Chapter 4
Studies of Fatigue and Human Performance in the Field

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Field vs. the Lab Studies

Inquiry into fatigue and human performance in the field explore the mechanisms through which performance declines in individuals and groups consequent to fatiguing influences. These include sleep loss and the circadian timing of sleep, as well as physical, emotional, and psychological exhaustion and strain. Akersteadt and Wright further discriminate between fatigue and sleepiness: "cognitive and muscle fatigue symptoms may be reduced by sedentary activity or rest without sleeping, whereas subjective sleepiness and the propensity for sleep are often exacerbated by sedentary activity or rest" [1]. Differentiating between the two general concepts of sleepiness and fatigue is essential so that we can determine strategies to understand and mitigate their course.

Field studies generally examine real-life changes in the industries of transportation and emergency work in order to determine how fatigue is manifested in those actively working in these environments. Studies in the field are important for several reasons. First they allow us to examine real-life causes of fatigue and sleepiness as well as strategies used by workers to allay fatigue. The latter may better guide us in understanding the subject experience of fatigue and sleepiness. Secondly, field studies allow us to examine what fatigue means to different industries, and the manner in which non-experimentally induced schedule preferences and individual fatigue management strategies are naturally used in these workplaces. Thirdly, field studies facilitate our recognition of how the subjective experiences of fatigue and sleepiness are mitigated by factors such as years of experience, sleep loss resilience, gender, burnout, comorbid depression, and coping strategies. In one study, variability between residents on a night off, on call, or on working emergency admissions

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appeared to be due to individual differences and not differences in the level of sleep deprivation [2].

The value of field studies is that they help us to better organize and design the schedule of workers with personal preference and proclivities in mind. They also facilitate identifying the most vulnerable times of the day to human error and weariness. Though several studies have established the impact of sleep loss and fatigue on performance, this has been well established and needs only select additional discussion here, to illuminate the specific problems in our population of focus.

One difficulty with field studies is that they lack the controls and manipulations of experimental lab studies and thus may have more unforeseen bias. Major design flaws in many of the lab, as well as field studies, have involved relatively small numbers of participants, selection bias, and measures that involve overlearned tasks or are not sensitive to sleep loss. Owens points out that self-report is an additional flaw in most of these studies [3]. However, alternatively, randomization and manipulation may also alter the behavior being observed, leading to bias. Field studies are more likely to expose natural behaviors of which the experimenter may have been unaware, and/or which may mitigate the sleepiness and fatigue. In addition to being more amenable to larger numbers of subjects who can be enrolled, field studies allow us to additionally observe how fatigue and sleepiness are experienced in natural environments and the strategies developed by individuals to compensate and adapt.

Field Studies in Specific Populations

Some of the major professional areas in which fatigue/sleepiness are of critical interest include health care, transportation, power plant, military, and law enforcement. One fascinating aspect of how fatigue is manifested in the field is the fact that it is defined differently in each of the abovementioned fields, and emphasis on what aspects of fatigue are important is variable. Studies of military, law enforcement, power plant, and transportation are focused heavily on physical reaction time, whereas studies of residents, medical students, and their attending physicians are largely focused on performance measures such as surgical outcome, decision-making, and procedures, though some emphasis has also been placed on mood and overall well-being [2, 4]. Studies of nursing professionals have an additional strong emphasis, rarely examined in field studies of physicians and physicians in training, of compassion and emotional fatigue.

Field Studies of Fatigue and Sleep Loss in Physicians

This chapter will review ways in which the effects of fatigue, one of the major mediators of which is sleepiness, sleep loss, and inappropriate timing of sleep, has been demonstrated *in the field* in physicians and physicians in training. There is no

