# Optimal Shift Duration and Sequence: Recommended Approach for Short-Term Emergency Response Activations for Public Health and Emergency Management

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Since September 11, 2001, and the consequent restructuring of the US preparedness and response activities, public health workers are increasingly called on to activate a temporary round-the-clock staffing schedule. These workers may have to make key decisions that could significantly impact the health and safety of the public.

The unique physiological demands of rotational shift work and night shift work have the potential to negatively impact decisionmaking ability. A responsible, evidence-based approach to scheduling applies the principles of circadian physiology, as well as unique individual physiologies and preferences. Optimal scheduling would use a clockwise (morning-afternoon-night) rotational schedule: limiting night shifts to blocks of 3, limiting shift duration to 8 hours, and allowing 3 days of recuperation after night shifts. (*Am J Public Health.* 2007;97: S88–S92. doi:10.2105/AJPH.2005.078782)

**WHEN EMERGENCIES ARISE,** some organizations for which the work responsibilities are generally during business hours need to provide surveillance, advice, and consultation 24 hours a day. For example, when a natural disaster strikes, emergency management officials mount an emergency response that requires 24-hours-a-day service rather than business as usual. Since September 11, 2001, and the consequent restructuring of the nation's preparedness and response activities, public health workers are increasingly called on to "gear up" preparedness and response activities by activating a round-the-clock staffing schedule. The Director's Emergency Operations Center at 8the Centers for Disease Control and Prevention, for instance, may activate a 24-hour response readiness unit that requires a designated lead group, of which the members typically work during usual business hours, to provide 24-hour staffing for the Director's Emergency Operations Center on a short-term basis.

In an emergency, public health and emergency management workers may be called on to make judgments and decisions that could significantly impact the health and safety of the public. The unique physiological demands of rotating shift work and night shift work have the potential to negatively impact decisionmaking ability. The health and safety of the public demands a thoughtful, evidence-based approach to scheduling.

## PUBLIC HEALTH RELEVANCE

A look at the time of occurrence of industrial and engineering disasters provides insight into a possible association between human error and circadian rhythm as it relates to shift work (see the box on this page). The incident at the Three Mile Island nuclear facility in Pennsylvania on March 28, 1979, occurred because night shift workers failed to recognize the loss of core coolant water resulting from a stuck valve between 4:00 AM and 6:00 AM. Similarly, on June 9, 1985, the Davis–Besse reactor in Oak Harbor, Ohio, went into automatic shutdown followed by a total loss on the main feed water at 1:35 AM. The incident reached more critical proportions when an operator in those early morning night shift hours pushed the wrong 2 buttons in the control room, defeating the safety function of the auxiliary feedwater system. When the Racho Seco nuclear reactor near Sacramento, Calif, automatically tripped after DC power to the integrated control system was lost at 4:14 AM on December 26, 1985, human errors of omission and commission caused time delays in regaining control of the plant. Even the nuclear plant catastrophe at Chernobyl is officially acknowledged to have begun at 1:23 AM as the result of human error.[1]

The Presidential Commission on the space shuttle *Challenger* accident cited the contribution of human error and poor judgment related to sleep loss and shift work during the early

**Examples of Incidents Attributed to Human Error During Nights or Night Shifts**

- Three-Mile Island nuclear reactor
- Davis–Besse nuclear reactor at Oak Harbor, Ohio
- Racho Seco nuclear reactor near Sacramento, Calif
- Chernobyl nuclear plant
- Space shuttle *Challenger* accident
- Launch of the space shuttle *Columbia*
- Bhopal Union Carbide tragedy
- *Exxon Valdez* accident
- *Estonia* ferry accident
- Peak incidence of single-vehicle motor accidents
- 18% increase in human error incidents in afternoon shift relative to morning shift
- 30% increase in human error incidents on night shift relative to morning shift

morning hours. This same commission also cited early morning shift work error in a previous near-catastrophic launch of the shuttle *Columbia* on January 6, 1986.[1]

The incidents involving the Bhopal Union Carbide tragedy and the *Exxon Valdez*, as well as the *Estonia* ferry incident, all occurred in the early morning hours. Investigations have concluded that all of these were at least in part attributable to fatigue and human error.[2]

