Psychosocial Hazards: Fatigue

Core Body of Knowledge for the Generalist OHS Professional

Safety Institute of Australia Ltd

Australian OHS Education Accreditation Board

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Disclaimer

The OHS Body of Knowledge for Generalist OHS Professionals has been developed under the auspices of the **Health and Safety Professionals Alliance**

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The Technical Panel established by the Health and Safety Professionals Alliance (HaSPA) was responsible for developing the conceptual framework of the OHS Body of Knowledge and for selecting contributing authors and peer-reviewers. The Technical Panel comprised representatives from:

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The Safety Institute of Australia supported the development of the OHS Body of Knowledge and will be providing ongoing support for the dissemination of the OHS Body of Knowledge and for the maintenance and further development of the Body of Knowledge through the Australian OHS Education Accreditation Board which is auspiced by the Safety Institute of Australia.

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A synopsis of the OHS Body of Knowledge

Background

A defined body of knowledge is required as a basis for professional certification and for accreditation of education programs giving entry to a profession. The lack of such a body of knowledge for OHS professionals was identified in reviews of OHS legislation and OHS education in Australia. After a 2009 scoping study, WorkSafe Victoria provided funding to support a national project to develop and implement a core body of knowledge for generalist OHS professionals in Australia.

Development

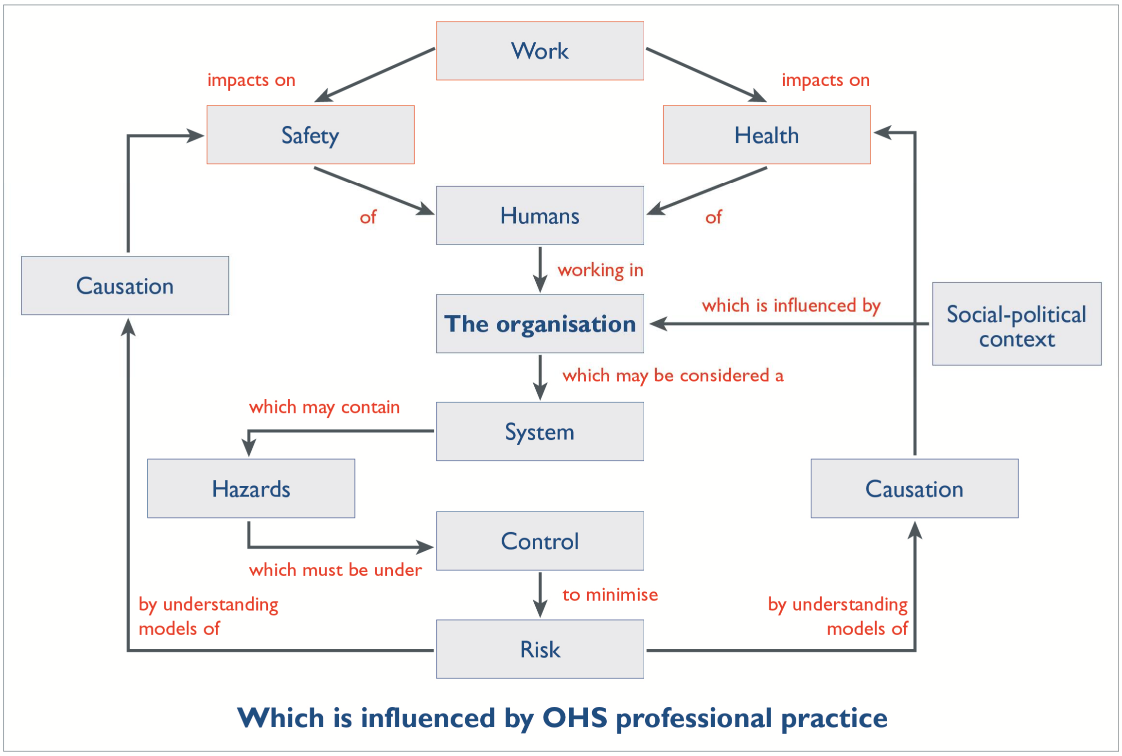
The process of developing and structuring the main content of this document was managed by a Technical Panel with representation from Victorian universities that teach OHS and from the Safety Institute of Australia, which is the main professional body for generalist OHS professionals in Australia. The Panel developed an initial conceptual framework which was then amended in accord with feedback received from OHS tertiary-level educators throughout Australia and the wider OHS profession. Specialist authors were invited to contribute chapters, which were then subjected to peer review and editing. It is anticipated that the resultant OHS Body of Knowledge will in future be regularly amended and updated as people use it and as the evidence base expands.