doubt that individuals with greater resilience to physical and emotional stress, as well as to sleep loss and/or circadian disruption, may self-select into fields where these more abrasive and challenging work schedules are anticipated. *However*, such individuals may also be less aware of or willing to acknowledge impairment. This is likely magnified by the bias in medical training to create a façade of health, even during significant times of distress, and to resist help-seeking behavior [5]. In fact, one study found that a vast majority of physicians report barriers to seeking help when their health suffers from stress or strain to include concern about letting colleagues down (70.6%) [5]. Fatigue, and possibly to a lesser degree sleepiness, may be affected not only by the total hours worked and the circadian timing of sleep but by other variables such as the work load demands, novelty, threat, risk, access to countermeasures, and breaks. Fragmentation of sleep and sleep inertia are also critical contributors to sleep-related performance errors. It may take several hours, with the first 15–30 being most vulnerable, to reach a fully alerted state upon waking from a high sleep pressure nap condition [6]. As residents are typically woken while on duty call to make immediate and sometimes critical decisions, this does not bode well for risk or medical error. In a study of 356 internal medicine residents, West et al. found that subjective medical errors were associated with subjective fatigue (self-defined) and sleepiness (Epworth) but that this relationship was mediated by levels of burnout and depression [7].

Types of Deficit Consequent to Sleep Loss and Fatigue

Health-care workers face a more specialized set of causes for fatigue than those in the transportation industry, consequent to the personalized nature of life or death situations that they face. Multiple field studies have been conducted with physicians and nurses to determine how emotional and psychological stress as well as work hours, timing of work, and patient loads affect performance. Deficits may come in the form of performance deficits (ability to carefully and accurately perform medical duties and to diagnose and treat properly), personal consequences to well-being (illness, mood disturbance, marital stress, lack of family time, increased risk for substance abuse, lack of self-enrichment time), and cognitive deficits (reaction time, ability to access divergent information, attention, concentration, and memory).

Performance Deficits

The most important studies to examine the contemporary effects of sleep loss on physicians in training are those studies conducted since the ACGME training guideline changes in 2003—which should provide a more representative contemporary sample of sleep and fatigue. One such study from 2012 indicated that of 27 orthopedic surgical residents, average total sleep time was 5.3 h [8]. In most experimental

studies, significant deficits are seen when sleep consistently dips below 6 h of sleep, a dip which Horne refers to as violating the "core sleep" required to "repair the effects of wear and tear on the cerebrum" [9]. This would suggest a continued chronic state of neurocognitive harm to those in training. Post-call fatigue has been demonstrated to impair performance and poor surgical decision-making [10] and increased performance error during laparoscopic maneuvers [11]. Though short-duration reaction time test have not proven to show substantial deficit in sleep-deprived physicians [12], performance of more complex divergent thinking has been shown to be substantially impaired. Marcus and Loughlin (1996) found that 49% of house staff they interviewed noted falling asleep at the wheel within the past 3 years, 90% of which occurred post-call [13]. Hawkins found deficits in a number of areas including higher cognitive functioning in acutely sleep-deprived residents. Most interestingly, however, was that they were largely unaware of the extent of their impairment while sleep deprived [14]. Sawyer et al. examined the effects of call in residents taking call every second, third, or fourth night in relation to operating room participation and overall satisfaction. They found that on-call fatigue across groups was strongly related to the number of self-report errors. Increases of objective rates of error up to 20% in addition to slowed performance has also been found via repeated measures in surgical residents post-call compared with non-post-call status [15]. Arnedt found that the number of commission errors, driving simulator lane and speed variability, and psychomotor performance errors after 4 weeks of heavy call rotation (about 90 h per a week) was equivalent to a month of light call (~44 h duty per week) plus moderate alcohol intake 20 min before testing (~0.005 g% blood alcohol level) [16]. Given that the current ACGME guidelines allow for 88 h per week of call in specialty residencies, it does not require a leap of faith to imagine the likely impairment of residents under these conditions. However, this relationship is not always clearly linear. Barger et al. conducted a web-based survey of 2737 PGY1 critical care residents. Extended duration shifts were associated with a far greater incidence of preventable adverse events, medical errors, and attentional failures (falling asleep during surgery or while examining a patient). Residents were queried on their "belief that sleep deprivation or fatigue caused [them] to make a significant medical error" to determine the degree to which they *perceived* sleep loss and fatigue as responsible for errors. Extended duration of work shifts was associated with substantially more fatigue-related medical errors and fatality-related errors [17].

