

Fatigue

Core Body of Knowledge for the
Generalist OHS Professional

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20

WORK SAFETY



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This chapter is re-published with updated references, a discussion of the physical and mental health impacts of fatigue, and a summary of future directions for fatigue research.

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Fatigue

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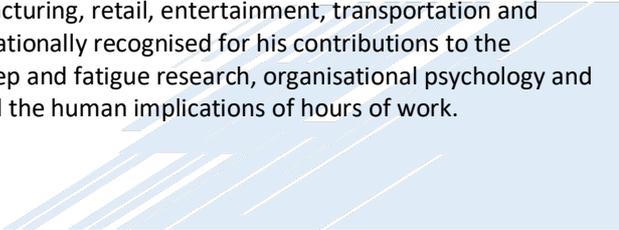
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Fatigue

Abstract

Economic pressures for longer hours and round-the-clock working time arrangements along with a deregulated industrial landscape highlight the necessity to manage fatigue as an Occupational Health and Safety (OHS) hazard. There have been significant advances in scientific knowledge regarding the causes, consequences and methods for controlling fatigue-related risk. Changes in the amount of sleep and/or wakefulness, circadian disruption and time on task are recognised as key contributors to an individual being fatigued. Also, the cognitive demands of a given task can shape the susceptibility of a task to fatigue-related error.

The experience of fatigue is associated with increased feelings of sleepiness, impaired neuro-behavioural performance and negative mood. From an operational perspective, fatigue can sometimes manifest as an increased likelihood of fatigue-related error and/or fatigue-related accident or injury due to cognitive impairment. There are also documented negative consequences of fatigue for mental and physical health.

Traditionally, fatigue has been managed primarily through the regulation of working time arrangements; specifically, regulation of shift maxima and break minima along with aggregate limits on total working hours over a specified period of time. Recent research suggests that this is of limited benefit and that a systems approach based on the principles of risk and safety management may provide better risk mitigation. This chapter outlines the Defences in Depth (DiD) approach to fatigue management that encompasses five levels of fatigue-related hazards and their associated controls. The chapter also provides an overview of emerging research areas in the study of fatigue. Understanding and managing fatigue is essential to building a healthy and safe workplace.

Keywords

fatigue, risk, sleep, safety, health

Contextual reading

Readers should refer to 1 *Preliminaries* for a full list of chapters and authors and a synopsis of the OHS Body of Knowledge. Chapter 2, *Introduction* describes the background and development process while Chapter 3, *The OHS Professional* provides a context by describing the role and professional environment.

Terminology

Depending on the jurisdiction and the organisation, Australian terminology refers to 'Occupational Health and Safety' (OHS), 'Occupational Safety and Health (OSH) or 'Work Health and Safety' (WHS). In line with international practice this publication uses OHS with the exception of specific reference to the Work Health and Safety (WHS) Act and related legislation.

Jurisdictional application

This chapter includes a reference to the Australian model work health and safety legislation. This is in line with the Australian national application of the *OHS Body of Knowledge*. Readers working in other legal jurisdictions should consider these references as examples and refer to the relevant legislation in their jurisdiction of operation.

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1 Introduction

Psychosocial hazards represent a major Occupational Health and Safety (OHS) issue and are poised to eclipse many other hazards in terms of direct and indirect costs, contribution to ill health, and importance to businesses and their undertakings. Fatigue – defined as “decreased capability to perform mental or physical work, produced as a function of inadequate sleep, circadian disruption or time on task” (Brown, 1994) – is recognised as a significant OHS psychosocial hazard due to its relationship with working time and influence on both physical and mental function. For the purposes of this chapter, fatigue is defined in line with Brown’s (1994) definition. This definition refers primarily to the mental aspects of fatigue. For a thorough discussion of the differences between physical and mental fatigue see Dawson and McCulloch (2005). In summary, physical fatigue is thought to be less complicated than mental fatigue, accumulating and dissipating in a monotonic way, and therefore able to be managed primarily through regulating break minima and shift maxima. Mental fatigue, however, is more complex and requires consideration of not only break minima and shift maxima, but also the timing of work and rest periods and the type of work being conducted.

After brief consideration of the historical context of fatigue as an OHS hazard this chapter outlines the mechanisms of action of fatigue and the negative consequences of fatigue for mental and physical health and safety. Control of fatigue-related hazards via implementation of Fatigue Risk Management Systems (FRMSs) are discussed, with particular reference to the Defences in Depth (DiD) Model. Emerging research priorities in the field of workplace fatigue are discussed. Finally, implications for OHS practice are considered.

2 Historical context

The current salience of fatigue as an OHS hazard is due, in large part, to the rising prevalence of shift-work schedules in working time arrangements. This, in turn, may be attributed to increasing societal demand for 24-hour access to services. The integration of electricity into modern life in the early 19th century is often seen as a turning point for this increase in 24-hour operations. However, as early as the 1600s, bakers, innkeepers and soldiers were engaged in round-the-clock working time arrangements (Harrington, 2001).

Balancing the work and social demands associated with a 24-hour society with the physiological need for sleep presents an enduring challenge. The 8-hour-day movement of the early 19th century represented workers’ desire to achieve this balance by dividing their day into three 8-hour segments of work, rest and play. Since then however, there has been a shift away from the 8-hour 9-to-5 workday and a move towards 24-hour operations. Accompanying the rise in supply and demand for a 24-hour society, and the resulting sleep

restriction, are multiple scientific advances highlighting the associated hazards for health and safety. Fatigue is identified as key amongst these hazards, given its well-documented negative effects on safe and effective functioning.

Recent changes in OHS legislation have made explicit specific roles and responsibilities for employers with respect to their duty of care obligations. This is particularly relevant to managing fatigue-related risk. For example, the increased emphasis on safety as a 'shared responsibility' means that workers could arguably be required to self-identify as 'fatigue impaired' due to non-work factors (for example, behaviour occurring outside the workplace that resulted in inadequate sleep). While the OHS legislation is clear, a worker has a statutory obligation to identify a workplace hazard and notify their employer, applying this to fatigue will constitute a significant cultural shift.

For many years, workers have probably felt that what goes on outside of work is beyond the purview of the employer and in one sense, a private activity. This is probably no longer the case - if it ever was. If one were to consider other impairing activities undertaken outside the workplace (e.g. the use of drugs and alcohol), these could result in impairment while at work. If an employee were to turn up for work intoxicated albeit due to activities undertaken outside of the workplace, it would be clearly prescribed. Most workplace drug and alcohol policies prohibit working if the concentration of drugs or alcohol in your body exceeds certain prescribed limits. (e.g. 0.05% blood alcohol concentration (BAC) for some industries, and even as low as 0.0% BAC in some sections of the transport and mining industries in Australia.)

A failure to obtain sufficient sleep in order to return to work 'fit-for-duty' is arguably no different to coming to work intoxicated. Indeed, many studies have shown that the effects of sleep deprivation and moderate alcohol intoxication are not dissimilar (Dawson & Reid, 1997; Williamson et al., 2001). The only practical difference is that there is not yet a legally defined amount of sleep below which one is considered/deemed impaired. There is a significant pre-existing body of research quantifying the relationship between hours of sleep obtained and impairment and its 'equivalency' in terms of both psychomotor impairment (Van Dongen et al., 2003) and accident and injury risk (Dawson et al., 2018).

