Fatigue Countermeasures in Aviation: The Position of the Aerospace Medical Association

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Institutes for Behavior Resources

May 2, 2009

Presented at the *Airlines Medical Directors Association Meeting,* Los Angeles, CA

For the full publication, please see:
Caldwell JA, Mallis, MM, Caldwell JL, Michel AP, Miller JC, Neri DF. (2009). Fatigue Countermeasures in Aviation. *Aviat Space Environ Med, 80*(1):29-59.

Fatigue in Aviation

Multiple flight legs, long duty hours, limited time off, early report times, less-than-optimal sleeping conditions, rotating and non-standard work shifts, jet lag[1,2,3]

↓

Disturbs sleep, both quantity and quality

Accumulates sleep debt

Disrupts circadian clock[3]

[1] *Neville et al., 1994*
[2] *Samel et al., 1995*
[3] *Rosekind et al., 1996*

Fatigue is Complex

- Fatigue is not a one-dimensional phenomenon
  - Homeostatic sleep drive and circadian rhythms are major components
  - Interact nonlinearly to produce changes in human alertness and cognitive performance[1]
- There are no biochemical markers for fatigue and no breathalyzer for sleepiness
  - The fact that fatigue is difficult to directly measure doesn't mean it isn't a serious concern
- Subjective estimates of sleepiness and fatigue levels are unreliable
- Individual differences exist in responses to sleep loss[2]

[1] Van Dongen et al., 2007
[2] Van Dongen et al., 2005

Homeostatic Sleep Drive

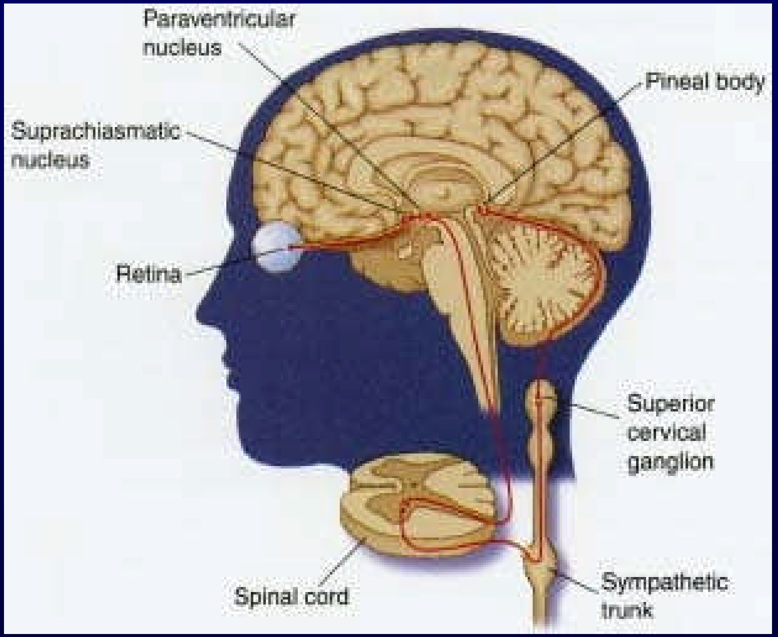
- Vital physiological need: required for survival
- Responsive to time awake
  - Biological pressure to sleep builds over waking hours
  - >16 hrs of continuous wakefulness, the homeostatic sleep drive begins to manifest itself in performance decrements and increased sleepiness[1]
- Affected by sleep quality and sleep consolidation
  - Inadequate sleep duration for one or more consecutive days
  - Physiological disrupted sleep due to medical conditions or environmental factors

[1] Van Dongen et al., 2003

Circadian Rhythms

The biological clock

- Coordinates daily alterations in behavior and physiology
- Hard wired in the brain: SCN
- Can be synchronized to external time signals (zeitgeber); but also continues in absence of signals
- “Free-running” intrinsic period is 24.18 hours[1]



- Modulates daily highs and lows in both physiological and neurobehavioral functions
- Defines periods of alertness and sleepiness

[1] *Czeisler et al., 1999*

Despite its complex nature, the operational causes and consequences of aircrew fatigue are strikingly consistent across diverse types of aviation operations[1,2,3,4,5,6,7,8,9]

[1] *Belland et al., 1994*
[2] *Bourgeois-Bougrine et al., 2003*
[3] *Caldwell et al., 2001*
[4] *Cornum et al., 1996*
[5] *Melfi et al., 2006*
[6] *Neville et al., 1994*
[7] *Rosekind et al., 2000*
[8] *Schultz et al., 2004*
[9] *Schultz et al., 2004*

Short Haul Operations

- Not immune to extended duty days
- Economic demands result in scheduling with short turn-around times
  - Increased take-offs and landings
  - Increased workload resulting from additional time constraints
- Early morning report times across multiple days and extended duty days are most challenging[1,2]
  - Difficult to maintain a regular sleep/wake cycle
  - Opportunities for recovery sleep are reduced
- Most frequently blame their fatigue on sleep deprivation and high workload

