Rapid review on evidence of managing the risks associated with fatigue

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Executive summary

Background

In November 2013, Safe Work Australia (SWA) published guidance on managing the risk of fatigue at work, and fatigue management for workers (fatigue guidance). Recently, SWA Members agreed to develop a model Code of Practice on fatigue to replace SWA's existing fatigue guidance. This will provide more authoritative and up to date guidance.

Fatigue is more than feeling tired and drowsy. In a work context, fatigue is an acute (i.e. short-term) or ongoing (i.e. chronic or long-term) state of exhaustion. Fatigue can be:

- physical – that is, pronounced physical exhaustion and reduced ability to engage in physical activities (e.g. manual labour)
- mental – that is, pronounced mental exhaustion and reduced ability to engage in mental or cognitive activities (e.g. making decisions)
- emotional – that is, pronounced emotional exhaustion and reduced ability to engage in emotional activities (e.g. empathising with or caring for others)
- visual – as a result of long periods of visually intensive work
- caused by the physical, emotional and psychological impact of helping others, referred to as compassion fatigue, or
- a combination of all of these.

Fatigue can harm workers and others. It can:

- harm workers' psychological and physical health and safety, in both the short and long term, and
- create a risk to workers' and others' health and safety when it impairs safe work (e.g. where systems of work rely on workers not making errors to prevent incidents or injuries).

Purpose

This report will report on a rapid review of the literature and present the following.

- A definition of fatigue, how it causes harm and any thresholds for harm
- Identification of hazards at work that may give rise to fatigue, and hazards and risks arising from fatigue
- Assessment of the risks
- Potential risk controls (both physical and psychosocial), taking a systems-based approach which will include the hierarchy of risk controls
- Evidence on review of control measures
- Methods for monitoring the health of workers and the conditions at the workplace for the purpose of preventing fatigue-related illness or injury of workers arising from the conduct of the business or undertaking
- Tools for managing the risks of fatigue

Rapid review

To examine the contemporary evidence on fatigue, a rapid review was undertaken. Three databases were searched (CINAHL, MEDLINE, PsycINFO) for articles published between 2013 and April 2024. After screening by the research team, 111 were included for data extraction. Of the 111, 70 were intervention studies and the further 41 were citations outlining fatigue assessment tools only, and as such the combination form the evidence base on which this report is written.

In summary, included studies were from studies conducted in 24 countries. Most were conducted in the USA (n=13) or Iran (n=9), with only one study conducted in Australia. Industries covered in the studies included healthcare (n=38), aviation (n=7) and public services (n=5) as the three most frequently referred to, and professional, scientific and technical services (n=1) as one of the least referred to. In relation to the type of fatigue measured, the most common was 'general fatigue' (n=62), with compassion and visual fatigue the next most common (n=3 and n=2 respectively). The most frequently used study design was randomised control trial (RCT) (n=19), followed by pre/post-test design (n=18).

Interventions

Overall, 43 of the 70 studies reported that the interventions tested were effective. The range of study types and interventions varied, making it difficult to draw robust conclusions as to the effectiveness of different types of interventions. Randomised controlled trials are generally considered the most robust design, of which there were 19, and 12 were effective. On balance, lighting interventions appeared to be effective, with 10 of the 13 interventions reporting effectiveness at reducing general fatigue.

Risk controls

Using a systems model, interventions were coded according to the level at which they were targeted. This identified that most were at the organisational level (n=28), followed by individual level (n=20), then physical work environment level (n=6) and task/equipment level (n=6), with seven interventions targeting multiple systems levels.

Interventions were also coded according to where they were within the hierarchy of risk controls. Most were at the substitution level (n=40), followed by administration (n=21). Substitution involved shift rostering, lighting and napping. Administration involved education, mindfulness and exercise programs as examples.

Tools for managing fatigue

In total, 63 tools were identified as measuring fatigue. Six tools were classified as fatigue risk management tools designed for use by organisations as a means to both assess worker fatigue and manage risks arising from it. No evidence of use of these fatigue risk management tools in intervention studies was found; rather, all the fatigue risk management tools identified had been used in observation studies.

Future opportunities

Based on the findings from this review, a number of gaps were identified in the interventions being used to reduce fatigue risk and in the tools available for use by workplaces to reduce fatigue risk. Interventions need to take into account the multifactorial nature of fatigue. Most of the interventions identified in this review address only one level in the systems model, and although many addressed organisational issues these mostly involved shift work design. Further work is needed to understand fatigue risks in occupations without shift work and there should be an increased focus on the psychosocial factors associated with fatigue risk.

Glossary of terms

Key definitions relevant to this report on fatigue are provided here.

Fatigue is more than a feeling of just feeling tired and drowsy. In a work context, fatigue is a state of mental and/or physical exhaustion which reduces a person's ability to perform work safely and effectively.

Hazards are considered the source of potential harm or injury. [1] Many different definitions of 'hazard' exist. It is often confused with the term 'risk' and they are often used interchangeably although they are conceptually different.