Conceptual structure

The OHS Body of Knowledge takes a ćconceptualô approach. As concepts are abstract, the OHS professional needs to organise the concepts into a framework in order to solve a problem. The overall framework used to structure the OHS Body of Knowledge is that:

> **Work** impacts on the **safety** and **health** of humans who work in **organisations**. Organisations are influenced by the **socio-political context**. Organisations may be considered a **system** which may contain **hazards** which must be under control to minimise **risk**. This can be achieved by understanding **models causation** for safety and for health which will result in improvement in the safety and health of people at work. The OHS professional applies **professional practice** to influence the organisation to being about this improvement.

This can be represented as:



Audience

The OHS Body of Knowledge provides a basis for accreditation of OHS professional education programs and certification of individual OHS professionals. It provides guidance for OHS educators in course development, and for OHS professionals and professional bodies in developing continuing professional development activities. Also, OHS regulators, employers and recruiters may find it useful for benchmarking OHS professional practice.

Application

Importantly, the OHS Body of Knowledge is neither a textbook nor a curriculum; rather it describes the key concepts, core theories and related evidence that should be shared by Australian generalist OHS professionals. This knowledge will be gained through a combination of education and experience.

Accessing and using the OHS Body of Knowledge for generalist OHS professionals

The OHS Body of Knowledge is published electronically. Each chapter can be downloaded separately. However users are advised to read the Introduction, which provides background to the information in individual chapters. They should also note the copyright requirements and the disclaimer before using or acting on the information.

Psychosocial Hazards: Fatigue

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Core Body of Knowledge for the Generalist OHS Professional

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Psychosocial Hazards: 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 neurobehavioural performance and negative mood. From an operational perspective, fatigue can sometimes manifest as an increased chance of fatigue-related error and/or fatigue-related accident or injury due to cognitive impairment.

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. Understanding and managing fatigue is essential to building a healthy and safe workplace.

Keywords:
fatigue, risk, sleep, safety, health

Contents

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 ï defined as ñdecreased capability to perform mental or physical work, produced as a function of inadequate sleep, circadian disruption or time on taskò (Brown, 1994) ï is recognised as a significant OHS psychosocial hazard due to its relationship with working time and influence on both physical and mental function. After brief consideration of the historical context of fatigue as an OHS hazard and the extent of the problem, this chapter outlines the mechanisms of action of fatigue and its consequences. Control of fatigue-related hazards via implementation of Fatigue Risk Management System (FRMSs) are discussed, with particular reference to the Defences in Depth (DiD) Model. 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 workersô 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.

3 Extent of the problem

Long working-time duration ï a trend that began in the 1980s ï is a significant problem for part- and full-time workers in Australia (I. Campbell, 2002). 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, Lorandeau, & Berger, 2007).

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 (N.T.S.B., 1999). Since then, fatigue has been cited as a causal factor in 57% of fatal truck accidents (Walsh, Dement, & Dinges, 2005).

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 Brownôs (1994) definition (section 1) ï ñinadequate sleep, circadian disruption or time on taskò ï 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 ï 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 4ï 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 óadequateô 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 ósleep debt.ô 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 7.5ï 8.5 hours sleep per night (Basner et al., 2007; Johns & Hocking, 1997; Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; T.H. Monk, Buysse, Rose, Hall, & Kupfer, 2000; Taillard, Philip, & Bioulac, 1999). However, most people extend their sleep time on the weekend by 30ï 45 minutes on average (Hale, 2005; T.H. Monk et al., 2000; Taillard et al., 1999), suggesting an accumulated sleep debt and subsequent need for recovery.

While ótypicalô sleep time may be 7.5ï 8.5 hours, nearly everyone obtains less sleep than this sometimes and many people obtain less sleep than this all the time. 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 ócircadian disruptionô aspect of fatigue (section 4.1.2).

The definition of óadequateô sleep is likely to change over the course of an individualôs 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 ótipping pointô 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 et al., 2004). Therefore, the definition of óadequateô sleep is likely to be affected by the age of the individual.