As with the introduction of drug and alcohol impairment regulations, impairment is not always universally accepted as a legitimate workplace hazard. Community standards typically evolve over years and decades. This can be seen in the evolution of legal prosecutions over fatigue-related accidents and injuries. Current OHS case law in Australian jurisdictions has not established a generally accepted level of sleep loss above which an individual can be 'deemed impaired'. Indeed, internationally only one jurisdiction has done so, albeit in the criminal domain.

Following the highly publicised death of a young college student in New Jersey in 1997, Maggie's law was enacted whereby anyone who has been awake continuously for 24h or more was 'deemed impaired' by fatigue. The consequence of this is that the prosecution is no longer required to demonstrate that the driver was sufficiently impaired to be unsafe as part of their case. Once it can be established that the driver was awake for 24h continuously, they are 'deemed impaired' in the same way as if their BAC or drug levels were above the legally prescribed limit.

There is no such law or equivalent in Australia, so courts still require the prosecution to prove that an individual was impaired and that this was the most likely cause of the accident or injury. On the other hand, OHS prosecutions over fatigue-related accidents and injuries have been relatively frequent in Australia when compared with other jurisdictions. Fatigue-related accidents (especially while commuting) have been consistently prosecuted when the accident is demonstrably fatigue-related and the fatigue directly attributable to the working time arrangements of the worker. While the majority of cases reflect the prosecution of the employer, a number of recent cases have focussed on forensic investigation of worker behaviour outside of work (e.g. mobile phone, text and internet use, credit card and CCTV evidence). In our view, it is only a matter of time until a worker who has a fatigue-related accident due to non-work activity is prosecuted under OHS and/or criminal law.

However, the prosecutions to date have influenced some workplace attitudes toward fatigue-related risk. In many industries across Australia, minimum sleep and maximum wake thresholds have been issued at least as guidance materials to help workers decide when to self-identify as 'fatigue impaired'. Based on several scientific reviews (Dawson & McCulloch, 2005; Dinges et al., 1997), the consensus view is that for most people on most tasks, less than 5h sleep in the 24h prior to starting work, less than 12h sleep in the 48h prior to starting work, or being awake longer than the amount of sleep obtained in the 48h prior to starting work, constitutes an elevated level of risk that requires explicit risk assessment and mitigation in order to continue working safely. While typically issued as 'guidance' rather than regulation, it demonstrates an equivalent historical trajectory to drug and alcohol related impairment. That is, the community having decided that sleep loss constitutes a workplace hazard, now move to quantify and prescribe fatigue related impairment above a certain level.

3 Extent of the problem

Long working-time duration – a trend that began in the 1980s – is a significant problem for part- and full-time workers in Australia (I. Campbell, 2019). This trend is concerning given the known relationship between working time and fatigue, and the considerable economic and social costs associated with fatigue.

Increased economic cost can manifest as a result of fatigue-induced inefficiency. In a study of Australian rail car drivers, it was found that highly fatigued drivers used 9% more fuel than rested drivers; this was calculated to represent an approximate extra weekly cost of \$3512 per fatigued driver (Dorrian, Hussey, & Dawson, 2007). More generally, in the US it was estimated that worker fatigue costs employers more than USD\$136 billion in lost productive time each year (Ricci, Chee, Lorandean, & Berger, 2007). On-call working time arrangements, which are increasingly common and involve 24h scheduling, are associated with sleep-loss related injuries estimated to cost AUD\$2.25billion per year in Australia alone (Vincent, Kinchin, Ferguson, & Jay, 2018).

The high social and safety costs of fatigue have become increasingly apparent. In 1999, a report by the US National Transportation Safety Board estimated that fatigue was the cause of up to 30% of all transportation accidents (NTSB, 1999). Since then, fatigue has been cited as a causal factor in 57% of fatal truck accidents (Walsh, Dement, & Dinges, 2005). In a recent survey of n=1011 Australian adults, 29% reported making errors at work because of sleepiness or trouble sleeping, 29% reported driving drowsy in the previous month and 20% have nodded off while driving, and 5% reported a motor vehicle accident in the past year because of drowsy driving (Adams et al., 2017).

Given the increasing prevalence of long work hours in Australia and the serious consequences of the resulting fatigue, it is important to understand the various mechanisms through which fatigue results in impairment.

4 Understanding fatigue as a hazard

4.1 Mechanisms of action

The factors implicated in fatigue in Brown's (1994) definition (see Section 1) – “inadequate sleep, circadian disruption or time on task” – provide a framework through which the mechanisms of action for fatigue may be understood. These factors, described below, may result in fatigue in isolation or in combination.

4.1.1 Inadequate sleep

Inadequate sleep typically takes two forms – acute or partial sleep loss. Acute sleep loss refers to a period during which no sleep occurs. Partial sleep loss is when the amount of sleep obtained is less than the optimum. There is evidence that partial sleep loss where sleep is restricted to 4–6 hours per night for two weeks results in performance impairments comparable with two nights of acute sleep loss (Van Dongen, Maislin, Mullington, & Dinges,

2003). Discussions of inadequate sleep require an understanding of what constitutes 'adequate' sleep.

Adequate, or optimum, sleep is a relatively elusive and ambiguous concept. Indeed, the definition of adequate sleep may differ greatly between individuals, change dramatically over the lifespan, and be dependent upon what is required of the sleeper upon waking. The need for sleep increases during wakefulness and dissipates during sleep; this is referred to as the homeostatic sleep drive (section 4.1.2, Figure 1). When partial sleep loss occurs, and inadequate sleep is obtained, the body accumulates a 'sleep debt.' This debt can be carried over into subsequent days and result in impaired functioning. The only way to eliminate sleep debt is to obtain recovery sleep. Healthy adults typically report getting 7.5–8.5 hours sleep per night (Basner, Fomberstein, Razavi, et al., 2007; Johns & Hocking, 1997; Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Monk, Buysse, Rose, Hall, & Kupfer, 2000; Taillard, Philip, & Bioulac, 1999). However, the 2016 Sleep Health Foundation survey of Australian adults (n=1011) revealed an average reported sleep time of 7 hours (Adams, Appleton, Taylor, et al., 2017). Most people extend their sleep time on the weekend by 30–45 minutes on average (Hale, 2005; Monk et al., 2000; Taillard et al., 1999), suggesting an accumulated sleep debt and subsequent need for recovery.

While 'ideal' sleep time may be 7.5–8.5 hours, nearly everyone obtains less sleep than this sometimes and many people obtain less sleep than this all the time. The Sleep Health Foundation survey found that 12% of the adults sampled reported sleeping less than 5½ hours (Adams et al., 2017). Previous research in an Australian sample has also shown that 20-35% of adults report frequent difficulty initiating or maintaining sleep, and daytime fatigue, sleepiness and irritability (Hillman & Lack, 2013). One population at particular risk of inadequate sleep is shift workers. Indeed, research has indicated that shift workers experience sleep reductions of up to 4 hours prior to morning shifts and following night shifts (Åkerstedt, 2003). Further, the sleep of shift workers is more likely to occur at times other than during the biological night. This represents the 'circadian disruption' aspect of fatigue (section 4.1.2).

The definition of 'adequate' sleep is likely to change over the course of an individual's lifespan. Indeed, age is one of the most commonly cited factors affecting sleep duration in shift workers and the general population (Härmä, 1996). Studies show that sleep time decreases with age, and suggest that the late 40s are perhaps a 'tipping point' for increases in sleep disturbance (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002; P. M. Krueger & Friedman, 2009; Parkes, 2002). However, there is also evidence to suggest that older adults are less vulnerable to fatigue-related performance impairment as a result of sleep loss than young adults (Philip, Taillard, Sagaspe, et al., 2004). Therefore, the definition of 'adequate' sleep is likely to be affected by the age of the individual.