Risks refer to outcomes or consequences of exposure to hazards. Risk is a complex concept that is challenging to concisely define in a meaningful way. Usual definitions consider 'risk' as a product of the consequences and the likelihood of the outcome occurring. Very simple models of risk assume one hazard and one event leading to a single consequence. For complex issues such as fatigue, this is an inadequate concept of risk: hazards arise from multiple sources or events and so require multiple controls to mitigate risk of fatigue.

Psychosocial hazards are anything in the organisational context that could cause psychological harm. They include high job demands (e.g. high workloads and high-paced work), low levels of job control, and lack of role clarity (e.g. conflicting work demands). A second sub-group is that of social context, inadequate reward and recognition (i.e. being valued) and poor physical environment (see: https://www.safeworkaustralia.gov.au/safety-topic/managing-health-and-safety/mental-health/psychosocial-hazards).

Focus of interventions

Individual controls. These interventions are focused on changes to an individual's behaviour. They include training, stretching, exercises, education and other behaviour change approaches.

Task-specific and equipment controls. These interventions are focused on changes to an individual's equipment. They may include workstation adjustments, or the provision of a tool or piece of equipment to reduce physical demands on an individual. Changes to the broader physical or psychosocial environment were not included in this category.

Work organisation and job design controls. These interventions are targeted at making changes at an organisation level, such as working hours, overall job design or manager training in comprehensive OHS risk management. Interventions might cover addressing workload, inadequate rest breaks and reducing work hours, for example.

Workplace environment controls. Interventions are focused on addressing risks arising from the physical and psychosocial environment. These include air quality, extreme heat or cold, and loud noise. The psychosocial environment includes factors arising from the general workplace culture or climate, such as widespread perceptions that getting work done quickly is more important than workers' health and safety, low job security, autocratic style of management with minimal participation by employees at lower levels, and so on.

Multifactorial controls. These interventions include a combination of interventions, such as a change to an individual's workstation and training. Changes might be at the same level in the system but include multiple aspects of intervention, or be at different levels in the system.

Hierarchy of risk controls. This provides a system for considering the effectiveness and reliability of risk controls. Variations exist but most have elimination as the highest level of control, followed by substitution/isolation/engineering controls, then administrative. Personal protective equipment (PPE) is the lowest level of control.

Background

High levels of fatigue and the resultant risks arising from being in a state of fatigue require comprehensive risk management strategies that consider the broad range of hazards which impact workers and the different levels from which they arise within the workplace system. Often the focus for fatigue risk management is on individual workers and addressing their responses to workplace factors. Providing workers with skills and knowledge is important and appropriate as one part of an overall fatigue risk management strategy; however, more attention is required to address the multidimensional nature of fatigue and the potential impacts arising from this state.

This report commissioned by SafeWork Australia (SWA) will review contemporary literature on fatigue to provide up to date evidence to inform development of a model code of practice. It will review the current evidence of managing fatigue and identify the range of contemporary tools available for organisations to use in managing fatigue.

The report will begin with outlining the definition of fatigue and report briefly on the potential impacts. It will then outline systems thinking as it applies to fatigue, and a systems framework used to underpin the rapid review undertaken to address the brief outlined by SWA.

Defining fatigue

Comprehensive definitions of fatigue vary slightly, but central to their focus is that it is more than just a feeling of being tired or drowsy. Definitions of fatigue include:

- a physiological state of reduced mental or physical capability, which may develop as a result of sleep loss or extended wakefulness, disrupted circadian rhythm or increased workload [2]
- “the state of an organism’s muscles, viscera, or central nervous system, in which prior physical activity and/or mental processing, in the absence of sufficient rest, results in insufficient cellular capacity or systemwide energy to maintain the original level of activity and/or processing by using normal resources” (p.469). [3]

Based on these definitions, major causes of fatigue include muscular exertion, prolonged attention, attention to a repetitive stimulus, prolonged performance of a complex or repetitive task, long periods without sleep, disruption to circadian rhythm, or combinations of these activities.

Fatigue can be separated into three types: acute, cumulative and circadian. Acute fatigue typically results from an extended period of wakefulness exceeding 16 hours. Cumulative fatigue, also known as sleep debt, results from an accumulation of suboptimal sleep times, which may be for days, weeks or months. Circadian fatigue, or chrono disruption, is a form of fatigue that arises from shifting the sleep/wake cycle, either due to changes in working hours or following travel. [2,4]

Fatigue can be:

- physical – that is, pronounced physical exhaustion and reduced ability to engage in physical activities (e.g. manual labour)
- mental – that is, pronounced mental exhaustion and reduced ability to engage in mental or cognitive activities (e.g. making decisions)
- emotional – that is, pronounced emotional exhaustion and reduced ability to engage in emotional activities (e.g. empathising with or caring for others), or
- a combination of physical, mental and emotional.

Typically, acute fatigue is relieved by quality rest, sleep, appropriate diet, and exercise. This report focuses on acute fatigue caused by exposure to workplace factors. It particularly examines the acute mental aspects of fatigue, which include exhaustion, rather than the physical aspects. Mental fatigue is considered more complex and requires consideration of factors beyond the setting of break times and shift lengths, such as the timing of work and rest and the work being undertaken. [5] Emotional fatigue was not included except in studies where it was defined as exhaustion, as the terms are sometimes used interchangeably.