[1] Bourgeois-Bougrine et al., 2003
[2] Powell et a;l., 2007

Long Haul Operations

- Microsleeps have been documented in cockpit [1,2]
- Jet lag from circadian misalignment and flying on backside of clock
- Frequently attribute their fatigue to sleep deprivation and circadian disturbances associated with time-zone transitions
- Other operational factors include time pressure, multiple flight legs, and consecutive duty periods without sufficient recovery breaks

[1] *Samel et al., 1997*
[2] *Rosekind et al., 1994*

Fatigue Affects Human Performance[1]

- Accuracy and timing degrade
- Lower standards of performance become acceptable
- Attentional resources are difficult to divide
- The ability to integrate information is lost
- Social interactions decline
- The ability to logically reason is impaired
- Attention wanes
- Mood deteriorates
- Involuntary lapses into sleep occur

[1] *Cabon et al., 1993*

Current Regulations, Practices, & Alternative Approaches

- Crew Rest Guidelines
- Flight and Duty Time Guidelines
- Fatigue Risk Management System (FRMS): An Alternative Regulatory Approach
- Ultra Long-Range Flights: A Non-Traditional Approach

Crew Rest, Flight & Duty Time Regulations

- Developed in 1930's to mitigate aircrew fatigue
- Few changes since first introduced
- Scientific understanding of fatigue, sleep, shift work, and circadian physiology has advanced significantly over the past several decades
- Current regulations and industry practices have failed to adequately incorporate the new knowledge[1]
- Vary among different countries[2]

[1] Dinges et al., 1996
[2] Australian Government Civil Aviation Safety Authority, 2004

Crew Rest Guidelines

- Crew rest: is any time that a crew member is free from all duties and responsibilities, including flying and administrative work
- Includes local travel time to and from a place of rest
- Do not account for the timing of sleep with respect to circadian phase
- Rest period durations are constant and independent of time of day

Flight and Duty Time Guidelines

- Flight time: time b/t "block-out" and "block-in"
- Important to consider total duty time - not just flight time and workload
- Duty time is longer - includes the time period between when pilots report for a flight and when they are released after a flight

Fatigue Risk Management System

- Evidence-based system for the measurement, mitigation and management of fatigue risk[1]
- Multi-component approach that addresses both physiological and operational factors; has a scientific foundation
- Offers an interactive way to safely schedule and conduct flight operations on a case-by-case basis
- Offers alternative approach to traditional prescriptive duty and flight time limitations and rest time regulations

[1] Signal et al., 2006

Ultra Long-Range Flights: A Non-Traditional Approach

- Ultra long-range (ULR) aircraft will extend the longest flight-duty days from 14 to 16 hours to 20+ hours[1]
- Current regulations do not address 4-to-6-hr increase in flight duration
- FAA is currently using a case-by-case approach to approve ULR city pairs
  - approving ops by issuing a non-standard operations specification paragraph (OpSpec A332)
  - contains requirements designed to optimize opportunities for flight crew members to obtain adequate rest to safely perform their operational duties during all phases of this ULR trip sequence

[1] Neri, 2005

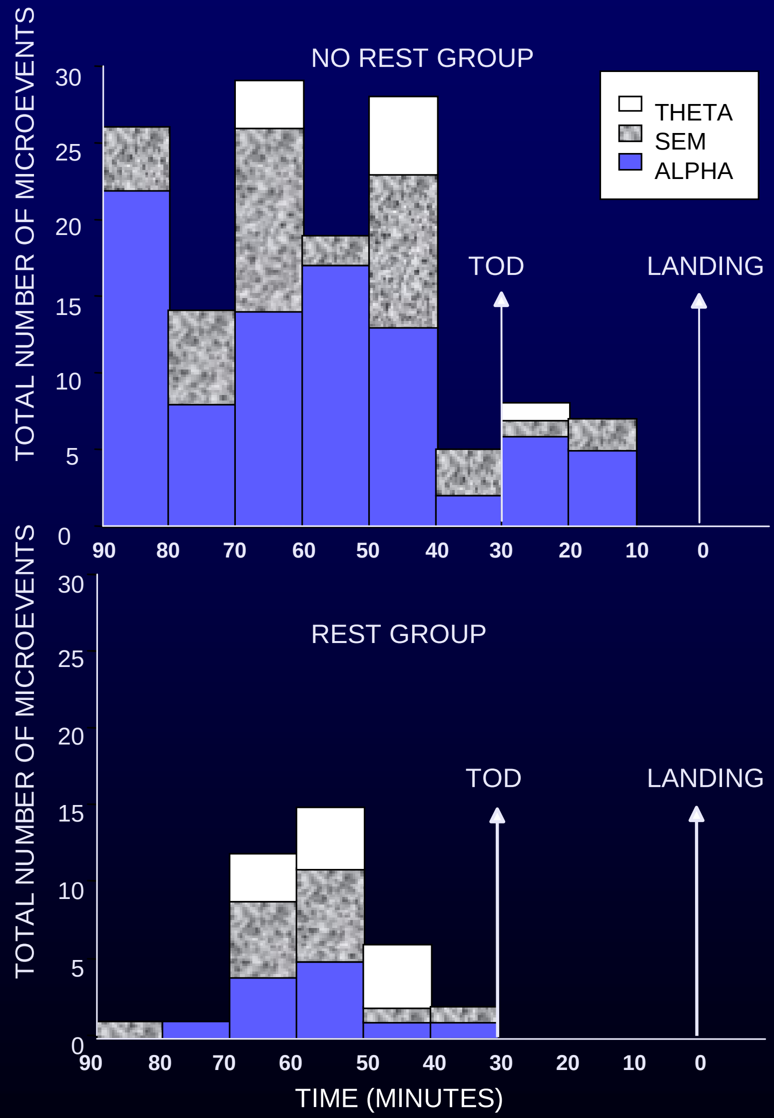
Position Statement on Crew Rest, Flight, and Duty Time Regulations