As mentioned previously, 'adequate' sleep may be defined relative to the tasks to be completed by the sleeper upon waking. From an OHS perspective, of relevance is the amount of sleep necessary for a worker to be fit for duty when beginning a shift. Current parameters indicate that individuals are more likely to make a fatigue-related error if they have:

- Obtained less than 5 hours sleep in the previous 24 hours
- Obtained less than 12 hours sleep in the previous 48 hours, or
- By shift end been awake for a period exceeding their total sleep time in the previous 48 hours (Dawson & McCulloch, 2005).

Derived from a review of literature relating to the subjective, neurobehavioural and electrophysiological effects of sleep loss, and validated in a shift work population (Thomas & Ferguson, 2010), these parameters are components of the Prior Sleep Wake Model (Dawson & McCulloch, 2005). In accordance with the model, two 'fatigue' points are accumulated for each hour of sleep below the 24-hour threshold (5 h), one point for each hour of sleep below the 48-hour threshold (12 h) and one point for each hour of wakefulness beyond the 48-hour threshold. Accumulated points classify risk as low (score=0), medium (1–5), high (6–12) or extreme (+). It is important to note that these thresholds should be determined relative to the workplace in which they are applied, and using a formal fatigue risk assessment procedure.¹ It is also important to note that the definitions of 'adequate' sleep to be fit for duty are relatively ambiguous. That is, these sleep 'doses' may affect different individuals in different ways.² The relative inadequacy of considering only prior sleep/wake history is discussed in the context of fatigue management in section 5.

4.1.2 Circadian disruption

Circadian disruption refers to wake and sleep that occur outside of the body's circadian rhythm. Circadian rhythms regulate different functions of the body to an average 24.2-hour cycle (Czeisler, Duffy, Shanahan, Brown et al., 1999). These rhythms are evident in functions such as sleep propensity (the ability to initiate and maintain sleep), body temperature, performance and mood (S. S. Campbell & Murphy, 2007; Clark, Watson, & Leeka, 1989; Kryger, Roth, & Carskadon, 1994; Lack & Lushington, 2003). The circadian rhythm of sleep propensity is shown in Figure 1. This figure also demonstrates how the homeostatic drive for sleep and the circadian system interact to regulate the sleep/wake cycle; this interaction is called the Two-Process Model (Borbély, 1982; Borbély & Achermann, 1999; Kryger et al., 1994).

¹ For a discussion of the application of the Prior Sleep Wake Model See Dawson, Darwent, & Roach, 2017.

² For a review of some of the other factors which may influence an individual's fatigue levels see Di Milia et al., 2011.

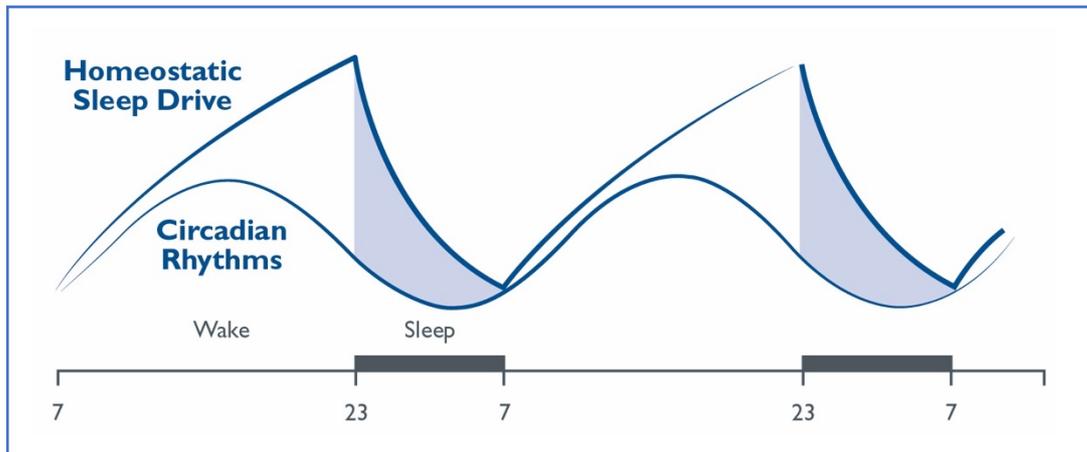


Figure 1: The Two-Process Model of Sleep Regulation (Homeostatic and Circadian) (adapted from Borbély & Achermann, 1999)

The circadian rhythm has peaks and troughs. The circadian nadir – the ‘low point’ of the circadian rhythm – typically occurs in the early hours of the morning. During this time, core body temperature is at its lowest and sleep propensity is at its highest (Dijk & Czeisler, 1995). Sleep during the circadian nadir is associated with greater restorative value and feelings of rest upon waking (Åkerstedt, Hume, Minors, & Waterhouse, 1997). If wake occurs during this time, the individual is likely to experience depressed mood and is unlikely to perform at an optimum level (Åkerstedt, 2003; Frey, Badia, & Wright, 2004; T. H. Monk et al., 1997).

In the hours following the circadian nadir there is an increase in core body temperature and a decrease in sleep propensity, leading to wake. The circadian acrophase – the ‘peak’ of the circadian rhythm – is when core body temperature is highest and sleep propensity is lowest, and typically occurs at approximately 17:00 (Åkerstedt, 2003). This time of day is associated with high levels of function and alertness. Sleep occurring during the acrophase is likely to be restless and truncated (Åkerstedt, 2003).

In summary, wake that occurs out of synchrony with the circadian drive for wakefulness is characterised by impaired functioning, excessive sleepiness and increased fatigue. Also, sleep that occurs out of synchrony with the circadian rhythm is likely to be of reduced restorative value. Both of these circumstances are likely to result in increased fatigue.

4.1.3 Time on task

Time on task can refer to the amount of time that an individual has spent on one particular task (e.g. driving), the amount of time that an individual has spent engaged in general work activities since a break period, or the number of consecutive shifts an individual has completed within a roster schedule.

Elapsed time into a work period has been associated with exponentially increased risk of fatigue-related error, such that by the 12th hour of a shift, risk is doubled relative to the first 8 hours of a shift (Folkard & Tucker, 2003). Driving has been demonstrated as particularly sensitive to time-on-task fatigue with increased time at the wheel associated with increased risk of driving error (Philip, Taillard, Klein, et al., 2003; Thiffault & Bergeron, 2003; Walker & Trick, 2018). The effect of shift length on fatigue may be mitigated to an extent by prior sleep. For example, a study of train drivers and controllers revealed that while every hour increase in shift length resulted in a 15% increase in the risk of severe sleepiness, every hour of sleep prior to the shift decreased this risk by the same amount (Härmä, Sallinen, Ranta, Mutanen, & Müller, 2002). The consequences of time on task for fatigue-related risk also have been demonstrated in terms of time since a within-shift break. For example, fatigue-related risk increases linearly in the time following a break, such that in the last 30 minutes of a 120-minute work period risk is doubled relative to the first 30 minutes (Folkard & Tucker, 2003). Regular breaks have been shown to mitigate fatigue risk temporarily (Tucker & Folkard, 2003).

Although the time-on-task effect may also apply to consecutive shifts, cumulative sleep debt plays a significant role in impairment in this instance. Folkard and Tucker (2003) demonstrated that the risk over four consecutive night shifts increased relative to the first shift by 6%, 17% and 36%. This accumulation of fatigue includes the known risks associated with the inadequate sleep and circadian disruption that accompany successive night shifts. A similar pattern of negative consequences was evident in terms of four consecutive morning shifts, but the risk was smaller, increasing by 2%, 7% and 17% relative to the first shift (Folkard & Tucker, 2003).