This review includes visual fatigue and exhaustion (not emotional exhaustion) as these were identified in the review process and following discussion a decision to retain these in addition to the more general fatigue which is the primary focus of the review.

Hazardous exposures associated with fatigue

Fatigue usually arises from exposure to multiple risk factors.

- Sleep deprivation
- Mental exertion
- Physical exertion
- Workload characteristics (e.g. overtime and long work hours, incomplete recovery)
- Environmental characteristics (e.g. lighting, noise, vibration)
- Social context at work (e.g. relationships with colleagues, support from managers/supervisors)
- Individual characteristics (e.g. responsibilities outside of work, medications, commuting, individual sleep requirements).

Harm arising from fatigue

Many of the factors outlined in the previous section coexist, and interactions can increase the worker's experience of fatigue. For example, working long hours at physically demanding and noisy work with little job control to take rest breaks is likely to increase fatigue levels more than exposure to a single hazard.

Impacts from fatigue are also multifactorial and can include:

- Psychological harm: including psychological distress, depression, anxiety and impaired emotional regulation. [6-8]
- Physical harm: including musculoskeletal [9] and cardiovascular symptoms[10]
- Risks associated with shift work including cognitive impairment, type 2 diabetes, accidents, weight gain, coronary heart disease, stroke and cancer [11,12]
- Health and safety risks arising from impaired ability to work safely[13]
- Reduced productivity including, slowed reaction time and decision-making, reduced quality of work[14]

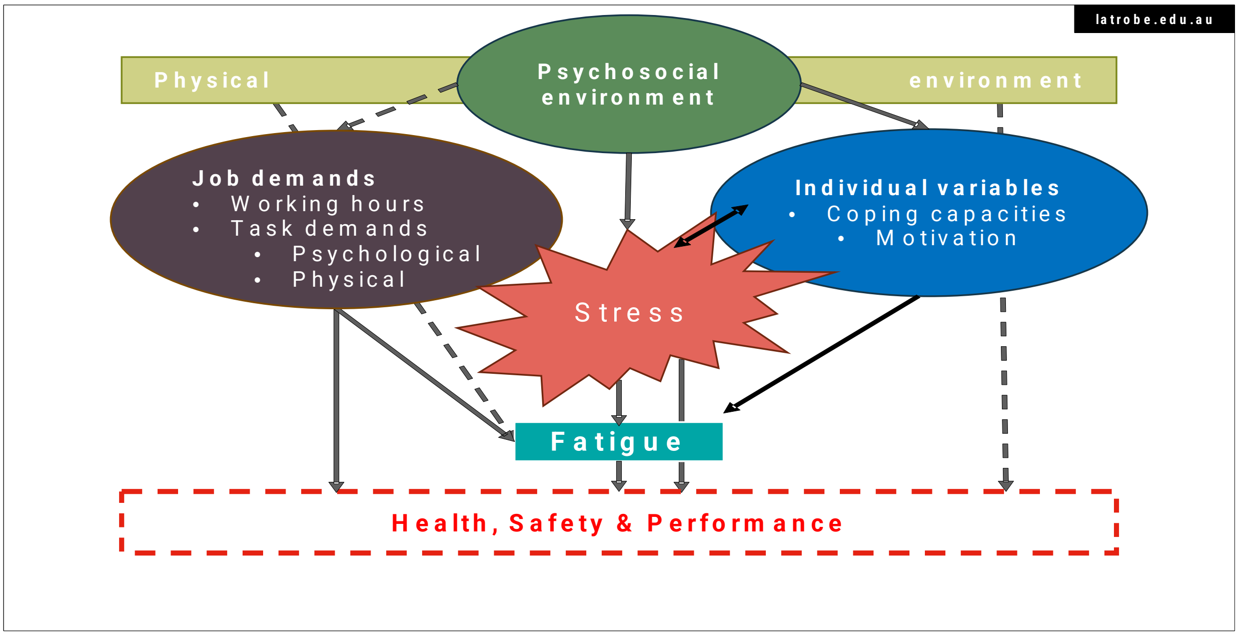

FIGURE 1 Outline of a model of fatigue and the relationships between various job demands, the physical and psychosocial environment factors, and individual variables (from Macdonald, 2006) 2

Assessing the risks of fatigue

Management of the various kinds of risks arising from high levels of workplace fatigue is a complex and challenging process. Risk management systems for fatigue have evolved and continue to evolve as research in the areas of circadian impacts and sleep has developed, resulting in improved understanding of an individual's exposure and their response to workplace factors, sleep and recovery. Conceptualisation of fatigue has shifted. It is now recognised as a work health and safety issue caused by exposure to a range of hazards, as outlined in previous sections.

Early work by Macdonald [15] outlined the impact of job demands and workload on stress and fatigue, extending previous narrower conceptualisations which focused on hours of work without consideration of workload. Fatigue modelling likelihood approaches were developed [16-18] and used to guide work scheduling and improvements to productivity. This body of research has informed the development of fatigue risk management assessments and modelling approaches to help design work schedules that reduce the impacts of fatigue on workers who are exposed to long hours and shift work, but gaps still appear to exist in areas where fatigue is due to high work demands or other well-documented hazards associated with stress and subsequently with fatigue.