Several investigators have studied the temporal distribution of single-vehicle accidents, which have a high probability of being related to inadvertent lapses in driver attention. The major peak occurs between midnight and 7:00 AM. A secondary peak occurs between 1:00 PM and 4:00 PM. A German Federal Railways study revealed 2 peaks on the incidence of human errors causing emergency braking incidents, one between 3:00 AM and 6:00 AM, and a second between 1:00 PM and 3:00 PM. One US study of 493 single-vehicle truck accidents revealed a peak time of occurrence to be between 1:00 AM and 7:00 AM.[1]

These and other studies, coupled with an understanding of the physiology of circadian rhythm disruption, suggest that human performance is at a low ebb, and mistakes leading to catastrophes are more likely to occur, during certain periods in the day. Policy agencies in both public and private sectors should be aware of the past real and potential future losses sustained by society as a function of diminished capacity during these zones of vulnerability. A thoughtful approach to shift work assignments is 1 such policy implication.

## PHYSIOLOGY OF CIRCADIAN RHYTHMICITY

The particular physiological variations that approximate a 24-hour pattern of recurrence are termed circadian rhythms, from the Latin *circa dies*, meaning "about a day."[3] Examples of human physiological systems having a circadian rhythm are the sleep–wake cycle, rapid eye movement sleep, core body temperature, and hormonal secretions, such as cortisol, adrenalin, noradrenalin, and melatonin.[4] Circadian rhythms are synchronized with this 24-hour periodicity by influential clue-giving environmental factors, known as *zeitgebers*, from the German for "time givers."[3] An example of a powerful *zeitgeber* is the light–dark cycle. Entrainment is the process whereby endogenous circadian rhythms are matched to environmental timing clues.[4] Circadian rhythm is relatively stable, and its entrainment to environmental clues takes time. The lag time during which one is out of phase with the environment is called desynchronosis. Desynchronosis, commonly referred to as jet lag or shift lag, can potentially result in an array of ill effects such as malaise, fatigue, gastrointestinal distress, and poor mood. Night workers, rotating shift workers, and air travelers commonly report these effects. A decrease in both quantity and quality of sleep is probably the most common and severe consequence of the desynchronosis resulting from shift work.[4] Night shift workers sleep 25% to 33% less, on average, than do day shift or swing shift workers.[3] Studies have shown that workers tend to lose 1 to 4 h of sleep each night for approximately 3 days after they rotate shifts.[5]

The sleep–wake cycle is perhaps the most obvious example of a circadian rhythm susceptible to disruption by the demands of shift work of any kind. Neural processes controlling alertness and sleep work together to produce an increased sleep tendency and diminished capacity to function during certain early morning hours (approximately 2:00 AM to 7:00 AM) and, to a lesser extent, during a midafternoon period (approximately 2:00 PM to 5:00 PM).[1] The early morning nadir in alertness corresponds with the period of minimum core body temperature and high levels of melatonin.[4] A rise in body temperature is the primary stimulus for spontaneous awakening, making the duration of the sleep period more a function of the phase of circadian rhythm than a function of the length of previous wakefulness. This is at least part of the explanation for the sleep deprivation suffered by night shift workers.[6]

Circadian rhythms are difficult to alter. In most night shift workers, the circadian adjustments that do take place occur during the first 1 to 3 days of night shift work and then proceed at a slower pace.[4] Shift rotations of less than 7 days produce no permanent shift in circadian rhythms.[3] However, permanent night shift workers tend to reassume conventional social and family schedules on their days off; instead of permanently shifting circadian patterns, the on–off work schedule creates more of a roller-coaster effect on internal rhythmicity.