Call Status: the Chronicity of Sleep Loss, and the Trajectory of Recovery

Sleep deprivation research has often quantified sleep based upon the number of rested hours within a 24- or 36-h period [18, 19]. Such a strategy erroneously assumes that the effects of the deprivation are not cumulative. The effects of deprivation persist the day following rested sleep [20]. It is therefore important to control for the cumulative effects of sleep deprivation and to acknowledge that recovery

may not be rapid post-call. The lack of positive findings in some studies may be due to the fact that the residents are assumed to be "rested" when not on call, despite that they are still sleep deprived, from the previous night call. Additionally, despite that residents and interns may have a prescribed time available to sleep, causes of sleep disruption that may further add to sleep difficulty are often under-recognized in studies. Richardson et al. found that total sleep time was often significantly impaired by the constant interruption of pages and difficulty returning to sleep [21]. Additionally, younger physicians may be less skilled at managing their personal time and in prioritizing their sleep and rest.

There is substantial evidence that house staff suffer significant impairment consequent to the acute sleep deprivation secondary to a day call. Friedman et al. found within subject differences between fatigued and non-fatigued residents in sustained attention tasks [22]. Hart et al. found that compared with non-sleep-deprived residents (those sleeping an average of 7.9 h in 24 h), sleep-deprived residents (those sleeping an average of 2.7 h in 24 h) were impaired on a number of vigilance and memory tasks [23]. Others have likewise found that performances on a variety of tests measuring reaction time, information processing, recall, sustained attention, and concentration were all impaired in residents post-call [24].

Some field studies examining the effects of post-call fatigue in physicians suggest a relatively rapid recovery (48 h) with regard to subjective mental fatigue and feelings of restedness [25]. The deficits in slow-wave sleep, sleep fragmentation, and sleep efficiency are significantly improved with protected sleep time and coverage [21]. However the impact of the mental fatigue and lack of restedness during the interim recovery work time is unknown. Schwartz et al. found that residents attributed their bleakest days more to lack of sleep than to any other queried factor, though other factors such as inadequate support, patient load, and peer competition also magnified their distress [26].

The Secondary Impact of ACGME Changes

The prominence of performance deficits as indicated via medical and diagnostic errors, as well as dangerous attentional lapses such as self-needle sticks and MVAs, has been well established in those on 24 h shift. At least for physicians in training, ACGME has set regulations restricting duty hours worked so that those in training in the USA at least no longer are subjected to the previously prolonged duty hours. In 2003 the ACGME restricted resident training hours to a maximum of 24 h shifts, and no more than 80 h per week. In 2011, these guidelines were further restricted to minimize PGY1 hours to 16 duty hours per shift and *recommend* strategic napping for other residents. Transfer of care hours was also restricted from 6 to 0 for PGY1 and 4 for PGY≥2. Recommendations for length of time between shifts was also changed from "should have" language to "must have" depending upon PGY year and specialty.

This does not affect the hours regulated for attending physicians. In addition to an increase in attending staff work hours, Owens points out that the restriction on resident training hours has ironically likely led to an increase in working hours for nursing staff, as they are asked to cover an increasing number of nights, weekends, and extended shifts [27].

However, we should be cautious not to suggest that this means that the work load should be re-intensified for physicians in training but rather that hospitals need to increase staff to create reasonable work conditions. Studies of MVAs in nurses have shown that they are far more likely to report MVA after a rotating shift [28]. It is unclear if nursing staff have been working substantially longer since these changes. One study of 5317 self-report work shifts suggested that hospital staff nurses generally worked longer than scheduled daily, and generally worked more than 40 h per week. Half of the shifts worked exceeded ten and a half hours, and 39% of shifts were reported to include rotations of at least 12.5 consecutive hours of duty [29]. Rotating shift work and night shift have also been found to be associated with increased medication administration error by nursing staff [30].