- Prescriptive approaches do not address inherent sleep and circadian challenges nor do they provide operational flexibility
- Addressing fatigue as part of a scientifically-based, comprehensive safety management system can help to minimize the risk associated with current and future aviation operations
- An FRMS offers a way to more safely conduct flights beyond existing regulatory limits and should be considered an acceptable alternative to prescriptive flight and duty time and rest period regulations

In-Flight Countermeasures and Strategies

- Cockpit Napping
- Activity Breaks
- Bunk Sleep
- In-Flight Rostering
- Cockpit Lighting

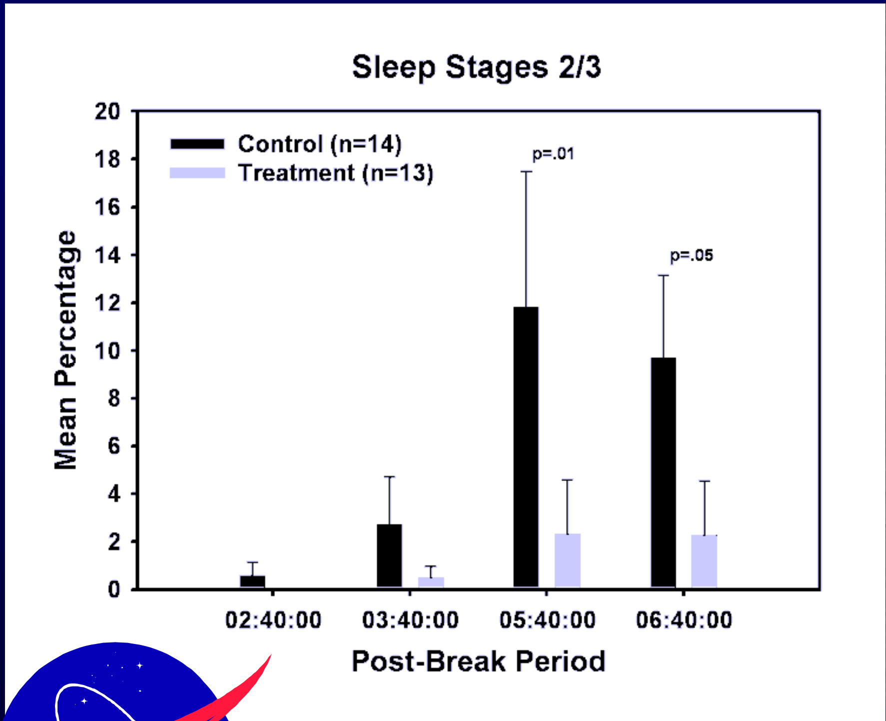
Controlled Rest on the Flight Deck



A 26-min nap resulted in significant improvements in subsequent physiological alertness and performance compared to no nap, especially during descent and landing.

Rosekind et al., 1994

Activity Breaks



Hourly, brief (7-min) activity breaks reduced physiological and subjective sleepiness for 15-25 min, especially around the time of the circadian trough.