4.2 Consequences of fatigue

So far this chapter has described what fatigue is, the development of our understanding of fatigue as a significant work hazard, the economic and social costs of fatigue together with the factors that can result in an individual becoming fatigued. This section describes some of the consequences of fatigue for safety, mental health, and physical health.

4.2.1 The consequences of fatigue for safety

Laboratory-based research has been vital in understanding the consequences of fatigue for performance, using a setting where the risk associated with impaired performance is low. These studies typically use simulators to elucidate how fatigue impacts work performance and have consistently revealed that fatigue is associated with increased error making, reduced cognitive and psychomotor function, increased subjective sleepiness and negative mood (Åkerstedt, Peters, Anund, & Kecklund, 2005; Caldwell, Caldwell, Smith, & Brown, 2004; Eastridge, Hamilton, O’Keefe et al., 2003; Kahol, Leyba, Deka et al., 2008; Morris & Miller, 1996; Philip, Sagaspe, Moore et al., 2005; Porcù, Bellatreccia, Ferrara, & Casagrande, 1998). Notably, Dawson and Reid (1997) demonstrated that after 17 hours of wakefulness in the laboratory, performance decrements were comparable to those demonstrated by individuals with a blood alcohol concentration of .05, the legal limit for driving in Australia. After 24 hours of wakefulness, performance was impaired to a level comparable to that of an individual with a blood alcohol concentration of twice the legal limit (.10). This study was key in highlighting the consequences of fatigue for performance.³

A large body of research has addressed the operational consequences of fatigue in field environments. Field studies are valuable as they facilitate an understanding of the real-world operational consequences of naturally occurring fatigue (rather than experimentally induced fatigue as in laboratory studies). Field studies have typically focused on populations of shift workers, given that fatigue is a common experience for these individuals. Aviation, rail and mining are examples of 24-hour industries in which significant research effort has focused on examining the consequences of fatigue for OHS. While it is important to note that performance impairment can manifest in different ways depending on job profile, and is therefore likely to change across industries, the operational consequences of fatigue are relatively homogenous. Overall, impairments associated with fatigue manifest as:

- Decrements in sustained attention
- Cognitive impairment
- Increased chance of an accident or error, and severe sleepiness (Baulk, Fletcher, Kandelaars, Dawson, & Roach, 2009; Cabon, Coblentz, Mollard, & Fouillot, 1993; Caldwell Jr., Caldwell, Brown, & Smith, 2009; Gander, Mulrine, van den Berg et al., 2015; Goode, 2003; Halvani, Zare, & Mirmohammadi, 2009; Härmä, Salinen, Ranta et al., 2002; Jay, Dawson, Ferguson, & Lamond, 2008; Kazemi, Haidarimoghadam, Motamedzedehe et al., 2016; Petrilli, Roach, Dawson, & Lamond, 2006; Roach, Dorrian, Fletcher, & Dawson, 2001).

There are several recent reviews documenting the implications of fatigue for performance and safety in industry settings including aviation (Bendak & Rashid, 2020), healthcare (Di

³ For a recent review of fatigue and human performance testing in laboratory settings see Bonnet & Arand (2018).

Muzio, Dionisi, Di Sinome et al., 2019; Gates, Wingert, Featherstone et al., 2018), and transport (Phillips, Kecklund, Anund, & Sallinen, 2017).

Healthcare, in particular, is associated with long, irregular hours and a high-risk error profile for both workers and patients. Field studies in healthcare environments have revealed that sleep loss and fatigue resulting from work schedules are associated with reduced cognitive performance, reduced vigilance, increased errors, decreased likelihood of catching someone else's error, slower completion of standard procedures and an increased chance of falling asleep on the drive home (Dorrian, Lamond, van den Heuvel et al., 2006; Gaba & Howard, 2002; Gold, Rogacz, Bock et al., 1992; Lockley, Barger, Ayas et al., 2007; Olds & Clarke, 2010; reviewed in Veasey, Rosen, Barzansky, Rosen, & Owens, 2002; Weaver, Landrigan, Sullivan et al., 2020; reviewed in Weinger & Ancoli-Israel, 2002). Indeed, driving has consistently been associated with increased vulnerability to fatigue-related error. Field studies of driver fatigue have indicated its association with increased feelings of sleepiness, slower reaction times, increased lane deviations and increased chance of a road crash resulting in serious injury or death (Anderson, Ftouni, Ronda et al., 2017; Czeisler, Wickwire, Barger et al., 2016; Droblich, 2005; reviewed in Lal & Craig, 2001; Lee, Howard, Horrey et al., 2016; reviewed in May & Baldwin, 2009; Mulhall, Sletten, Magee et al., 2019; Philip et al., 2005; Philip, Sagaspe, et al., 2003; Philip, Vervialle, Le Breton, Taillard, & Horne, 2001; Scott, Arslanian & Engoren, 2014)

Fatigue has been implicated in a number of high-profile accidents. Human error resulting from fatigue was cited as a causal factor in the 1979 Three Mile Island and 1986 Chernobyl nuclear disasters (Mitler, Carskaddon, Czeiler et al., 1988). Both of these events (along with two other US nuclear power reactor incidents), occurred close to the circadian nadir, a time of increased human vulnerability to impaired performance (04:00 and 01:23, respectively). Official reports following the 1986 Space Shuttle Challenger disaster identified workers' irregular hours and inadequate sleep as one reason for their impaired communication and decision-making skills, which ultimately led to the catastrophic decision to launch (Mitler et al., 1988). The 2010 Shen Neng incident, in which a coal carrier went off course and collided with a section of Australia's Great Barrier Reef, leaving a 3 km scar and spilling approximately 4 tonnes of oil into the Pacific Ocean, also has been attributed to fatigue. The subsequent Australian Transport Safety Bureau investigation identified that the chief mate had obtained only 2.5 hours sleep in the 38.5 hours prior to the incident, resulting in significant fatigue-related impairment and ultimately, the incident (ATSB, 2011). Similarly, the catastrophic 1989 Exxon Valdez oil spill was attributed to fatigue resulting from sleep loss and irregular work hours (Åkerstedt, 2003).

4.2.2 The consequences of fatigue for health

As described above (see Section 4.1), one of the primary causes of fatigue is inadequate sleep and/or circadian disruption. These factors have well-documented negative consequences for both mental and physical health.

Fatigue, inadequate sleep and circadian disruption have all been associated with psychological distress, depressive symptoms, anxiety, and impaired emotion regulation (Courtney, Francis, & Paxton, 2010; Kelly, A. Hillier, Aria, Gulotta, & Haynes, 2019; Pires, Bezerra, Tufik, & Andersen, 2016; Tsuchiya, Takahashi, Miki, Kubo, & Izawa, 2016). It is also worth noting that the kind of work that leads to increased fatigue, for example work requiring extended hours or work during the biological night, is often also the kind of work that involves exposure to workplace stressors associated with poor mental health. For example, exposure to critically ill patients in healthcare and emergency response settings (Hegg-Deloye, Brassard, Jauvin et al., 2014).