The extent to which the circadian system regulates sleep–wake behavior varies individually, making some people more tolerant of shift work than others. People who have little trouble with night shift work are more often "night owls"; those who demonstrate intolerance to night shift work are most often "morning larks."[7] Only 5% to 10% of the population are purists regarding these chronobiologic types, meaning that most of the population falls somewhere in between and has varying abilities to adapt to shift work.[4]

The relative ability to tolerate circadian disharmony (the jet lag malaise experienced until adaptation to a new shift occurs) and inappropriate phasing (trying to stay awake or go to sleep when the circadian clock dictates otherwise) also varies individually. Workers who prefer working their night shifts in prolonged blocks may abhor the feelings associated with phase intolerance but yet may be able to overcome circadian disharmony in a short time. Workers who prefer to avoid prolonged night shift rotations and opt instead for stand-alone night shifts may better tolerate the discord experienced by inappropriate phasing and may have more difficulties overcoming circadian disharmony.[7] Older workers tend to be less tolerant of shift change and less able to sleep during the day, which is perhaps at least partially attributable to decreasing levels of melatonin measured with advancing age.[4]

## THE RESEARCH

The peaks and valleys of hormones and body temperatures evident in circadian rhythms have the potential to adversely impact the ability to perform work during nonphysiologic working hours. One group of researchers pooled frequencies from available data on the risk of incidents resulting from human error and found that the risk of

such incidents increased by 18% for the afternoon shift and by 30% for the night shift relative to the morning shift.[2,8]

Traditionally, industrial shift rotations have been scheduled in a weekly counterclockwise rotation (morning–night–afternoon) referred to as the Southern Swing. Although this type of scheduling has fallen out of favor because of circadian research, it is still used widely in mining and in some civil service industries.[7] Research has shown that the human free-running biological clock has a cycle of approximately 25 hours, rather than 24 hours, if no environmental cues are provided. This makes phase delay easier than phase advance. That is, delaying sleep is easier than advancing it, which is the physiological reason why jet lag is worse for eastward-bound air travel crossing time zones than for similar westward-bound travel.[9] Studies showing increased productivity and job satisfaction when shift rotations were scheduled on a clockwise (morning–afternoon–night) rather than counterclockwise (morning–night–afternoon) rotational basis support these premises of circadian rhythmicity. These studies lead many chronobiologists to recommend clockwise shift rotation in lieu of counterclockwise rotation.[10]

Although some chronobiologists recommend that the clockwise shift rotation change no more often than monthly to allow adequate time for circadian stabilization, others recommend a more frequent shift change. A slowly rotating schedule (e.g., 3 weeks on each shift before a change is instituted) allows for better circadian adaptation to the night shift, but sleep debt and consequent negative effects also build up.[4] Many European shift workers use what is known as the French system, a clockwise rotation through 3 mornings, 3 evenings, and 3 nights (e.g., working 7:00 AM to 3:00 PM for 3 shifts, then 3:00 PM to 11:00 PM for 3 shifts, then 11:00 PM to 7:00 AM for 3 shifts, then 3 recuperative days off) This system is based on the premise that biological clocks are very difficult to reset, so getting resetting over with quickly is best.[7] After working a night shift in a rotational schedule, adequate recovery time must be allowed. After a 12-hour shift of the sleep–wake cycle, sleep and alertness are substantially impaired for at least 3 days.[4]

Theoretically, the circadian gold standard for any industry requiring continuous coverage is not to change shifts at all.[7] No permanent shift in circadian rhythms occurs until one has worked 7 consecutive days on a particular shift rotation.[11] Because permanent night shift workers still generally adopt conventional social and family schedules that require daytime awakeness on the 2 days after a 5-night work week, they do not truly adopt a full circadian shift. Instead, they continue to subject their internal rhythms to weekly roller-coaster swings.[3] Thus, workers who seek to maintain family and social commitments that require daytime awakeness cannot realistically achieve the theoretical gold standard.

One study of attending emergency physicians demonstrated a decrease in speed and accuracy of intubation and decreased scores on triage and treatment scenarios designed to test decisionmaking ability each time the physicians rotated through the night shift.[8] Another study concluded that working a series of 5 night shifts results in a substantial decline in cognitive performance in physicians in the emergency department.[11] Other studies of workers in general have demonstrated a consistent trend in the risk of negative occurrences over successive night shifts. On average, in a pooled analysis, the risk of a negative occurrence was approximately 6% higher on the second night, 17% higher on the third night, and 36% higher on the fourth night.[2] Such studies and others have led some experts to recommend short blocks of no longer than 3 nights each. This results in less accumulation of sleep debt than do more slowly rotating schedules requiring longer blocks of nights.[11] After 1 or more night shifts, at least 3 days of recuperative time are required to fully overcome impairment in sleep and alertness induced by the sudden shift in the sleep–wake cycle.[4]