Risk-based approaches to fatigue management include identification and then control. Although these are described as three distinct approaches, in reality the distinction is more arbitrary.

- Predictive: identify hazards at source (e.g. organisational design issues impacting scheduling)
- Proactive: focus on individual factors such as fitness for duty assessment or real-time monitoring of workers. Training on sleep and health is part of a proactive process management for fatigue
- Reactive: following a fatigue 'event' where a worker has experienced elevated levels of fatigue or been involved in a fatigue-related incident. Reactive processes include investigation of incidents related to fatigue.

Sprajcer et al. (2023) [32] propose that fatigue risk management can be conceptualised as a spectrum from prescriptive, compliance-based systems to a comprehensive risk-based system, or fatigue risk management system (FRMS). Each system has strengths and weaknesses, shown in Table 1 (see Sprajcer et al. 2023 [32] for full details) in terms of their ease of use, data collected and level of commitment from the organisation.

TABLE 1 Strengths and weaknesses of prescriptive and risk-based fatigue management systems (adapted from Sprajcer, 2023)

Approach	Strengths	Weaknesses
Prescriptive	Able to demonstrate compliance easily Ease of implementation Ease of management	Inflexible Can conflate compliance with safety
Hybrid	More cost-effective than a risk-based approach Relatively simple to implement Can be easier to regulate than a risk-based approach Offers greater flexibility than a prescriptive approach	Organisations may continue to rely on more prescriptive approaches Limited risk assessment undertaken Increased burden of demonstrating compliance
Risk-based approach	Flexibility Tailoring of system to suit organisational context	High costs of implementation and management Complex Commitment from organisational leaders and managers

Adoption of risk-based approaches is highly dependent on the industry sector and the regulatory framework in which the industry operates. In general, FRMS are optional and not mandatory, and can be adapted to suit the needs of the organisation. A hybrid system may include prescriptive limits which can vary, based on appropriate risk assessments being undertaken to reduce potential impacts of increased fatigue.

Systems thinking and fatigue risk management

Traditional approaches to workplace fatigue have considered it an individual issue, one that can be solved by ensuring rosters and working hours are controlled and kept to reasonable levels with sufficient rest breaks within and between shifts. [20] Despite much progress in fatigue research, more attention is required to address factors arising from work design and organisational strategy and to incorporate these into FRMS. [21] Taking a systems approach to the conceptualisation and measurement of fatigue necessitates identifying the hazards for and fatigue levels of workers in their specific workplace context. Use of a systems framework is particularly important when the risk in question is influenced by a large and diverse range of potentially interacting hazards, [22] such as is the case with fatigue [23] (see Figure 1). Within both OHS and ergonomics professional contexts, the importance of 'systems thinking' is recognised as needed to support development of more effective OHS risk management practices, [24,25] which in turn are needed to support identification of all relevant hazards and the development of appropriate risk controls targeted at the level in the system at which the hazard arises. A challenge for developing strategies for fatigue risk management is the need for a nuanced approach which accommodates individual responses, inherent to the nature of fatigue, but also addresses the contributing factors higher up in the system which impact how work is done (e.g. design of work).

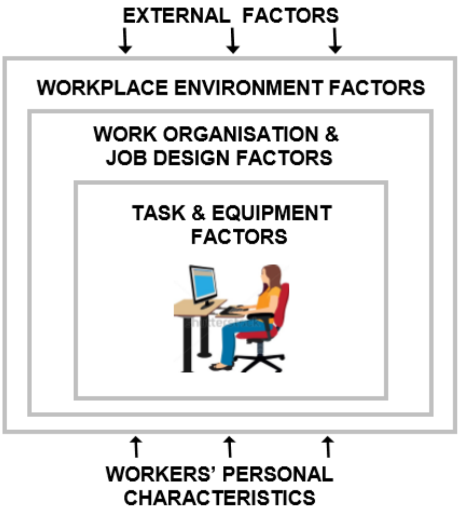

FIGURE 2 the system of workplace factors affecting workers' fatigue and health, safety and performance [18]

The ergonomics systems model shown in Figure 2 represents various levels external to and within a workplace at which factors may arise that impact fatigue risk. Some are beyond the control of workplace managers.

Definitions associated with each of the levels that workers interact with and are impacted by in relation to fatigue are:

- *External Factors*: OHS regulatory enforcement practices; injury compensation legislation and practices; state of the job market, pay levels and other economic factors; general societal norms concerning absenteeism and a 'fair day's work'; and of course, OHS legislation and associated codes, regulatory standards and related guidance information.

- *Work Organisation & Job Design Factors*: how work is organised and jobs are designed. These factors include very long working hours, pressure to complete excessively large amounts of work in the time available, inadequate rest breaks, night shifts, jobs with low control over work rate (e.g. due to a moving assembly line, frequent deadlines), little variety or interest, few opportunities to use existing skills or develop new ones, little opportunity to interact with others, inadequate support from supervisors or colleagues, low rewards (not only financial) in relation to personal effort invested, etc.

