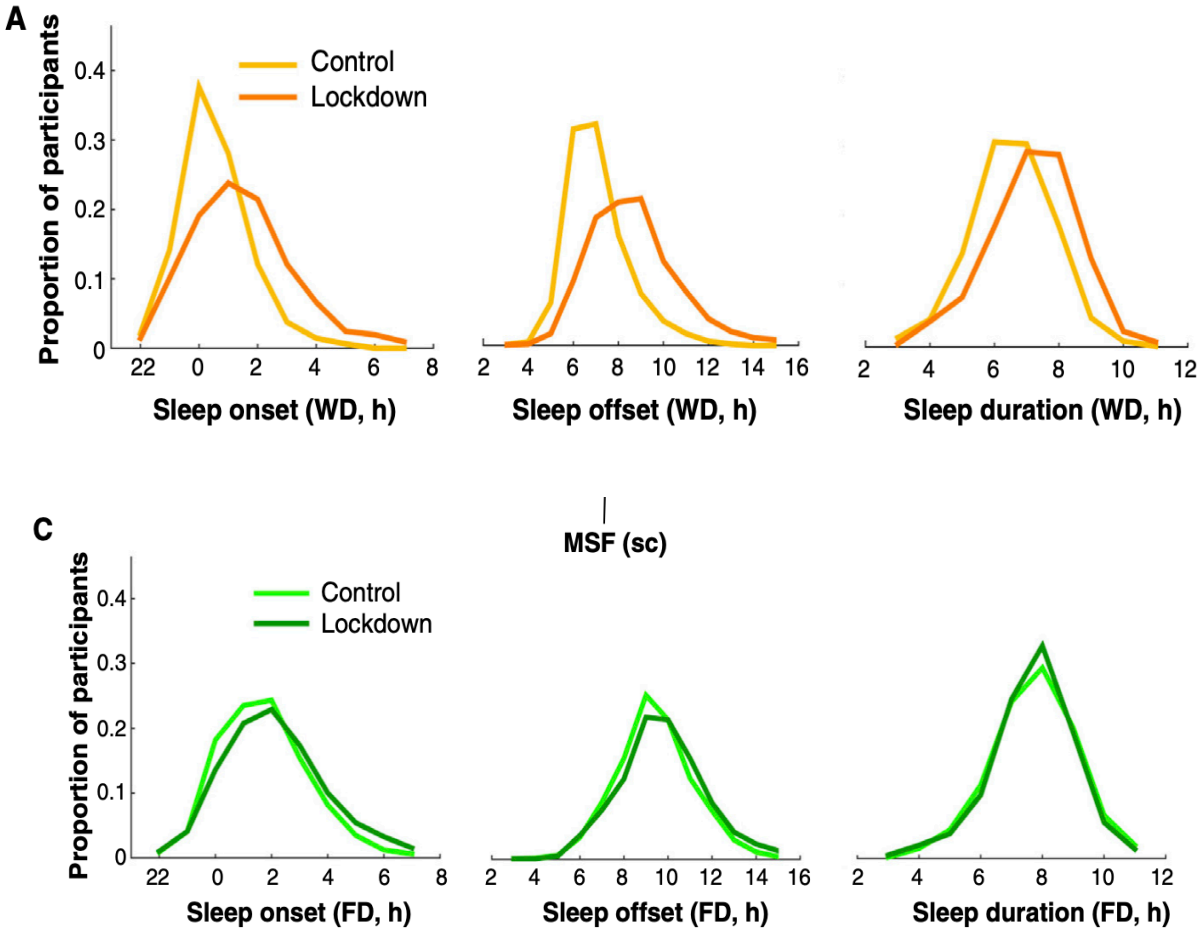
NorthShore University HealthSystem

COVID-19 PANDEMIC
CONSIDERATIONS OF SLEEP AND IMMUNITY

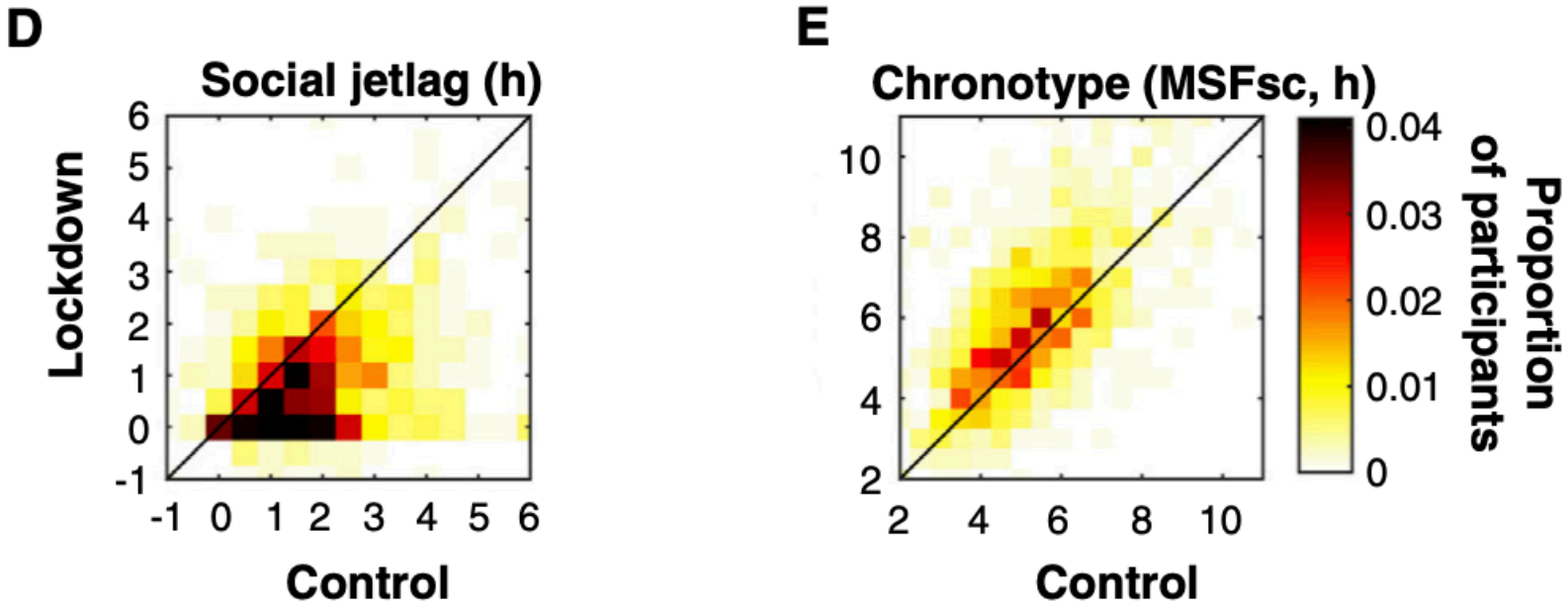
- Likely more prone to infection when sleep deprived
- Sleep deprivation experiments generally show that there are detrimental effects on immune-cell number, function, and cytokine productions
- Chronic partial sleep loss may be worse than short term total sleep loss on immune function
  - This is more of a reality for the current population (shift work, pressured lifestyles, and other stressors and changes in society)
- Sleep has important implications for protecting the population against infection and malignancy

COVID-19 PANDEMIC
Effects of lockdown on sleep

- Lockdown reduces sunlight exposure and disrupts daily routines, both of which are the main factors to entrain circadian rhythms
- Participants slept longer and later
- Sleep onset and offset were delayed but only on weekdays, not weekend "FD"
- Offset was more extreme
- Weekday and weekend hours became more aligned
- Less use of alarm clocks and naps
- Biggest effects noted for late adolescence



COVID-19 PANDEMIC
Effects of lockdown on sleep



- Social jetlag reduced due to lack of discrepancy between weekday and weekend
- MSF – midpoint of sleep on free days

COVID-19 PANDEMIC

- Similar findings found in university students forced to do remote learning (sleep logs)
- Despite the increased sleep time, sleep quality was either the same or reduced
  - PSQI (Pittsburgh sleep quality index questionnaire)
  - Increase in self-perceived burden
  - These effects on quality may be alleviated by exposure to natural daylight and physical exercise

COVID-19 IMPACT ON ATHLETES

- Loss of optimal circadian rhythm