Physical health is also negatively affected by fatigue, and its causal factors. For example, rotating shift schedules have been associated with poor sleep, increased fatigue, gastrointestinal discomfort, musculoskeletal symptoms, and cardiovascular symptoms including chest pain and tightness (Ferri, Guadi, Marcheselli et al., 2016; Sveinsdóttir, 2006). Similarly, the disturbances of sleep and circadian rhythms that lead to fatigue have been associated with negative changes in energy balance and an increased risk of weight gain (Broussard & Van Cauter, 2016). There is now a significant body of evidence demonstrating a link between shift work, circadian disruption, sleep loss and cancer, particularly breast and prostate cancer (Haus & Smolensky, 2013; Kogevinas et al., 2019). More broadly, a recent review found that shift work increased the risk of cognitive impairment, cardiometabolic stress, accidents, type 2 diabetes, weight gain, coronary heart disease, stroke, and cancer (Kecklund and Axelsson, 2016).

It is evident that fatigue can result in negative impacts on health and safety. As such, the management of fatigue as a psychosocial work hazard is imperative. The following section notes relevant legislation with section 6 describing current approaches to fatigue management in the workplace.

5 Legislation and standards

The national model *Work Health and Safety Act* (WHS Act s 19) requires a person conducting a business or undertaking (PCBU) to ensure, so far as is reasonably practicable, the health and safety of workers and others who may be put at risk by the conduct of the business or undertaking (SWA, 2016).⁴ As a recognised hazard impacting on the health and safety of workers, fatigue must be considered as a factor when determining what is reasonably practicable in ensuring health and safety.

⁴ See also OHS BoK 9.2 Work Health and Safety Law in Australia.

There are some differences across industries in terms of specific regulations and standards for fatigue management. In all cases, hours-of-service (HOS) regulations remain a critical component of managing fatigue-related risk, typically through the use of biomathematical fatigue models.⁵ However, many operators are moving towards multidimensional approaches to fatigue. For example, rather than solely abide by the mandatory prescriptive rules of rostering, the Council of the International Civil Aviation Organisation (ICAO) has introduced international Fatigue Risk Management System (FRMS) standards. The Australian Civil Aviation Safety Authority (CASA) recently updated their FRMS to ensure it reflects current best practice.

In 2010, the Australian Transport Council endorsed the formation of an expert panel to provide evidence-based recommendations regarding fatigue-management policies in the Australian rail industry (NRSR, 2011). The subsequent panel consensus was to move towards fatigue-management regulations that encompass HOS regulations and a risk-based approach to hazard management (NRSR, 2011). Similarly, the National Transport Commission's FRMS encompasses HOS regulations (reviewed to ensure Australia-wide consistency) as well as a multidimensional approach to fatigue management that includes risk identification, assessment and control, and ongoing monitoring and review.

Safe Work Australia released a Guide for Managing the Risk of Fatigue at Work in 2013. While this guide can be applied to all industries and workplaces, it is not intended to provide information relevant to any specific industry. In 2019/20, the Office of National Rail Safety Regulator (ONRSR) and the National Heavy Vehicle Regulator (NHVR) undertook reviews of the fatigue risk management guidelines. Partly in response to the changes in community attitudes to fatigue-related impairment and partly in response to recent changes in OHS legislation, regulators thought it reasonable to re-assess their approaches and the regulatory frameworks they had in place to mitigate fatigue-related risk. The NHVR also undertook a review of rapidly emerging fatigue and distraction technologies⁶, and their rapid adoption by the industry (Higginson, Dawson & Sprajcer, 2019), to see if the regulatory frameworks required updating. While still underway, both these reviews have identified an increased focus on employee accountability and a need for more flexible regulation. There is a clear and emerging consensus that prescribed working time arrangements no longer provide the most effective way to balance the competing operational and safety requirements in many industries, especially transport (Noy et al., 2011) and health care (see Queensland Health's Fatigue Risk Management Resource Pack⁷).

⁵ For a review of modelling tools, see Dawson, Noy, Härmä, Åkerstedt & Belenky, 2011.

⁶ For the interim report, see <https://www.nhvr.gov.au/files/201907-1074-fatigue-monitoring-trial-phase1-summary.pdf>.

⁷ <https://trove.nla.gov.au/work/31912323?q&versionId=45500194>.

The above examples represent the uptake of next-generation FRMSs, reflecting both current scientific knowledge about the nature of fatigue and a more flexible approach than previously allowed by prescriptive HOS regulations. For further discussion see Gander et al., (2011) for an overview of the evolution of fatigue risk management in the transport industry while Lerman et al., (2012) provide an extremely detailed and thorough overview of all aspects of fatigue and its management in the workplace.

6 Control of fatigue-related hazards

Accompanying the rise in demand for a 24-hour society are multiple approaches to managing the risk posed by fatigue in the workplace.

Initially, fatigue management focused on the regulation of hours of service (HOS); maximum work hours and minimum break opportunities were imposed. This approach stemmed from the management of physical fatigue; because physical fatigue accumulates and dissipates in a relatively uniform way, it can be effectively managed by regulating break minima and shift maxima. However, the accumulation and dissipation of mental fatigue is far more complex; regulating HOS alone is of limited benefit. It is now evident that a systems approach based on the principles of risk and safety management as described in AS/NZS ISO 31000: *Risk Management – Principles and Guidelines* (SA/SNZ, 2018a) and AS/NZS ISO 45001: *Occupational Health and Safety Management Systems – Requirements with Guidance for Use* (SA/SNZ, 2018b) may provide better risk mitigation. As a result, HOS approaches to fatigue management are implicated as part of an overall safety management system. A safety management system⁸ is a systematic process through which potential OHS hazards are identified, assessed and mitigated using multiple, strategic controls.⁹ In line with the safety management system approach, an OHS error or incident is the result of a breakdown at multiple levels of defence against the potential hazard, in this case fatigue. This concept is represented by Reason's (1997) Swiss Cheese Model (Figure 2), which can be applied to any workplace hazard.¹⁰ Each layer of the cheese represents an imperfect defence against the hazard. For an error to occur, the hazard must penetrate the hole in each layer of defence. In this way, an incident cannot be attributed solely to human or technological error, but to a breakdown of the entire defence system.

Below we discuss the Defences in Depth approach to fatigue management (Dawson & McCulloch, 2005), which was developed based on the swiss cheese model, and constitutes a safety management system (SMS) specifically tailored to fatigue. Many organisations

⁸ See OHS BoK 12.1 Systems and 12.2 OHS Management Systems (in development at time of writing).

⁹ See OHS BoK 34 Prevention and Intervention.

¹⁰ See OHS BoK 32 Models of Causation.

apply a SMS approach to the management of fatigue, for example the Office of the National Rail Safety Regulator (ONRSR). The DiD approach was developed with consideration of other SMS based systems for fatigue risk management including those of Queensland Transport, the Australian Civil Aviation Safety Authority, multiple rail organisations, and the North American Federal Railroad Administration (Dawson & McCulloch, 2005).