Neri et al., 1999

Bunk Sleep

- Ensuring adequate bunk sleep is one of the most important in-flight countermeasures that can be implemented[1]
- Operationally feasible approach to address sleep loss associated with extended hours of wakefulness, crossing multiple time zones, and flying during nighttime hours
- Need to be scheduled in consideration of operational demands and of a duration that allows all crew members to receive ample rest periods
- Utilizing periods of increased physiological sleep propensity will help to increase both the quantity and quality of bunk sleep[2,3,4]

[1] Flight Safety Foundation, 2005
[2] Carskadon, 1989
[3] Dijk, 2005
[4] Dinges, 1986

In-Flight Rostering

- Not commonly discussed as a fatigue countermeasure
- Scheduling of flight crew to assigned positions on the flightdeck, freeing other flight crew to obtain in-flight rest or bunk sleep
- Allows for scheduling of bunk sleep in a way that minimizes the hours of continuous wakefulness for the landing pilots and utilizing crew members who are well rested during other critical phases of flight

Cockpit Lighting

- Light can have an acute, immediate, alerting effect on mood and performance independent of its circadian phase-shifting properties[1,2]
- Potentially useful countermeasure at night where conditions allow its use
- Increasing the flightdeck light level at night to at least 100 lux (room light level) must not interfere with flightcrew performance or visual requirements

[1] Cajochen, 2007
[2] Cajochen et al., 2000

Position Statement on the Use of In-Flight Countermeasures

- Application of in-flight countermeasure strategies should be based on the currently available scientific knowledge and should be implemented only after thoughtful consideration
- Recommend the authorized use of in-seat cockpit napping and in-flight activity breaks in commercial flight operations, under appropriate circumstances, with appropriate safeguards, and in accordance with clear guidelines to ensure operational safety
- Bunk sleep and in-flight rostering go hand-in-hand when used as a fatigue mitigation strategy
- Increasing the flightdeck light level, particularly at night, has the potential to temporarily boost alertness and performance

Pre/Post-Flight Strategies & Countermeasures

- Hypnotics
- Improving Sleep and Alertness
  - Healthy Sleep Practices
  - Napping
  - Circadian Adjustment
  - Exercise
  - Nutrition
- Non-FDA-Regulated Substances

Hypnotics

- ***Temazepam*** (15-30 mg)[1,2,3,4,5]
  - Best choice for optimizing 8-hr sleep periods that are out-of-phase with the body's circadian cycle
  - Useful when sleep is often easy to initiate, but difficult to maintain due to the circadian rise in alertness

- ***Zolpidem*** (5-10 mg)[6,7,8,9,10]
  - Optimal choice for sleep periods less than 8 hours
  - Especially useful for promoting short- to moderate-length sleep durations (of 4 to 7 hours) when these shorter sleep opportunities occur at times that are not naturally conducive to sleep

- ***Zaleplon*** (5-10 mg)[11,12,13]
  - Best choice for initiating very short naps (1 to 2 hours) during a period of otherwise sustained wakefulness
  - Helpful in initiating early sleep onsets in personnel who are trying to ensure sufficient sleep prior to a very early start time the next morning

[1] Caldwell et al., 2003
[2] Mitler et al., 1979
[3] Muller et al., 1987
[4] Nicholson et al., 1980
[5] Porcu et al., 1997
[6] Lavie, 1986
[7] Nicholson, 1986
[8] Stone et al., 1997
[9] Suhner et al., 2001
[10] Waterhouse et al., 1997
[11] Chagan et al., 1999
[12] Elie et al., 1999
[13] Fry et al., 2000

Position Statement on the Use of Hypnotics

It is recommended that Zolpidem be authorized for civilian commercial pilots a maximum of 4 times per week in situations where natural sleep is difficult or impossible due to circadian or other reasons provided:

1) Pilot has checked for any unusual reactions to the medication during an off-duty period
2) Dose does not exceed 10 mg in any given 24-hr period
3) There is a minimal interval of 12 hours between the ingestion of the medication and the return to duty

Improving Sleep and Alertness

- Healthy Sleep Practices
- Napping
- Circadian adjustment
- Exercise
- Nutrition

Healthy Sleep Practices

- Getting a sufficient quantity of high quality sleep on a daily basis is the number one focus in fighting fatigue
- Keep a regular sleep/wake schedule; protect sleep time
- Develop and practice a regular pre-sleep routine
- Use bedroom only for sleep; avoid work, worry, exercise
- Do not drink or eat heavily before bedtime
- If you don’t fall asleep in 30 minutes, get out of bed

Napping

- Nap timing or placement
  - Nap taken during the day before an all-night work shift (a prophylactic nap), with no sleep loss prior to the shift, will result in improved performance over the night[1,2]
  - Naps taken later in the sleep-deprivation period also are beneficial; should be longer than prophylactic naps
- Nap length
  - Research has shown a dose-response relationship between the length of the nap and performance[1]
- Placement of nap with regard to phase of body clock
  - Take into account the impact of circadian phase on sleep propensity, structure, and quality across the day as well as the effects on performance both immediately after awakening and later in the work period[3]