- *Task & Equipment Factors:* characteristics of specific work tasks and the tools or equipment used in performing these tasks. These include the physical hazards associated with 'manual handling' tasks, which are widely recognised as affecting fatigue. They also include some psychosocial hazards, such as bus drivers' stressful encounters with difficult passengers, or nurses' struggles to manage verbally abusive or distressed patients. In such cases it is often possible to mitigate risk by changes to task equipment, the immediate work space and/or design of the particular task.

- *Workplace Environment Factors*: both physical and psychosocial. Physical environment factors include lighting type and levels which are associated with fatigue risk. The psychosocial environment includes factors arising from the general workplace culture or climate, such as widespread perceptions that getting work done quickly is more important than workers' health and safety, low job security, and autocratic style of management with minimal participation by employees at lower levels.

- *Workers' Personal Characteristics*: the unique physical and psychological strengths and weaknesses that people bring with them to work, including vulnerabilities arising from fatigue or stress due to inadequate sleep, non-work personal responsibilities and problems, and pre-existing injuries or health problems.

Hierarchy of risk controls

In the conventional hierarchy, priority order is: *eliminate* the hazard; *reduce severity* of the hazard; and prevent or minimise *exposure* to the hazard by various means that are also prioritised. It was formulated during the 1950s by the US National Safety Council [26] with a clear focus on physical hazards of various kinds — chemical and biological substances, air quality and temperature, noise, radiation, electricity – and various physical characteristics of work equipment and workplace environments. Consistent with this physical focus, Olishifski [27] (p.439) specified the hierarchy as "substitution, alteration of the workplace, isolation or enclosure, wet methods to reduce dust exposure, local exhaust, general ventilation, personal protective devices, good housekeeping, medical controls, and training." More recent versions all place 'Elimination' at the top of the hierarchy, including the SWA version, shown in Figure 3.

Some challenges arise in using the hierarchy of risk controls for developing effective risk controls for hazards associated with fatigue. For example, elimination is considered the most effective control but with many of the factors that cause fatigue, such as those associated with shift work, these are intrinsic to the nature of the work being undertaken so are not practically reasonable. Optimisation is usually the most appropriate goal for many psychosocial hazards, which are highly relevant when managing symptoms of fatigue, but this type of guidance in relation to hierarchies of risk controls with a focus on optimisation is not currently available. See Figure 3 for the hierarchy of risk control framework used for the purpose of this report.

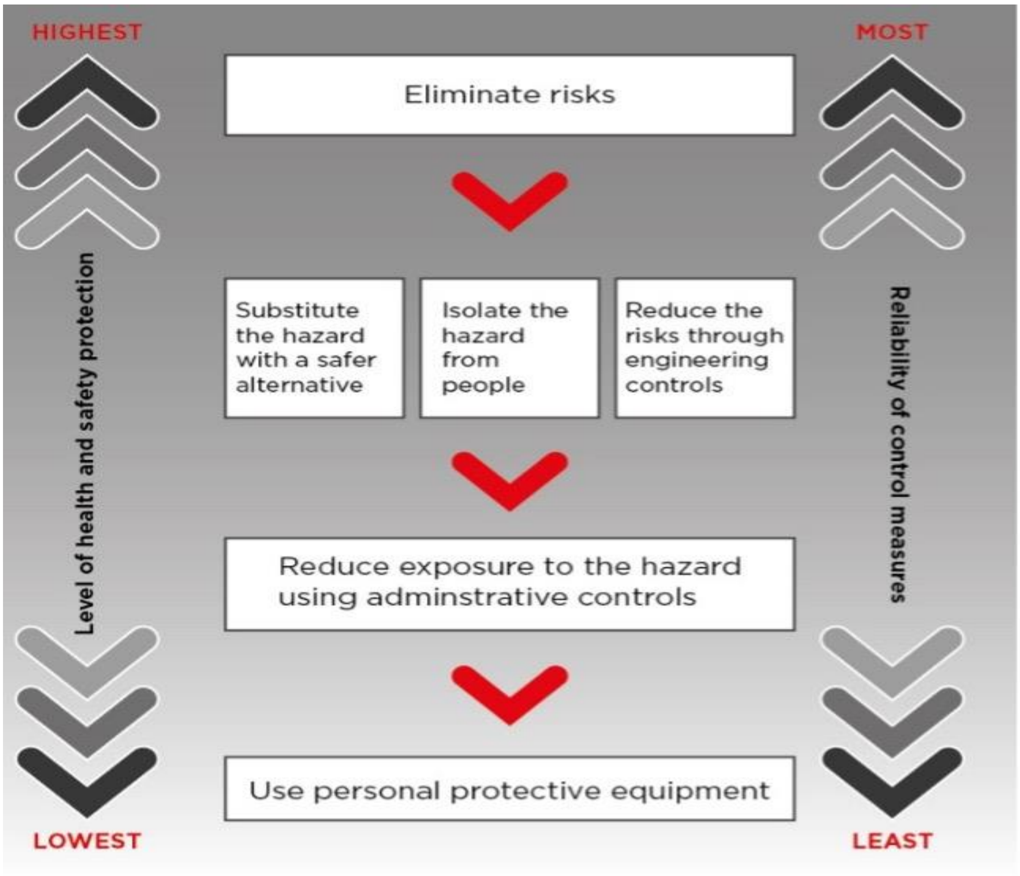

FIGURE 3 Hierarchy of risk control [1]