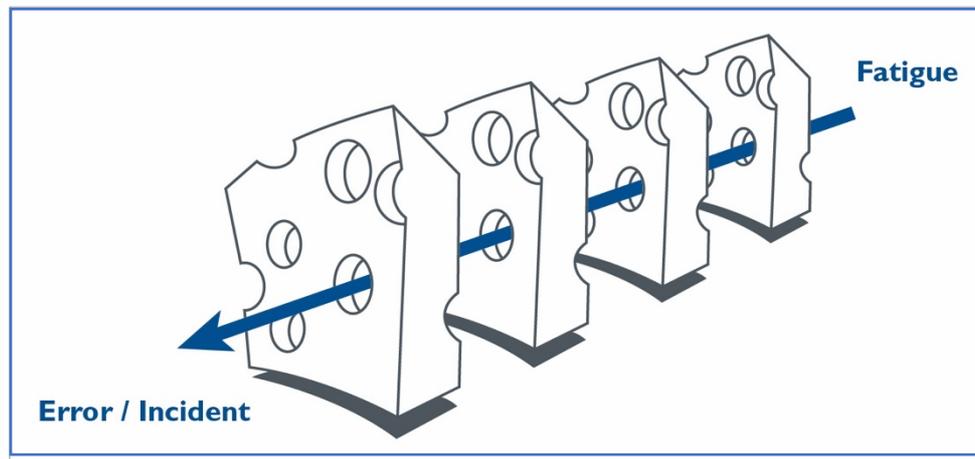


Figure 2: The Swiss Cheese Model (adapted from Reason, 1997)

6.1 Defences in Depth Model

Based on Reason’s model, Dawson and McCulloch (2005) proposed the Defences in Depth approach, which constitutes a safety management system component specifically tailored to fatigue management. Representing current best practice in fatigue management in the workplace, and in line with the principles of risk and safety management as espoused in AS/NZS ISO 31000 and AS/NZS ISO 45001, the Defences in Depth (DiD) model details the controls necessary to mitigate the likelihood of a fatigue-related error (Figure 3).

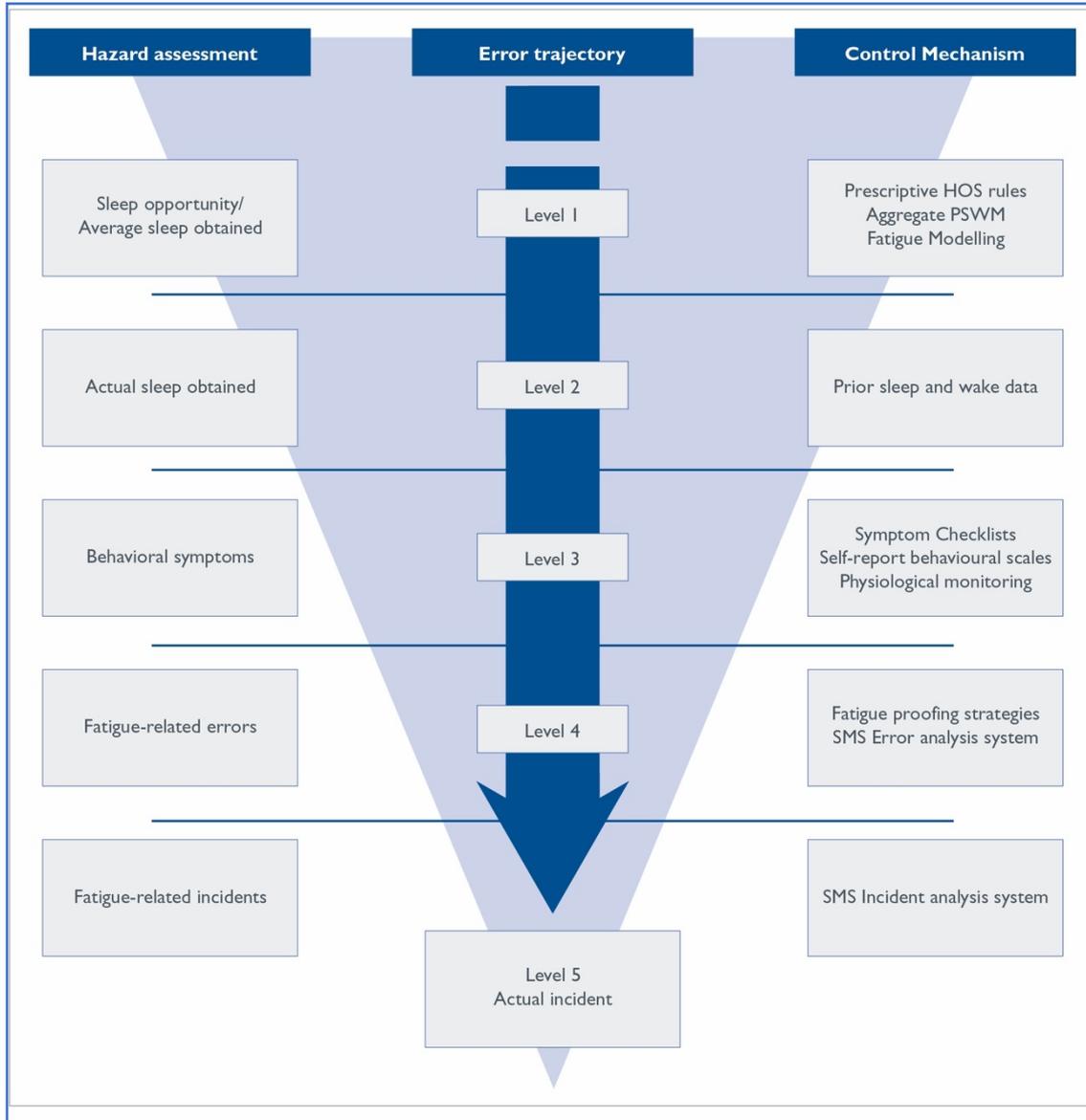


Figure 3: The Defences in Depth (DiD) approach to fatigue management (Dawson & McCulloch, 2005)

The DiD model shows the error trajectory between fatigue and a fatigue-related incident. At each level of the trajectory there are certain control mechanisms and hazard assessments in place to minimise the likelihood of an incident occurring.

6.1.1 DiD Level 1

Level 1 of this trajectory is to ensure that adequate sleep opportunity has been provided to the worker. This may be achieved using traditional HOS regulations (as discussed above;

FRA, 2011), the Prior Sleep Wake Model (section 3.1) or fatigue-modelling tools. Fatigue-modelling tools are algorithm-based software programs that use either sleep/wake times or work hours to determine the likelihood that a given work schedule will result in fatigue-related impairment.¹¹ Previously, industrial relations law regulated HOS limits, however, this function has been moved from industrial relations control to OHS legislation. This deregulation means that unions are no longer able to monitor rules of rostering within an organisation; consequently, rules of rostering are more vulnerable to inadequate regulation. Although Level 1 controls represent the first line of defence against fatigue, a Level 1 control alone is an inadequate FRMS.

6.1.2 DiD Level 2

While DiD Level 1 regulates the work and recovery time allocated to an employee, DiD Level 2 involves assessment of the prior sleep/wake behaviour of an individual reporting for work. Consequently, there is some personal responsibility for the worker to obtain adequate recovery sleep, and both the employer and the worker share the responsibility for fatigue management. A fatigue calculator is an effective Level 2 control; using the employees' actual sleep/wake history as the input, this tool uses the Prior Sleep Wake Model algorithm (section 4.1.1) to determine the likelihood that a worker is impaired by fatigue (Dawson et al., 2011). For a Level 2 control to be effective, it is vital that the worker understands both the nature of fatigue and the requirements for fitness for duty in terms of prior sleep, implicating fatigue-awareness programs at an organisational level. Further, the willingness of the employee to report their prior sleep/wake data to the employer, particularly in the case of inadequate sleep, requires an open and just organisational safety culture.

6.1.3 DiD Level 3

DiD Level 3 is focused on identifying the behavioural symptoms of fatigue in a worker. Identifying these symptoms can be achieved by self-assessment and by visual assessment by co-workers, both of which rely on a certain degree of knowledge about fatigue and how it can manifest. A checklist may be a useful Level 3 control, allowing identification of the presence and severity of symptoms of fatigue, which can include reduced alertness, lack of energy, inability to concentrate and impaired mood (Burch, Yost, Johnson, & Allen, 2005; G. P. Krueger, 1989; Yoshitake, 1978). Also, changes may manifest in the form of performance impairment. For example, one of the key indicators of driver fatigue is changes in steering behaviour (Lal, Craig, Boord, Kirkup, & Nguyen, 2003).