In addition to the strains of dealing with circadian rhythm disturbance, emergency physicians also experience physiological effects that may be stress related, such as an elevation of diastolic blood pressure and an increase in heart rate variability during the night shift.[12] Emergency management decisionmakers could possibly experience similar stress responses. Attitudinal differences may also occur in night shift workers, with much research demonstrating problematic attitudes in these workers.[13] These attitudinal differences include feelings of resentment about the work hours, frustration about perceived lack of support for the job being done, and tension and strain in relationships with coworkers, as well as administrators.

Optimal shift length is another consideration in scheduling 24-hour operations. In general, the traditional approach to shift length is that length of shift should match the physical and mental loads of the task, with 8-hour shifts being the traditional choice.[14] Scientific studies from various work disciplines addressing the 8-hour versus 12-hour shift length yield conflicting results as to which is optimal.[15] One recent analysis pooling results from several different studies actually demonstrated that risk increased in an approximately exponential fashion with time on shift. Relative to 8-hour shifts, 10-hour shifts were associated with a 13% increased risk and 12-hour shifts with a 27% increased risk of negative occurrences.[2]

In general, 8-hour shifts are preferred over 12-hour shifts, because the ability to apply the clockwise rotation principal is applicable for 8-hour shifts, whereas 12-hour shifts call for abrupt, 180° swings without any chance for gradual adaptation.[15] Another advantage of 8-hour shifts is in allowing the possibility of participating in other personal activities, even on workdays.[15] On the other hand, the major advantage of 12-hour shifts is in allowing one third more days off as compared with 8-hour shifts.[15] The relative importance to the individual of having more days off typically determines preferred shift length for that individual.[13]

## RECOMMENDATIONS

When public health and emergency management officials are called on to temporarily provide 24-hour operations, scientific principles and common sense must be considered. The individual

physiology of people makes some of them more adaptable to blocks of night shifts than others; some persons tolerate an isolated night shift much better than a block.[16] Workers older than 45 years generally have less ability to adapt to a night shift, and scores on cognitive testing in shift workers worsen with age.[17] Thus, age should be taken into consideration when scheduling night shifts. This creates difficulties in appropriate night shift staffing for emergencies, because the population of the United States and of the public health workforce is aging as the Baby Boomers move well into middle age and beyond.[18] These graying workforce members are often in key positions of decision-making and also often have daytime work responsibilities that must be fulfilled even when they must be available during the nighttime hours. These individuals should be called on for nighttime duties only when absolutely necessary.

In addition to individual differences in physiology, differences in personal lifestyles and interests are important and should be given consideration. Night shift work often interferes with family and social functions and can affect the work attitudes of some persons more than those of others.[19] Childcare responsibilities of individuals may impact attitudes toward and performance during night shifts.[20]

In general, clockwise shift rotations should be used (day–evening–night). Ideally, a rotational schedule should include no more than 3 night shifts in a block, with 3 days of recuperation after the night shift work. In general, 8-hour shifts are preferable to 12-hour shifts. Circadian physiology suggests that morning shifts should begin no earlier than 8:00 AM for the physiological best fit to circadian rhythmicity.

The application of scientific principles to the real world of a ramped up 24-hour crisis response in public health and emergency management presents many challenges in addition to that of the graying workforce. Although preparedness is a fundamental component of public health, funding for it can be difficult to obtain. Even with the additional US$1 billion federal funding for state public health preparedness programs in fiscal year 2003, state public health officials estimate that 192 additional epidemiologists, an increase of 45.3%, are needed nationwide to fully staff terrorism preparedness programs.[21]

Another challenge in gearing up to a 24-hour response in emergencies stems from the fact that emergencies are initially and fundamentally local events. The personnel pool from which to draw for a 24-hour response in the local city or state level is generally small. Thus, it may not be possible to devise a shift work rotational schedule based on physiological principles. The best approach in this situation is to keep workers on dedicated shifts, with no more than 10 consecutive night shifts. Although a 3-day recuperative period is best after night shift work, the number of recuperative days off can be adjusted downward as necessary.