Thresholds for harm and risk from fatigue

Traditional management of fatigue has involved the regulation of working time arrangements, which includes maximum number of consecutive shifts, minimum number of hours between shifts and limits on total working hours. A growing body of evidence suggests this is of limited benefit, and that a systems-based approach is likely to be a more effective risk mitigation strategy. [5]

Fatigue is not an outcome but an intermediary state that predisposes an individual to other health and safety risks and to performance degradation. To define a threshold at which these risks arise is conceptually and practically challenging given the vast number of factors which influence how an individual will respond to hazards associated with fatigue. Fatigue risk could be considered a proxy for indicating an individual at risk, in the same way that musculoskeletal risk is measured by pain and discomfort scores. [29]

For workplace purposes, a more useful approach is to focus on identifying workplace hazards associated with increased fatigue risk. Often workplaces want to know, what is the ‘right’ amount of sleep that workers need before coming to work in order to reduce the likelihood of fatigue-related errors and incidents. The significant variation in individual factors that influence risk factors associated with fatigue – both temporary and longer-term health effects – make it challenging to develop prescriptive thresholds that are meaningful.

Fatigue increases with increased time on shift starting at approximately 2-4 hours[30] and a much larger increase after 9-10 hours. [31,32] Nearly double the likelihood of incident or accident has been found when increasing from a 10 hour compared to an 8 hour shift [31] increasing to threefold increase after 16 hours. [32]

Sleep loss has been compared to alcohol intoxication, with laboratory studies reporting that after 19 hours awake at 0800h an individual's performance was equivalent to that of an individual with a blood alcohol concentration (BAC%) of 0.05, the legal driving limit in Australia. After 24 hours awake, performance was at the level of a person with a BAC% = 0.10. [33] Being awake for more than 16 hours particular over a series of days is associated with a cumulative cost to sleepiness and performance. [4] In a recent review of 61 studies examining the impact of fatigue on driving, the authors reported that after either 6 or 7 hours of prior sleep, a modest level of impairment is generally seen compared with after ≥ 8 hours of prior sleep (ie, well rested), but the results depend on the test used. [34]

In relation to fatigue risk, the following parameters (based on Dawson's Prior Sleep–Wake Model [35]) indicate when a person is at higher risk of making errors due to fatigue:

- obtained less than 5 hours sleep in the previous 24 hours
- obtained less than 12 hours sleep in the previous 48 hours
- by shift end, had been awake for a period exceeding their total sleep time in the previous 48 hours.

Shifting from compliance-based systems to risk-based approaches offers a more sophisticated approach that takes into account a broader range of factors than the blunt parameters of the number of hours worked. However, this also creates some challenges for workplaces, as they may not have the full range of information needed for risk-based systems.

Biomathematical models (BMMs) are proposed to predict fatigue based on prior sleep–wake behaviour and the working time arrangements. [17] Supporters of BMMs hold that they are a more reliable and valid way of assessing risk, than perspective compliance approaches. BMMs are used to model the roster or schedule, to quantify the number of sleep hours afforded to the worker. The modelling then provides an output to determine the likelihood of a fatigue-related error. It involves a range of assumptions, which may not take into account sleep opportunity versus sleep taken, and the quality of the sleep.

A range of commercially and publicly available BMMs are available to assist workplaces in predicting fatigue, sleepiness, sleep opportunity and fatigue likelihood. Some examples:

- FAID [36]
- SAFTE [37]
- SAFE [38]
- Three process model of alertness. [16]

BMMs offer an improved capacity to predict the likelihood of fatigue, but it would be incorrect to assume this will automatically improve safety. More work is required to understand what constitutes safe work time arrangements, as these continue to be simplistic and consider upper limits rather than integrating a BMM and other metrics into a comprehensive system to identify and reduce fatigue-related risks. Research in this space appears to have plateaued. Deeper exploration of it is beyond the scope of the current report but this study highlights some of the gaps in currently available tools for fatigue risk management. [39]

Purpose of this review

This review of evidence relating to fatigue will address the following points. It will:

- define fatigue – how it causes harm and any thresholds for harm
- identify hazards at work that may give rise to fatigue, and hazards and risk arising from fatigue
- assess the risks associated with fatigue

- identify risk controls (physical and psychosocial), taking a systems-based approach which will include the hierarchy of risk controls
- identify evidence on review of control measures
- identify methods for monitoring the health of workers and the condition at the workplace for the purpose of preventing fatigue-related illness or injury of workers arising from the conduct of the business or undertaking
- identify tools for managing the risks of fatigue.

Methods

Peer reviewed literature

The project team worked in collaboration with SWA to clarify the scope and intention of this rapid evidence synthesis and refine the focus on the review.