In terms of identifying physiological symptoms of fatigue, electroencephalographic monitoring of fatigue-related changes in brain activity is considered the 'gold standard' (Lal et al., 2003). DiD Level 3 controls, particularly in regard to monitoring fatigue from a

¹¹ For a review of fatigue modelling tools and their use see Dawson, Noy, Härmä, Åkerstedt, & Belenky, 2011)

physiological perspective, have been the subject of significant research efforts in recent years.¹²

6.1.4 DiD Level 4

DiD Level 4 refers to preventing a fatigue-related error. A Level 4 control should consist of formal procedures for minimising the chance that an individual displaying symptoms of fatigue will make a fatigue-related error. While Levels 1–3 of the Defences in Depth model refer to reducing the likelihood that an individual will be impaired by fatigue in the workplace (i.e. fatigue-reduction strategies), Level 4 is focused on controls that decrease the likelihood that a fatigued individual in the workplace will make an error or cause an incident (i.e. fatigue-proofing strategies).

To date, there are few formalised fatigue-proofing strategies; however, there is evidence that such strategies are being applied informally in the workplace (see Dawson, Chapman, & Thomas, 2012). These strategies share two common themes:

- 1 A pre-signalling of risk between co-workers regarding elevated levels of fatigue, and
- 2 Constant monitoring for indicators of increased fatigue, such as error-making or behavioural changes, in co-workers.

The strategies require ongoing risk assessment followed by the application of a targeted risk-reduction strategy relevant to both the job profile and the organisational culture. As a result, these informal strategies are a particularly valuable and rich form of Level 4 control. An example observed in aviation involves a fatigued pilot beginning preparations for landing ahead of time to prevent time-critical decisions being made when fatigued (Dawson, Chapman & Thomas, 2012). There is now evidence of the use of fatigue-proofing strategies in multiple industries including aviation (Dawson, Cleggett, Thompson, & Thomas, 2017), emergency services (Dawson, Mayger, Thomas, & Thompson, 2015) and health care (Bérestégui, Jaspas, Ghuysen, & Nyssen, 2018, 2020; Ferguson, Neall, & Dorrian, 2013). To identify effective Level 4 controls, the generalist OHS professional may wish to consult with workers to detect informal fatigue-proofing strategies already being applied in the workplace then, potentially, formalise these strategies as part of the organisation's FRMS.

6.1.5 DiD Level 5

DiD Level 5 is concerned with the actual occurrence of a fatigue-related incident in the workplace. Level 5 controls refer to the ways that incidents are investigated and reported, and should involve a thorough incident investigation, analysis and reporting system. A

¹² For reviews on monitoring fatigue from a physiological perspective see Abe, Mollicone, Basner, & Dinges, 2014; Balkin, Horrey, Graeber, Czeisler, & Dinges, 2011; Dawson, Searle, & Paterson, 2014; Higginson, Dawson, & Sprajcer, 2019.

breakdown of the Defences in Depth approach to fatigue risk management at Levels 4 or 5 (the occurrence of a fatigue-related error or incident and the subsequent investigation of the occurrence) gives the organisation the opportunity to examine the fatigue risk management controls in place at each level of the DiD model and initiate system reform.

7 Emerging research areas

7.1 On-call work

In the past 20 years there has been a significant increase in the variety of working time arrangements employed in occupational settings (Ferguson, Paterson, Hall, Jay, & Aisbett, 2016). Of particular note is the increasing use of on-call working time arrangements. On-call work requires a worker to be available to attend work on an 'as-needed' basis (Campbell, Macdonald, & Charlesworth, 2019), and is often used to ensure a service can be made available during an otherwise 'off-peak' time (Nicol & Botterill, 2004), or in an emergency response scenario (Paterson, Aisbett, & Ferguson, 2016). On-call periods may be scheduled in addition to a workers's normal work hours, and/or during the biological night (Nicol & Botterill, 2004). Thus, on-call work has the potential to limit recovery time between shifts, result in long working hours, and disrupt sleep; all of which increase fatigue.

To date, research addressing the impact of on-call work has highlighted the negative consequences for sleep, fatigue, and performance. On-call work has been shown to disrupt sleep, and thus increase fatigue, even in the absence of a call being received (S.M. Jay, Thomas, Weissenfeld, Dawson, & Ferguson, 2008; Richardson, Turnock, Harris, Finley, & Carson, 2007; Takeyama et al., 2009; Torsvall & Åkerstedt, 1988). Fatigue-related impairments associated with on-call work include impaired mood, clinical decision regret, increased errors and near-misses (Kenyon, Gluesing, White, Dunkel, & Burlingame, 2007; L.D. Scott, Arslanian-Engoren, & Engoren, 2014; Wali et al., 2013). From a health perspective, on-call work has been associated with an increased risk of psychological health problems including depression and anxiety, and physical health problems including issues with hearing, skin problems, back pain, muscular pain, headache, eye fatigue, and abdominal pain (Baek, Park, Lee, & Jung, 2018).

On-call research is now moving towards an understanding of how to mitigate some of the specific fatigue-related risks associated with these working time arrangements. In particular, there is a growing body of research addressing the potential fatigue-related performance impairments associated with waking to respond to a call. Most individuals experience a period of grogginess and impaired performance for up to 30 minutes after waking, this is called sleep inertia (Tassi & Muzet, 2000). Sleep inertia is a significant safety concern for on-call workers who may be required to perform time- or safety-critical tasks immediately upon waking (Hilditch, Dorrian, & Banks, 2016). Concerns about sleep inertia, and about the

documented disruptions to sleep obtained under on-call conditions, has also raised questions about the most effective sleep strategy to use during an on-call period.¹³

One emerging area of sleep inertia research is the potential role of stress upon waking as a countermeasure for fatigue-related performance impairments. Previous research has been unable to identify a sleep inertia countermeasure that improves performance within moments of waking.¹⁴ However, on-call workers have anecdotally reported an ‘adrenaline burst’ upon waking to a call that has a perceived protective effect on performance (Paterson, Aisbett & Ferguson, 2016). As such, the role of adrenaline and stress have been the focus of more recent research. So far findings indicate that anticipating a simulated high-stress task reduces feelings of sleepiness, and has some protective effects on performance upon waking (Kovac et al., 2020; Sprajcer et al., 2018). There is some evidence that stress experienced upon waking, in this case in the form of a minor finger-prick blood draw used as part of the study protocol, may also mitigate against some performance impairments typical of sleep inertia (Sarah M. Jay, Carley, Aisbett, Ferguson, & Paterson, 2019).

7.2 The ‘gig’ economy

Another current area of interest in fatigue research is the health and safety implications of the ‘gig’ economy. Similar to on-call working time arrangements, gig work operates on the provision of a service on an ‘as-needed’ basis. These forms of work arrangements typically use peer-to-peer transactions, rely on user ratings for evaluation of performance, and require the employee to provide all resources necessary to complete the work (Tran & Sokas, 2017). Examples of organisations that rely on gig work include Uber, Deliveroo, and Lyft. While gig economy workers are technically covered by OHS legislation as sub-contractors, it is rarely the case that contractual arrangements specify fitness for duty with respect to fatigue. Recent research has shown that those who drive for work in the gig economy report increased fatigue, high physical and mental demand, long work hours and work during the biological night (Christie & Ward, 2018). In the same study, 16% of participants reported feeling so fatigued that they struggled to remain awake while driving, 42% had been involved in an accident involving vehicle damage, and 10% had been in an accident where someone had been hurt.