[1] Bonnet, 1991
[2] Schweitzer et al., 1992
[3] Gillberg, 1984

Circadian Adjustment

- Circadian clock cannot adapt immediately to a change in the duty/rest cycle or changes in environmental cues[1]
- Adjustment depends on direction of travel, the number of time zones crossed[2,3]
- Adjustment does not appear to be linear and those who are evening types or “owls” tend to adjust to the new time zone more quickly relative to morning types or “larks”
- Natural sunlight exposure, appropriately-timed naps, and proper exposure to zeitgebers (time cues) may facilitate circadian adjustment[4,5,6,7]

[1] Klein et al., 1980
[2] Boulos et al., 1995
[3] Sack et al., 2007
[4] Atkinson et al., 2007
[5] Burgess et al., 2002
[6] Skene et al., 2006
[7] Waterhouse et al., 2007

Exercise

- Shown to be an effective fatigue countermeasure in both the laboratory and aviation environments
- Regular exercise can result in improved sleep quantity and quality
- Increases physiological arousal and can help promote alertness short term
  - Subjective effects seen up to 30 minutes post exercise[1]
- Can also induce phase shifts in the melatonin circadian rhythm and the circadian clock[2,3,4,5]

[1] LeDuc et al., 2000
[2] Barger et al., 2004
[3] Buxton et al., 2003
[4] Eastman et al., 1995
[5] Horowitz et al., 2002

Nutrition

- When consuming food immediately before sleep - should favor grains, breads, pastas, vegetables, and/or fruits
- Avoid large meals, high-fat meals, high-acid meals, sweets, and significant hunger
- Purposeful manipulation of dietary CHO by aircrew to help induce and sustain their sleep periods may be ill-advised due to the unpredictability of effects (see 1,2,3,4,5)

[1] *Afaghi et al., 2007*
[2] *Landström et al., 2000*
[3] *Spring et al., 1982-1983*
[4] *Wells et al., 1997*
[5] *Zammit et al., 1995*

Position Statement on Improving Sleep and Alertness (1)

- Healthy sleep practices ensure that crews will be able to make the most of available sleep opportunities; provide educational materials that outline natural sleep-promoting behaviors:
  - Include importance of naps for bridging the gap between consolidated sleep episodes
  - Naps should be as long as possible and whenever feasible
  - Naps should occur at the circadian times most conducive to natural sleep
  - Allow for 30-min wake-up period prior to the performance of any safety-sensitive tasks

Position Statement on Improving Sleep and Alertness (2)

- Natural adjustment techniques such as controlling the timing of light exposure, meals, and other activities should be employed when moving to a new time zone
- Crew members should engage in at least 30 minutes of aerobic exercise every 24 hours
- Balanced meals at regular intervals help to promote and maintain general health; avoid consuming meals (particularly large meals) immediately prior to bedtime

Non-FDA-Regulated Substances (1)

Melatonin

- Efficacy as a hypnotic continues to be debated[1,2]
- Evidence of a soporific effect when taken outside the normal sleep period, particularly when taken to phase-advance the sleep period[3]
- Appropriate administration can improve circadian adjustment to new time schedules[4,5,6]

[1] Van den Heuvel et al., 2005
[2] Zhdanova, 2005
[3] Arendt, 2005
[4] Arendt et al., 2005
[5] Brzezinski et al., 2005
[6] Touitou et al., 2007

Non-FDA-Regulated Substances (2)

Valerian

- Some studies have shown significant effects on sleep but not the clinical efficacy needed to treat insomnia
- Can be helpful with mild insomnia when taken continuously[1,2,3,4]

Kava

- Data has shown it can decrease sleep latency and increase sleep quality in people with insomnia
- More studies are needed to establish its efficacy and safety[2]

[1] Hadley et al., 2003
[2] Monti, 2004
[3] Taibi et al., 2007
[4] Wing, 2001

Non-FDA-Regulated Substances (3)

Caffeine[1]

- Numerous studies have shown it increases vigilance and improves performance in sleep-deprived individuals
- Best for the short-term elevation of cortical arousal
- Regular use may lead to tolerance and various undesirable side effects, including elevated blood pressure, stomach problems, and insomnia
- Affects the nervous system within 15 to 20 min; effects last for ~ 4 - 5 hrs

Tyrosine[2,3]

- May prove useful under high stress conditions, including those associated with sleep loss

[1] Nehlig, 1999
[2] Neri et al., 1995
[3] Owasoyo et al., 1992

Position Statement on Non-FDA-Regulated Substances

- Consumed with the same caution as any prescription substance
  - Substances are not under federal control, the manufacturing quality is left to the individual companies
- Substances such as valerian and kava also should not be relied upon to manipulate either sleep or performance
- Caffeine is an effective alertness-enhancing compound and can be used as an aviation fatigue countermeasure
  - Avoid ingesting more than 1000 mg of caffeine in any 24-hr period
  - Make an effort to use caffeine judiciously
  - Avoid ingesting caffeine within 4 hours of bedtime