When workers are called on to work the night shift, it is important to incorporate coping mechanisms and strategies and to provide appropriate workforce education. Sleep management is critical when attempting to sleep during daytime hours. Basic strategies include fans, ear plugs, and white noise machines to minimize disruptive ambient noise.

**Recommendations for 24-Hour Emergency Coverage**

- Avoid the impulse to have key individuals available on a 24-hour basis during the early phases of response
- Create separate rotation rosters for executive decisionmakers and shift-watch personnel
- Delegate authority to the greatest extent possible to conserve executive resources
- If the size of personnel pool allows, use clockwise rotation: 3 day shifts, 3 evening shifts, 3 night shifts, and 3 recuperative days off
- 8-hour shifts are preferable to 12-hour shifts
- If the size of personnel pool is too limited to allow the rotation pattern above, individuals should remain on dedicated shifts, up to a maximum of 10 consecutive shifts followed by 3 recuperative days; the number of recuperative days can be lowered for fewer consecutive shifts

Rooms should be darkened to the greatest extent possible or eye masks worn, and sunglasses on the ride home from work may also be of benefit. Regular exercise, avoiding excess alcohol and caffeine intake, and maintaining close family and social ties are also important.[4] Other possible coping strategies include napping, anchor sleep (sleep occurring through at least half of the time normally reserved for sleep), medications, diet and lifestyle modifications, and bright light treatment.[4,7,8,22–25]

Taking a nap before a night shift has been demonstrated to increase subjective and objective alertness, oral temperature, and performance on complex cognitive tasks during the night shift. Napping is more effective in preventing sleep debt than in alleviating sleep debt, so the optimal time for napping is before the night shift occurs.[4] Some research has also demonstrated beneficial effects from nighttime napping at the workplace, and some companies have tried to bring this science to the workplace by allowing napping periods and providing facilities conducive to napping.[22–24]

Anchor sleep refers to sleep that occurs through at least half of the time normally reserved for sleep, thus anchoring circadian rhythms to a particular schedule and causing minimal disruption. For instance, if one sleeps from 8:00 AM to 4:00 PM after a night shift and from 4:00 AM to 12:00 PM on days off, the overlapping interval from 8:00 AM to 12:00 PM is anchor sleep and may help minimize circadian disruption.[26]

Because of the role of melatonin peaks and troughs in circadian rhythmicity, melatonin has been advocated by some as a sleep aid to counteract light–dark cues, but results of efficacy studies are inconclusive. Prescription medications, such as benzodiazepines, may also be considered, but substantial side effects must be considered in determining whether the benefits outweigh the risks.[4]

Bright lights can be used in the workplace to alleviate sleepiness and to aid in phase resetting.[25] However, more research must be done on this subject before recommendations can be made, because some studies have shown disruption in mood and

motivation toward the end of night shifts using bright lighting.[4]

The "jet lag diet" is a dietary manipulation of carbohydrate and protein intake sometimes recommended for travelers crossing multiple time zones. Essentially, protein is ingested before times of activity and carbohydrates are ingested before the sleep phase.[8] However, timing of meals, rather than content of the diet, has been proven of more assistance in entrainment to a new light–dark cycle. Low doses of caffeine (4 mg/kg, with 1 cup coffee=100 mg of caffeine) administered at 12:20 AM and 1:20 AM have been shown to effectively decrease sleep tendency on the night shift, enhance performance during the first 2 nights of a block of night shifts, and yet not disrupt daytime sleep.[4] Excesses of caffeine, however, should be avoided.

## CONCLUSIONS

Recommendations for emergency 24-hour coverage based on scientific principle and common sense are summarized in the box on page S91. Because a well-rested workforce is optimal, the tendency for key individuals to be available 24 hours per day should be avoided in the early phases of responses. Instead, a schedule roster should be created, and those not on duty should be resting. Separate rosters should be created for executive decision makers and those whose primary function is to stand watch. Although responsibility cannot be delegated, it is advisable to delegate authority to the extent possible to keep a rested executive worker pool during emergency response activities. Application of these basic scheduling principles will help public health workers and emergency management officials optimize their ability to positively impact the health and safety of the public. ■


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