As mentioned previously, óadequateô 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 (a) obtained less than 5 hours sleep in the previous 24 hours, (b) obtained less than 12 hours sleep in the previous 48 hours or (c) by shift end been awake for a period exceeding their total sleep time in the previous 48 hours (D. Dawson & McCulloch, 2005). Derived from a review of literature relating to the subjective, neurobehavioural and electrophysiological effects of sleep loss, these parameters are components of the Prior Sleep Wake Model (Dawson & McCulloch, 2005). In accordance with the model, two ófatigueô 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 (1ï 5), high (6ï 12) or extreme (13+). It is important to note that the definitions of óadequateô sleep to be fit for duty are relatively ambiguous. That is, these sleep ódosesô may affect different individuals in different ways. (for a review of some of the other factors which may influence an individualôs fatigue levels see Di Milia et al.,

2011) 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 bodyôs circadian rhythm. Circadian rhythms regulate different functions of the body to an average 24.2-hour cycle (Czeisler 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).

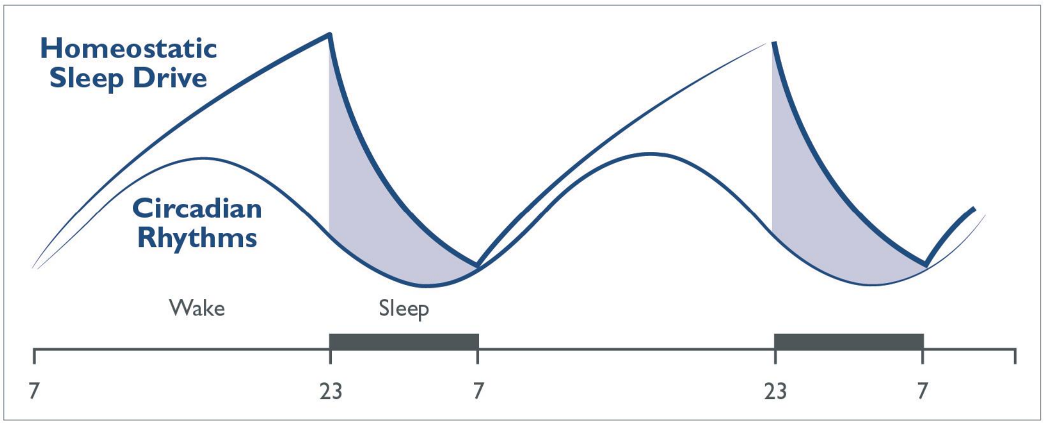

Figure 1: The Two-Process Model of Sleep Regulation (Homeostatic and Circadian) (adapted from Borbély & Achermann, 1999)

The circadian rhythm has peaks and troughs. The circadian nadir ï the ólow pointô of the circadian rhythm ï 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 ï the ópeakô of the circadian rhythm ï 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 position of a shift 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 et al., 2003; Thiffault & Bergeron, 2003). 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 and the factors that can result in an individual becoming fatigued. This section describes some of the consequences of working when impaired by fatigue. For a comprehensive review of the relationship between fatigue and safety outcomes, see Williamson et al. (2011).

Laboratory-based research has been vital in understanding the consequences of fatigue in 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 et al., 2003; Kahol et al., 2008; Morris & Miller, 1996; Philip 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.

Also, 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 the job profile and is therefore likely to change across industries, the operational consequences of fatigue are relatively universal. Overall, impairments associated with fatigue have been shown to 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, 2004; Goode, 2003; Halvani, Zare, & Mirmohammadi, 2009; Härmä et al., 2002; Jay, Dawson, Ferguson, & Lamond, 2008; Petrilli, Roach, Dawson, & Lamond, 2006; Roach, Dorrian, Fletcher, & Dawson, 2001).

Health care, in particular, is associated with long irregular hours and a high-risk error profile for both workers and patients. Field studies in health-care 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 elseǒs error, slower completion of standard procedures and an increased chance of falling asleep on the drive home (Dorrian et al., 2006; Gold et al., 1992; reviewed in Veasey, Rosen, Barzansky, Rosen, & Owens, 2002; reviewed in Weinger & Ancoli-Israel, 2002). Indeed, driving has consistently been demonstrated to be 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 (Drobnich, 2005; reviewed in Lal & Craig, 2001; reviewed in May & Baldwin, 2009; Philip et al., 2005; Philip, Sagaspe et al., 2003; Philip, Vervialle, Le Breton, Taillard, & Horne, 2001; Scott et al., 2007).

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 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 workersô irregular hours and inadequate sleep as the 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 Australiaǒs 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 (A.T.S.B., 2011). Similarly, the catastrophic 1989 Exxon Valdez oil spill was attributed to fatigue resulting from sleep loss and irregular work hours (Åkerstedt, 2003).

It is evident that fatigue is associated with substantial economic, social and environmental costs. As such, the management of fatigue as a psychosocial work hazard is imperative. The following section describes current approaches to fatigue management in the workplace.