  - Not waking up as early when training at home
  - Less discipline with disrupted pattern
  - Dietary habits worse when staying up later, can lead to weight gain
- Certain medical conditions at higher risk for COVID even in young individuals
  - Chronic lung disease, asthma, chronic kidney disease on dialysis, diabetes mellitus, hemoglobin disorders, liver disease, serious heart conditions, severe obesity (BMI >40 kg/m^2), immunocompromised states

CONCLUSION: ROLE OF ATHLETIC TRAINERS

- Optimize Sleep Health of Athletes
  - Prioritize proper scheduling and travel protocols
  - Incorporate time management and stress management
  - Educate on good sleep hygiene in athletes
  - All to improve overall health and performance
- Be knowledgeable of the common sleep disorders found in athletes and be able to screen the athletes for those disorders
- Standardized Screening questionnaires
  - STOP-BANG or Berlin questionnaire for OSA
  - Insomnia Severity Index
  - International RLS Study Group criteria
  - Horne-Osteberg Questionnaire, Morningness-Eveningness Questionnaire for circadian rhythm
- Engage in discussion and education if the athlete is in the higher risk category for COVID, relay knowledge of public health guidelines, and involve them in a shared decision-making process

ONGOING STUDIES AND OTHER REFERENCES

- ProjectREST
  (recovery enhancement and sleep training)
  - Several ongoing projects funded by the National Collegiate Athletics Association (NCAA) and the U of Arizona working on strategies to improve sleep health
- Other resources
  - https://www.olympic.org/athlete365/well-being/healthy-sleep-equals-healthy-mind/
  - https://www.olympic.org/athlete365/well-being/be-a-champion-of-sleep/

THANK YOU!

- References available on request