New Technologies

- On-line, Real Time Assessment
- Off-line Fatigue Prediction Algorithms

On-line, Real Time Assessment

- Provide meaningful measures of alertness levels and performance ability in real time
- Aim to monitor some aspect of the individual's physiology or behavior that is sensitive to increasing fatigue and sleepiness levels
- Examples include
  - EEG changes that occur simultaneously in the delta, theta, alpha, and beta bands[1,2]
  - Eye and visual system, under central nervous system control[3,4,5]
  - Facial feature recognition technology is also currently being validated
- Usefulness as real-time technologies is dependent on the requirements and conditions of the operational environment ; some may not even be practical for use in highly restrictive environments such as the flightdeck[6,7,8]

[1] Cajochen et al., 1999
[2] Fabiani et al., 2000
[3] Lavine et al., 2002
[4] Lobb et al., 1986
[5] Tsai et al., 2007
[6] Dinges et al., 1998
[7] Mallis et al., 1998
[8] Mallis et al., 2004

Off-line Fatigue Prediction Algorithms

- Provide an estimate of an individuals' alertness level or performance effectiveness during a work period to be performed in the future[1]
- These predictions of physiological state are measured relative to a standard such as the individual's baseline and/or a group norm
- Biomathematical models of alertness for the prediction of alertness and performance levels
  - Useful in the prediction of performance or effectiveness levels when comparing different operational schedules[2,3]
  - Vary in their specific algorithms and differ in the number and type of input variables, output variables and goals and capabilities

[1] Gilliand et al., 1993
[2] Mallis et al., 1998
[3] Mallis et al., 2004

Position Statement on New Technologies

- Fatigue detection technologies (fitness for duty and real-time assessment devices) and scheduling tools that incorporate biomathematical models of alertness should not be solely relied upon for the determination of safe or ‘fatigue-free’ flights
- They are tools that can be effectively incorporated as part of an overall safety management approach and should not be used in place of regulatory limitations
- Selection of the ‘best tool’ should be dependent on its demonstrated validity for mitigating fatigue risk during aviation operations

Conclusions

- While fatigue represents a significant risk in aviation when left unaddressed, there are currently numerous countermeasures and strategies that can be employed to increase safety
- New technologies and countermeasures are being developed that hold great promise for the future
- It is our hope that the countermeasures and strategies described in this paper, when employed appropriately, will serve to reduce the risk of aviation accidents and incidents attributable to the insidious effects of fatigue

Together we can address fatigue.

Together we can manage fatigue issues.

Alone, we cannot!

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Acknowledgements

- Dr. Thomas Nesthus, Chair of the Aerospace Human Factors Committee (AHFC) for his guidance and support throughout a lengthy process

- CAPT Nicholas Davenport for comments and information regarding U.S. Navy flight duty/rest regulations

- CAPT Barry Reeder for information about corresponding U.S. Air Force regulations though any errors remain ours.

- We thank the members of the AHFC for their comments on an earlier version of the manuscript, especially Dr. Ronald Hoffman and Dr. David Schroeder as well as the Aerospace Medical Association Executive Council for its comments and review, particularly Dr. Russell Rayman, Dr. Guillermo Salazar, Dr. Estrella Forster, and CAPT Christopher Armstrong

FAA Publishes Proceedings from Aviation Fatigue Symposium

The proceedings from the FAA-sponsored Aviation Fatigue Symposium: Partnerships for Solutions conducted on June 17 to 19, 2008 are now available online.

Please visit the following site to view the proceedings online or download a pdf copy:

http://www.faa.gov/news/conferences_events/2008_aviation_fatigue/

References

Afaghi, A., O'Connor, H., & Chow, C. M. (2007). High-glycemic-index carbohydrate meals shorten sleep onset. *Am J Clin Nutr, 85*, 426-430.

Arendt, J. (2005). Melatonin characteristics, concerns, an prospects. *J Biol Rhythms*, 20:291-303.

Arendt JT, Skene DJ. (2005). Melatonin as a chronobiotic. *Sleep Med Rev*, 9:25-39.

Atkinson G, Edwards B, Reilly T, Waterhouse J. (2007). Exercise as a synchronizer of human circadian rhythms: an update an discussion of the methodological problems. *Eur J Appl Physiol*, 99:331-41.

Barer LK. Wright KP, Jr Hughes RJ, Czeisler CA. (2004). Daily exercise facilitates phase delays of circadian melatonin rhythm in very dim light. *Am J Physiol Regul Integr Comp Physiol*, 286:R1077-84 Epub.