¹³ For a review of issues related to sleep and safety during on-call work see Ferguson, Paterson, Hall et al. 2016.

¹⁴ For a recent review of the efficacy of countermeasures to sleep inertia see Hilditch, Dorrian & Banks, 2016.

7.3 Flexible working times

Workers outside of traditional shift working occupations have been largely overlooked in fatigue research to date. However, the vast technological advances that have occurred in recent years have changed the nature of communication, information-sharing, and our understanding of working time (Cascio & Montealegre, 2016). These changes have resulted in an increased ability for people to work outside of traditional workplace environments and beyond scheduled work hours. This situation is distinct from on-call working time arrangements which typically involve a formal agreement between the workplace and the employee, and may include compensation for time spent on-call regardless of whether a call is received (Nicol & Botterill, 2004). While there are documented positive outcomes associated with flexible working time (Hayman, 2009), these arrangements may also limit opportunities for rest and recovery between work periods, and result in workers feeling unable to disconnect (Nowack & Deal, 2017; Zijlstra & Sonnentag, 2006). The consequences of these changes in the nature of working time arrangements for sleep, fatigue, health and safety are largely unknown, and are likely to be the focus of significant future research. This is timely given that these workers may not currently be considered as part of an organisation's FRMS, and given the growing body of evidence demonstrating the medium- to long-term effects of fatigue for health (as discussed above in Section 4.2).¹⁵

8 Implications for OHS practice

The role of the OHS professional is to apply their knowledge of the science of safety and the action of specific hazards to the “design of OHS management strategy and critical risk control management” (INSHPO, 2017, p. 11). This is especially important in the management of fatigue where the both our knowledge of the hazard, its impact and the effectiveness of control strategies is still evolving.

Approaches to fatigue management have evolved from a focus on control of HOS to a FRMS approach. Effective implementation of a FRMS requires “a base level of safety culture, infrastructure, and risk management expertise within the implementing organisation and relevant regulatory agencies” (Honn, et al., 2019, p. 57). While FRSM has been widely adopted in industries with well-established OHS management systems, other industries, especially those characterised by adversarial industrial relations or a large number of medium and small operators are less likely to have FRMS (Honn et al., 2019). FRMS have focused on the safety implications of fatigue with little consideration of psychosocial and health-related impacts. Honn et al., suggest that future evolutions of FRMS may move toward a hybridised approach that combines a prescriptive approach to HOS within a FRMS.

¹⁵ Flexible working hours are likely to have fatigue implications for workers working from home. See *OHS BoK 37.4 Workers working from home* (in development at time of writing).

The OHS professional can combine their knowledge of fatigue and fatigue risk control together with knowledge of their organisation and industry to advise on the design of strategies to control the fatigue hazards.

Where the organisation has an established FRMS the role of the generalist OHS should be to promote and monitor adherence to the FRMS. This can be achieved through regular workshops, distribution of materials, and by encouraging and facilitating open dialogue about fatigue. Also, it is important to constantly evaluate the FRMS to ensure that it remains efficient, relevant and effective for the workforce. Where the organisation does not have an established FRMS the priority may be to conduct a risk assessment, put together a business case and formalise an FRMS (or hybrid approach) to ensure a legally and scientifically defensible approach to fatigue management. In lieu of this, education sessions, materials and open dialogue about the causes, consequences and experience of fatigue should be routine.

In any case, fostering a healthy organisational culture will assist in the successful management of fatigue. Indeed, the success of any formal FRMS or any attempts to informally manage fatigue hinges on whether the culture of an organisation is supportive. Open communication and formalised education about fatigue are two of the best ways to create a supportive safety culture in which fatigue can be effectively managed as an OHS hazard. A recent consensus statement from the Working Time Society provides a useful overview of factors that need to be taken into consideration for professionals seeking to manage the risks associated with fatigue in the workplace (see Honn, Van Dongen, & Dawson, 2019). (Also included in Appendix.)

9 Summary

The risk posed by fatigue in the workplace may be managed, to an extent, in the same way that many other hazards are managed in the workplace. However, implementation of a Defences in Depth approach to fatigue management requires an understanding of the science of fatigue and its evolution as a recognised hazard. The unique challenge associated with fatigue management lies in recognising that fatigue-management interventions have technical, social and cultural implications. Managing these implications in line with regulatory, organisational and individual requirements is imperative for the success of any fatigue risk management system.

Key Authors and Thinkers

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Appendix 1: Working Time Society Consensus Statements

- 1) Historically, prescriptive rule sets specifying maximum shift durations, minimum break durations and aggregated total work hours were developed in order to limit health risks due to physical fatigue. While well-entrenched as a regulatory approach, prescriptive rule sets are not well suited to managing the risks associated with mental fatigue.
- 2) Ideally, approaches to regulating the fatigue-related risk associated with working time arrangements should ensure regulatory compliance improves safety outcomes.
- 3) Prescriptive rule sets tend to be least effective when working time arrangements involve work during the typical range of nocturnal sleep (i.e., between approximately 9pm and 9am). This is due to a variety of factors, including:
 - (a) the critical role of circadian rhythms in regulating sleepiness/alertness;
 - (b) the cumulative effects of sleep restriction typically associated with daytime sleep on mental fatigue.
- 4) Risk management-based approaches (e.g., Fatigue Risk Management Systems; FRMS) have considerable potential to be more effective and more flexible than prescriptive rule sets for mitigating the risks associated with mental fatigue.
- 5) An FRMS (as part of a broader Safety Management System) is typically comprised of:
 - (a) a policy and governance framework;
 - (b) a training and education program;
 - (c) an evidence-based risk assessment and mitigation methodology;
 - (d) a monitoring and review process to ensure continuous improvement in compliance and efficacy.
- 6) FRMS governance of working time arrangements should involve a “shared responsibility” framework for managing fatigue-related risk at work in accordance with “just culture” principles. In broad terms, the employer should be primarily responsible for managing work-related causes of fatigue and the employees for managing non-work-related causes of fatigue. Where an employee (or supervisor) believes a worker may be unable to work safely, there should be a documented process whereby they are able to (and required to) notify the organization, determine the cause, and mitigate the risk.
- 7) Monitoring and review of an FRMS should involve:
 - (a) quantifying the organizational risk and safety outcomes of fatigue including leading indicators and/or ‘near miss’ events;
 - (b) developing and reporting valid and reliable key performance indicators;
 - (c) assessing compliance with FRMS procedures;
 - (d) assessing the effectiveness of, and subsequently updating of the FRMS procedures.
- 8) In determining how best to manage fatigue-related risk, an organization needs to consider:
 - (a) the broader safety culture of the organization and societal context;
 - (b) the resources, infrastructure and expertise available for implementing the FRMS;
 - (c) the views of relevant stakeholders (e.g., employees and their representatives, relevant regulatory agencies, local communities, etc.);
 - (d) the likely cost/benefit ratio of a proposed FRMS.
- 9) Over time, hybrid frameworks may evolve that permit organizations to utilize the benefits of both prescriptive and risk-based approaches in their FRMS.
- 10) The optimal fatigue risk management approach, whether it be prescriptive, risk management-based, or a hybrid approach, depends upon the sophistication and maturity of the given organization’s broader safety system/culture.

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Full consensus among panel members on all statements.

(Honn et al., 2019, p. 265)