5 Legislation and standards

The national model *Work Health and Safety Act* (WHSA 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 (Safe Work Australia, 2011).[1] 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.

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. (For a review of modelling tools, see Dawson, Noy, Härmä, Åkerstedt & Belenky, 2011.) 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 that will come into effect from December 2011. In light of the ICAOȇs recommendations, the Australian Civil Aviation Safety Authority (CASA) is reviewing their FRMS to ensure it reflects current best practice (CASA, 2011).

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 (N.R.S.R., 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 Commissionȇs 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.

The above examples represent a move towards 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.

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

[1] *See OHS BoK* Socio-Political Context: OHS Law and Regulation in Australia

that a systems approach based on the principles of risk and safety management as described in AS/NZS 31000 (SA/SNZ, 2009) and AS/NZS 4801 (SA/SNZ, 2001) 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 system is a systematic process through which potential OHS hazards are identified, assessed and mitigated using multiple, strategic controls.[2] 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 Reasonôs (2000) Swiss Cheese Model (Figure 2), which can be applied to any workplace hazard.[3] 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.

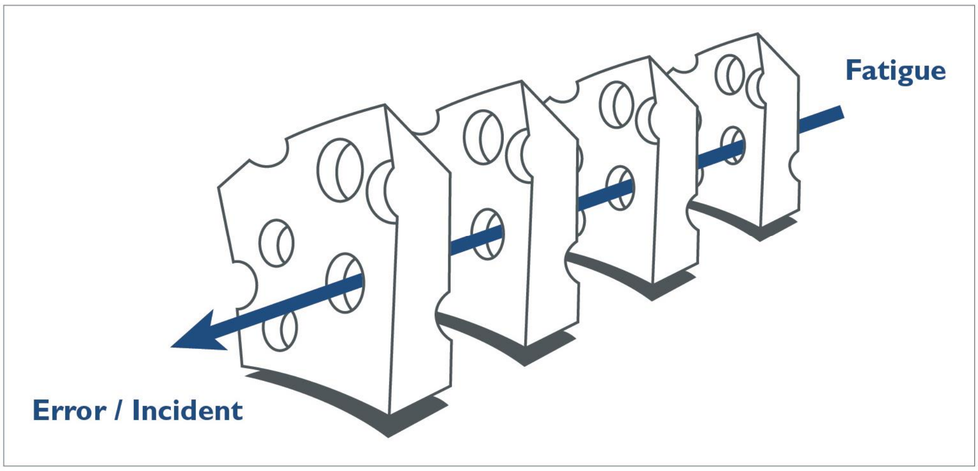

Figure 2: The Swiss Cheese Model (adapted from Reason, 2000)

Based on Reasonôs 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/NZS ISO 31000 and AS/NZS 4801), the Defences in Depth (DiD) model details the controls necessary to mitigate the likelihood of a fatigue-related error (Figure 3).

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[3] See *OHS BoK* Models of Causation: Safety