Bonnet MH. (1991). The effect of varying prophylactic naps on performance, alertness and mood throughout a 52-hour continuous operation. 14:307-15. Boulos Z, Campbell SS, Lewy AJ, Terman M, Dijk D,

Eastman CI. (1995). Light treatment for sleep disorders: consensus report. VI. Jet lag. *J Viol Rhythms*, 10:167-76.

References

Brzezinski A, Vangel MG, Wurtman RJ, Norrie G, Zhdanova I, Ben-Shushan A, et al. (2005). Effects of exogenous melatonin on sleep: a meta-analysis. *Sleep Med Rev*, 29:525-31.

Burgess HJ, Sharkey KM, Eastman CI. (2002) Bright light, dark and melatonin can promote circadian adaptation in night shift workers. *Sleep Med Rev*, 6:407-20.

Buxton OM, Lee CW, L'Hermite-Baleriaux M, Turkek FW, Van Cauter E. (2003). Exercise elicits phase shifs and acute alterations of melatonin that vary with circadian phase. *Am J Physiol Regul Intergr Comp Physiol*, 284:R714-24.

Cajochen C. (2007) Alerting effects of light. *Sleep Med Rev*, 11:453-64.

Cajochen C, Khalsa SB, Wyatt JK, Czeisler CA, Dijk DJ. (1999). EEG and ocular correlates of circadian melatonin phase and human performance decrements during sleep loss. *Am J Physiol*, 277:R640-9.

Caldwell JA, Mallis, MM, Caldwell JL, Michel AP, Miller JC, Neri DF. (2009). Fatigue Countermeasures in Aviation. *Aviat Space Environ Med, 80* (1):29-59.

Caldwell JL, Prazinko BF, Rowe T, Norman D, Hall KK, Caldwell JA. (2003). Improving daytime sleep with temazepam as a countermeasure for shift lag. *Aviat Space Environ Med*, 74:153-63.

References

Chagan L, Cicero LA. (1999). Zaleplon: A possible advance in the treatment of insomnia. *P&T*, 24:590-9.

Dinges DF, Mallis MM. (1998). Managing fatigue by drowsiness detection: can technological promises be realized? In: Hartley L, eds. Managing fatigue in transportation*. Kidlington, Oxford, UK: Elsevier Science Ltd*, 209-29.

Eastman CI, Boulos Z, Terman M, Campbell SS, Dijk D, Lewy AJ. (1995). Light treatment for sleep disorders: consensus report. VI. Hift work. *J Biol Rhythms*, 10:157-64.

Elie R, Ruther E, Farr I, Emilien G, Salinas E. (1999). Sleep latency is shortened during 4 weeks of treatment with zaleplon, a novel nonbenzodiazepine hypnotic. *J Clin Pschiatry*, 60:536-44.

Fabiani M, Gratton G, Coles MG Event-related brain potentials In: Caciooppo JT, Tassianary LG, Berntson GG, eds. (2000). Handbook of psychophysiology. *Cambridge, England: Cambidge University Press*, 53-84.

Fry J, Scharf M, Mangano R, Fujimori M. (2000). Zaleplon improves sleep without producing rebound effects in outpatients with insomnia. *Int Clin Psychopharmacol*, 15:14-52.

References

Gillberg M. (1984). The effects of two alternative timings of a one-hour nap on early morning performance. *Biol Psychol*, 19:45-54.

Gilliland K, Schlegel RE. (1993). Readiness to perform: a critical analysis of the concept and current practices. *Oklahoma City, OK: Office of Aviation Medicine, Federal Aviation Adminisration. NTIS No. AD*, A269:379.

Hadley S, Petry JJ. Valerian. (2003). Am Fam Physician, 67:1755-8.

Horowitz TS, Tanigawa T. (2002). Circadian-based new technologies for night workers. *Ind Health*, 40:223-36.

Klein KE, Wegmann HM. (1980) Significance of circadian rhythms in aerospace operations. *AGARDograph No. 246, Neuilly-sur-Seine, France.*

Landstrom U, Knutsson A, Lennernas M, Soderberg L. (2000). Laboratory studies of the effects of carbohydrate consumption on wakefulness. *Nutr Health*, 13:213-25.

Lavie P. (2002) Ultrashort sleep-waking schedule. III “Gates” and “forbidden zones” for sleep. *Electroencephalogr Clin Neurophysiol*, 63:414-25.

Lavine RA, Sibert JL, Gokturk M, Dickens B. (2002). Eye-tracking measures and human performance in a vigilance task. *Aviat Space Environ Med*, 73:367-72.

References

LeDuc PA, Caldwell JA, Ruyak PS. (2000). The effects of exercise versus napping on alertness and mood in sleep-deprived aviators. *Fort Rucker, AL: U.S. Aeromedical Research Laboratory, Technical Report* 2000-12.

Lobb ML, Stern JA. (1986). Pattern of eyelid motion predictive of decision errors during drowsiness: oculomotor indices of altered states. *Int J Neurosci*, 30:17-22.