Burnout and Compassion Fatigue

One area of fatigue discussed almost exclusively in the health-care field are burnout and compassion fatigue (the latter of which has been explored more in the nursing field). Burnout results from stress that arises from the clinician's interaction with the work environment [31], whereas compassion fatigue stems from the relationship between the clinician and the patient [9]. These types of fatigue are rarely discussed in non-emergency/health-care sectors and represent an additional layer of complexity to the more commonly evaluated and understood sleep- and circadian-related fatigue. Burnout and compassion fatigue likely magnify sleep-related fatigue as they are associated with greater dysphoria and likely sleep fragmentation. Sleep deprivation has been found a predictor of burnout in nursing in at least one study in nurses [32]. The concepts of compassion fatigue and burnout could be an instrumental dimension which has given greater depth to the impact of fatigue on health-care workers. Certainly, the associated dysphoria will magnify feelings of exhaustion, albeit not likely sleepiness. Therefore, theoretically we should see a clear relationship between burnout and compassion fatigue with generally low energy and lack of vigor but not sleep unless health-care staff suffering one of these simultaneously report comorbid insomnia.

Awareness and Self-Treatment

A valuable piece of evidence from the field that supports fatigue and sleepiness among medical student and health-care staff is the use of stimulant medication. A recent study shows that the use of stimulant prescription medication among medical

students is disproportionately high [33]. It is unlikely that the field of medicine necessarily attracts such a disproportionate number of legitimately diagnosed adult attention deficit sufferers but rather that recognition of the benefits of stimulant use to performance is the driving force behind stimulant use. An anonymous self-report study of 9600 physicians suggested that they are less likely than age- and sex-matched counterparts to use illicit substances, but they are more likely to have used alcohol, opiates, and benzodiazepines [34]. Estimates on use of performance enhancers in physicians in practice have not been well established.

Chronic sleep deprivation degrades one's ability to recognize impairment [35]. As do physicians, nurses do not seem to acknowledge the serious role that fatigue plays in critical incidents. When intensive care and operating room nurses were questioned about error, approximately 60% agreed with the statement that, "Even when I am fatigued, I perform effectively during critical times" [36]. A reduction in size and number of synaptic connections (representing a renormalization) following sleep [37] represents a restoration of neurocognitive functioning; there is thus little doubt that neurocognitive functioning is impaired with prolonged sleep deprivation. However, failure to recognize deficit may also be a protective mechanism that fosters confidence and the ability to make life or death decisions without potentially catastrophic hesitancy.

Summary

Regulation of duty hours is driven by many factors. Those enduring the sleep loss consequent to prolonged and poorly timed hours of work are at least in part driving the current regulations. In medicine, support for modification to the duty hours has been apparently mixed. This is particularly disturbing as physicians in training tend to be young adults who may still have sleep drive needs that exceed that of their older counterparts. Additionally, younger caregivers are more prone to burnout and stress reactions [38].

So long as there is financial gain and low perception of personal risk, the battle to implement more carefully regulated duty hours is an uphill battle. Magnifying this is that perception of impaired functioning when one is sleep deprived is in itself impaired. The unfortunate misperception that the ability to endure sleep loss and excessive work hours is somehow a sign of academic virility and/or fitness has endured for many decades and is unlikely to subside without legislative enforcement as well as a change in the cultures perpetuating these beliefs. Owens points out that sleep deprivation during residency is likely to have the highest risks and stakes. Levine et al. did an extensive review of research on resident factors since the ACGME reduction of >16-hour work shifts and found not only the absence of adverse effect on resident education but also improvements in patient safety and resident quality of life in most of studies [39]. However, it is important to recognize that as Landrigan points out, with very few institution-based exceptions, no such restriction on duty hours exists for other health-care professionals such as nursing [40].

Areas which would benefit from greater examination in the field among health-care professionals include how sleep loss and fatigue impact overall perceived quality of life (harkening back to the Schwartz study of 1987 regarding *bleakness*), burnout and perceived self-efficacy, and its effects of more complex divergent thinking and problem solving. Additionally, though a somewhat dangerous area on which to tread, better understanding of individual resilience and optimal fit of individual to schedule would likely bring improvements to the field of health-care.

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