Search strategy

This review aimed to locate published primary peer reviewed literature in the area of fatigue. Three databases were searched (CINAHL, MEDLINE, PsycINFO) for articles published between 2013 and April 2024. Articles prior to 2013 were excluded from the review as the most recent SWA guidance on fatigue was published in 2013 and the purpose of this review is to identify literature after that date. The search strategy was developed in consultation with a research librarian by identifying key search terms and synonyms. A preliminary search of one database was conducted by the research librarian to test the appropriateness of the search terms and identify availability of articles on the topic. A range of test articles were used to ensure the search was going to identify relevant articles. [40-43]

An initial search was conducted on 3 April 2024, and re-run after some modification and consultation with the research librarian. The final search was undertaken on 8 April 2024. See Appendix 1 for the final search terms.

Screening and selection criteria

Following the database searches, all citations were uploaded into EndNote 20 for initial compilation. Citations were then uploaded to Covidence where duplicates were removed. A random sample of 30 titles and abstracts was screened by the entire team against the eligibility criteria and overarching aim of the scoping review to test the appropriateness of the source materials. The team (JO, VW, SC, JL) met to discuss exceptions to the criteria and to provide clarification of eligibility criteria in relation to the research aim. Screening commenced once consensus was reached by the team, with each included citation then reviewed by two members of the research team. Conflicts were managed through a team meeting at which each article was discussed. Full texts were screened utilising the same process.

The following selection criteria were applied.

Population

This review focused on working adults who were over 18 years of age.

Concept

The concept of interest for the scoping review was (1) intervention to address workplace fatigue and (2) tools to assist with the risk management of fatigue.

Context

The context of the review was the workplace, including any size or sector.

Studies were excluded from data extraction if they:

- were qualitative
- were laboratory studies
- did not include outcome measures related to fatigue
- did not contain an intervention/risk management tool

- included athletes, military personnel and astronauts, as these were considered to be populations with specific fatigue risk management plans sufficiently different from those of most workplaces.

Types of studies

This rapid review considered quantitative study designs including observational, case and descriptive studies, and randomised control trials. Only studies published in English were considered for this review.

Data extraction

An extraction tool was developed, based on previously developed tools, to ensure sufficient data was collected to address the aims of the study (Appendix 2). Discussion was undertaken among the research team to ensure the extraction tool was relevant to the study. Once consensus was reached, the tool was trialled by all authors for ease of use and to confirm data extracted would meet the project requirements. Data was extracted from the included articles by one of the authors and checked by a second reviewer. Any disagreement between reviewers was resolved through discussion at regular team meetings. Data extracted included the following: author(s), year of publication, country of origin, study design, intervention type, intervention details, type of fatigue measured, number of participants, gender, age, fatigue tools used, systems level of the intervention, and intervention effectiveness.

The systems model coding was undertaken according to the levels outlined in the introduction (see Figure 2): external (interventions addressing factors external to the organisation), organisational (interventions addressing work organisation and job demand factors), physical work environment (interventions addressing physical work environment factors), task/equipment (interventions addressing task and/or equipment factors), and individual (interventions addressing individuals' skills and knowledge). Some articles reported interventions addressing multiple levels or multiple interventions.

Studies were then grouped by the type of intervention used in the study. Once the extraction table was completed, two authors (JO and VW) coded the level at which the intervention was targeted according to the hierarchy of risk controls. Each intervention was coded as either PPE, administrative, substitution or elimination according to the model shown in Figure 3. The substitution category also included interventions that achieved change through engineering means (e.g. altering overhead lighting).

Tools for managing fatigue

Studies that only described a tool were not extracted using this process, but were identified. Details were recorded of the name of the tool, its target level, whether it was a fatigue detection or risk management tool, its intended use, whether it was initially developed for clinical, general or occupational use, and whether it had been used as an intervention.

Data analysis and presentation

Extracted data was analysed using descriptive statistics for frequency of various study characteristics. We provide text description of the tables and figures to expand on the results in relation to the research questions.

Grey literature

Search capacity of the various government and other grey literature libraries was not as sophisticated as MEDLINE, PsycINFO and CINAHL. Therefore, we limited the search terms to single combinations: fatigue AND work AND safety. From the relevant literature that referred to fatigue and workplace safety, the research team selected eight of the most relevant pieces of grey literature, which were included in the qualitative synthesis. The eight pieces of grey literature were guidance documents providing information on how to assess and address workplace fatigue.

Results

Database searches yielded a total of 6016 relevant citations, of which 286 were identified for possible inclusion. After screening by the research team, 111 were included for data extraction. Of the 111 included citations, 70 were intervention studies and the further 41 were citations outlining fatigue assessment tools only, and as such they formed the evidence base on which this report is written. See Appendix 3 for the PRISMA diagram. In line with scoping review guidelines, quality of data and levels of evidence were not assessed. A table of evidence extracted is shown in Appendix 4.

The results are presented in two sections. Section 1 relates to the interventions identified in the search, also considered as risk controls for the purpose of this report. Section 2 relates to the tools identified for monitoring workers' fatigue levels and the workplace conditions associated with increased risk of fatigue.

Section 1

Interventions for reducing fatigue

Included studies were from studies conducted in 24 countries. Most were conducted in the USA (n=13) or Iran (n=9), with only one study conducted in Australia. See Table 2 for further breakdown of study locations.