Mallis M, Maislin G, Konowal N, Byrne V, Bierman D, Davis R, et al. (1998). Biobehavioral responses to drowsy driving alarms and alerting stimuli. *Washington, DC: U.S. Department of Transportation, Final Report: 1-127.*

Mallis MM, Mejdal S, Nguyen TT, Dinges DF. (2004). Summary of the key features of seven biomathematical models of human fatigue and performance. *Aviat Space Environ Med*, 75:A4-14.

Mitler MM, Carskadon MA, Phillips RL, Sterling WR, Zarcone VP, Jr., Spiegels R, et al. (1979). Hypnotic efficacy of temazepam: a long-term sleep laboratory evaluation. *Br J Clin Pharmacol*, 8:63S-8S.

References

Monti JM. (2004). Primary and secondary insomnia: prevalence, causes and current therapeutics. *Curr Med Chem Cent Nerv Syst Agents*, 4:119-37.

Muller FO, Dyk MV, Hundt HKL, Joubert AL, Luss HG, Groenewoud G, et al. (1987). Pharmacokinetics of temazepam after day-time and night-time oral administration. *Eur J Clin Pharmacol*, 33:211-4.

Nehlig A. (1999). Are we dependent upon coffee and caffeine? A review on human and animal data. *Neurosci Biobehav Rev*, 23:563-76.

Neri DF, Wiegmann D, Stanny RR, Shappell SA, McCardie A, McKay DL. (1995). The effects of tyrosine on cognitive performance during extended wakefulness. *Aviat Space Environ Med*, 66:313-9.

Nicholson AN, Pascoe PA, Spencer MB, Stone BM, Roehrs TA, Roth T. (1986). Sleep after transmeridian flights. *Lancet*, 2:1205-8.

Owasoyo JO, Neri DF, Lamberth JG. (1992) Tyrosine and its potential use as a countermeasure to performance decrement in military sustained operations. *Aviat Space Envirn Med, 63:364-9.*

Porcu s, Bellatreccia A, Ferrara M, Casagrande M. (1997). Performance, ability to stay awake, and tendency to fall asleep during the night after a diurnal sleep with temazepam or placebo. Sleep, 20:535-41.

References

Sack RL, Auckley D, Auger RR, Carskadon MA, Wright KP, Jr., Vitiello MV, et al. (2007). Circadian rhythm sleep disorders: part I, basic principles, shift work and jet lag disorders. An American Academy of Sleep Medicine review. *Sleep*. 30:1460-83.

Schweitzer PK, Muehlback MJ, Walsk JK. (1992). Countermeasures for night work performance deficits: the effect of napping or caffeine on continuous performance at night. *Work Stress*, 6:355-65.

Skene DJ, Arnedt J. (2006). Human circadian rhythms: physiological and therapeutic releveance of ligh and melatonin. *Ann Clin Biochem*, 43:344-53.

Spring B, Maller O, Wurman J, Digman L, Cozolino L. (1982-1983). Effects of protein and carbohydrate meals on mood and performance: interactions with sex and age. *J Psychiatr Res*, 17:155-67.

Stone BM, Turner C. (2001). Promoting sleep in shiftworkers and intercontinental travelers. *Chronobiol Int*, 14:133-43.

Suhner An, Schalagenhauf P, Hofer I, Johnson R, Tschopp A, Steffen R. (2001). Effectiveness and tolerability of melatonin and zolpidem for the alleviation of jet lag. *Aviat Space Environ Med*, 72:638-46.

References

Touitou Y, Bogdan A. (2007). Promoting adjustment of the sleep-wake cycle by chronobiotics. *Physiol Behav*, 90:294-300.

Tsai YF, Viirre E, Strychacz C, Chase B, Jung TP. (2007). Task performance and eye activity: predicting behavior relating to cognitive workload. *Aviat Space Environ Med*, 78 B176-85.

Van den Heuvel CJ, Forguson SA, Macchi MM, Dawson D. (2005). Melatonin as a hypnotic: con. *Sleep Med Rev*, 9:71-80.

Waterhouse J, Reilly T, Atikinson G. (1997). Jet-lag. *Lancet*, 350:1611-6.

Wells AS, Read NW, Uvnas-Moberg K, Alster P. (1997). Influences of fat and carbohydrate on postprandial sleepiness, mood, and hormones. *Physiol Behav*, 61:679-86.

Wing YK. (2001). Herbal treatment of insomnia. *Hong Kong Med J, 7:392-402.*

Zammit GK, Kolevzon A, Fauci M, Shindledecker R, Ackerman S. (1995). Postprandial sleep in healthy men. *Sleep*, 18:229-31.

Zhdanova IV. (2005). Melatonin as hypnotic: pro. *Sleep Med Rev*, 9:51-65.