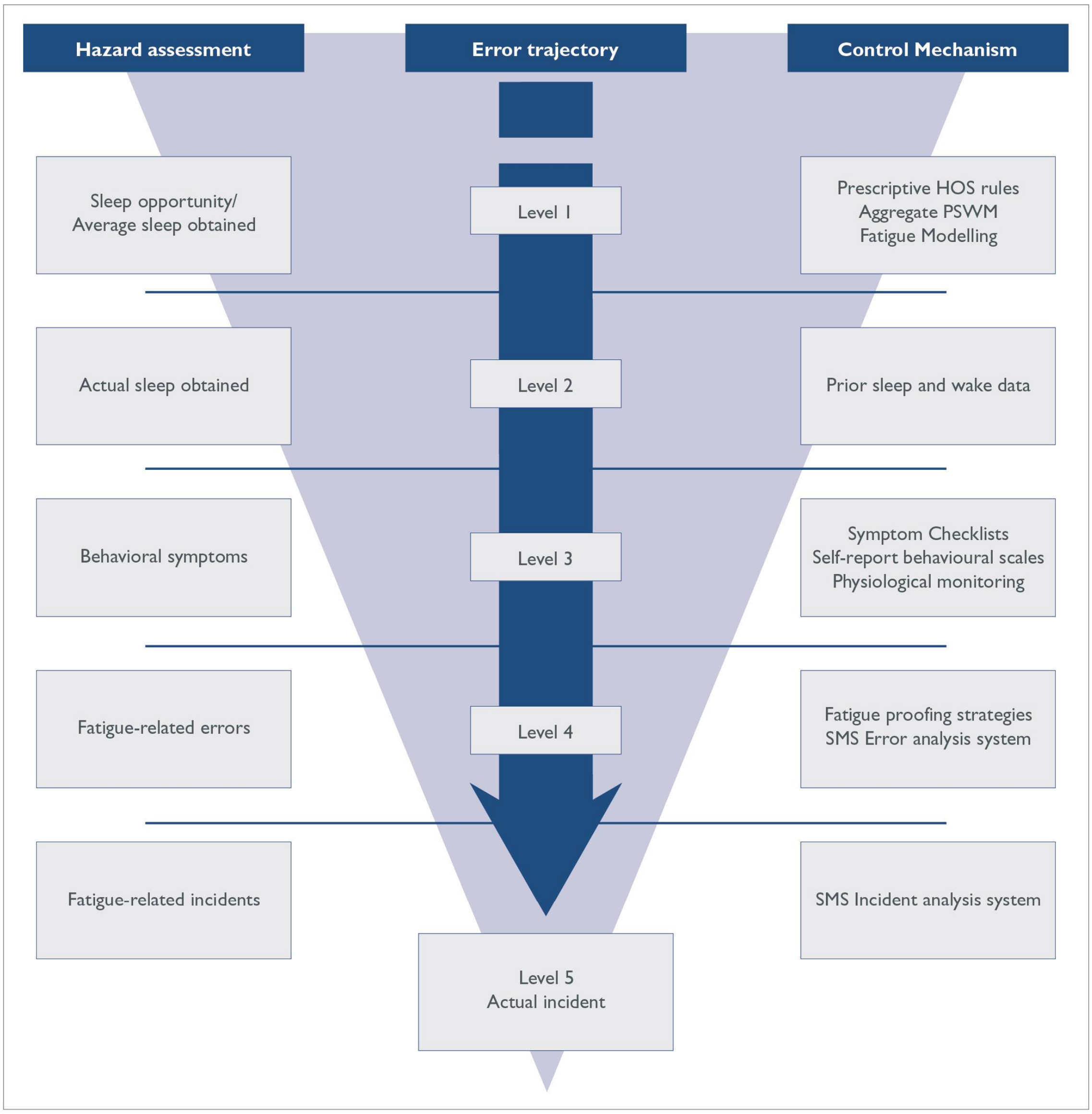

Figure 3: The Defences in Depth (DiD) approach to fatigue management (Dawson & McCulloch, 2005)

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. 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. (for a review of fatigue modelling tools and their use see D Dawson, Noy, Härmä, Åkerstedt, & Belenky, 2011). The Fatigue Audit Interdyne (FAID) software is one example of a DiD Level 1 control. This fatigue-modelling tool is widely used in the

Australian transportation industry. A roster is entered into the program, producing a ófatigue scoreô associated with that roster; that is, the likelihood that the roster will result in a worker experiencing fatigue-related impairment. Previously, industrial relations law regulated HOS limits. However, this function has been moved from industrial relations control to Work Health and Safety 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.

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 employeesô 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 (D 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.

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 ógold standardô (Lal et al., 2003). Although the monitoring equipment tends to be obtrusive and impractical, there have been recent technological advances in the monitoring of brain waves for signs of fatigue via a baseball cap fitted with electroencephalographic sensors. Also of increasing interest is electro-oculographic monitoring, which measures fatigue-related eye movements including eye closures and blink duration (Ji, Zhu, & Lan, 2004). Several new applications of this technology (e.g. in eyeglasses) can be used with little disruption to the worker. DiD Level 3 controls, particularly in regard to monitoring fatigue from a physiological perspective,

are the subject of a great deal of current research. (for a recent review see Balkin, Horrey, Graeber, Czeisler, & Dinges, 2011).

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 1ï 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. (for a review see D. Dawson, Chapman, & Thomas, 2011) 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. They 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, 2011). 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 organisationôs FRMS.

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 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 Implications for OHS practice

The primary role of the generalist OHS professional operating within an organisation with an established Fatigue Risk Management System (FRMS) should be to promote and monitor adherence to the FRMS. This can be achieved through regular workshops, distribution of printed 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.

The generalist OHS professional operating within an organisation that does not have an established FRMS faces a different set of challenges. It may be a priority for the organisation to conduct a risk assessment, put together a business case and formalise an FRMS to ensure they have a legally and scientifically defensible approach to fatigue management. In lieu of this, education sessions, printed materials and open dialogue about the causes, consequences and experience of fatigue should be routine.

In any case, fostering a healthy organisational safety 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.

8 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. (for a recent review of these issues see Gander et al., 2011)

Key Authors and Thinkers

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