TABLE 2 Study locations for included citations

Country	No of studies
USA	13
Iran	9
Canada	7
Japan	5
Denmark	3
Italy	3
Republic of Korea	3
Sweden	3
Austria	2
China	2
Finland	2
France	2
India	2
Netherlands	2
Taiwan	2
Israel	2
Australia	1
Brazil	1
Indonesia	1
Norway	1
Norway & Austria	1
Spain	1
Turkey	1
UK	1
Total	**70**

Industries covered in the studies included healthcare (n=38), aviation (n=7) and public services (n=5) as the three most frequently referred to. See Table 3 for a further breakdown of which industries were included in the studies.

TABLE 3 Industry sector where the study took place

Industry	No of studies
Healthcare	38
Aviation	7
Public service	5
Manufacturing	4
Transport	5
Various	3
Finance	2
Petrochemical	2
Construction	1
Diamond	1
Maritime	1
University	1
Total	**70**

In relation to the type of fatigue measured, the most common was 'general fatigue' (n=62), with compassion and visual fatigue the next most common (n=3 and n=2 respectively). See Table 4.

TABLE 4 Types of fatigue measured

Type of fatigue measured	No of studies
General fatigue	62
Compassion fatigue	3
Visual fatigue	2
Exhaustion (not emotional)	1
General fatigue; Visual fatigue	1
Mental fatigue; Visual fatigue; Physical fatigue	1
Total	**70**

The most frequently used study design was randomised control trial (RCT) (n=19), followed by pre/post-test design (n=18). See Table 5 for a further breakdown of study designs for included studies. Details of study design by type of intervention are shown in Appendix 5.

TABLE 5 Study design

Study design	No of studies
RCT	19
Pre/post test	18
Quasi experimental	13
Cross over	7
Case control	5
RCT cross over	2
Prospective	2
Retrospective	1
Parallel-group randomised	1
Non-randomised	1
Hybrid effectiveness-implementation	1

Total	70

In terms of intervention types, the data highlighted a range of interventions ranging from lighting (n=13) as the most frequent intervention type, to temperature (n=1) as one of the least frequent intervention types. See Table 6 for a full breakdown of intervention types and associated citations.

TABLE 6 Study interventions of included citations

Intervention type	No of studies	References
Lighting	13	44-56
Shift rostering	12	57-68
Education	7	69-75
Napping	6	76-81
Relaxation/meditation	5	82-86
Workload	4	87-90
Mindfulness	3	91-93
Work time flexibility	3	62,94,95
Aromatherapy	2	96,97
Exercise	2	98,99
Rest breaks	2	100,101
Shift rostering; Education	2	102,103
Participatory process	2	104,105
Education; Exercise	1	106
Equipment	1	107
Food/nutrition	1	108
Lighting; Exercise equipment	1	109
Napping; Education	1	110
Participatory process; Equipment	1	111
Temperature	1	112
Total	**70**	

Summary of intervention descriptions, study designs and reported efficacy

Appendix 5 presents a summary of the studies by their design and reported intervention efficacy. We did not undertake a quality assessment, in line with rapid reviews. Appendix 5 shows which of the study designs demonstrated effectiveness. We expand on the information included in this appendix in the text below, grouped by intervention type. Overall, 43 of the 70 studies demonstrated effectiveness in the interventions used. The range of study types and interventions varied, making it difficult to draw robust conclusions as to the effectiveness of different types of interventions. Randomised controlled trials are generally considered the most robust design. There were 19 of these, of which 12 were effective. On balance, lighting interventions appeared to be effective, with 10 of the 13 interventions reporting effectiveness at reducing general fatigue.

We have provided detailed information on the 15 of the studies with the most robust design, RCT/hybrid effectiveness trials, cross over design with randomisation. Caution on the interpretation of single studies is always required but to facilitate interpretation of the results in the absence of quality assessments and meta-analyses, taking into account the inclusion of a wide range of study designs, this approach provides some information about the studies that have more stringent quality controls incorporated in their design. Note for some categories of interventions there were no RCTs included: mindfulness, rest breaks, exercise, temperature, office equipment, shift rostering, worktime flexibility, we provide detail on some of these areas to indicate what was found to be effective.

Lighting

Thirteen studies reported the use of lighting by itself as an intervention to reduce fatigue. [44-56] Three of these studies were RCTs, [45,50,52] one of which aimed to address general fatigue and required participants to stay up, wear an eye mask and sleep in, or wear dark glasses and be exposed to light, depending on the shift. [45] This intervention was reported as effective. Another RCT, designed to address visual fatigue, provided participants with an LED task light. [50] This intervention was also reported to be effective. The third RCT addressed both general and visual fatigue through provision of blue light filter software on computers. It was reported to be effective in reducing visual fatigue, but not general fatigue. [52] One study used an RCT cross over design to address general fatigue by providing high illuminance light above workstations. [47] The intervention was reported to be effective.

Three studies used a cross over design to address general fatigue. [46,53,56] All three involved changing lighting illumination or lighting wavelength, one by providing participants with glasses. [46] One intervention was reported as effective,[113] one was effective only in the short-term [46] and one was reported as ineffective. [53]

Two studies used a pre/post test design to address general fatigue. [54,55] One study involved changing light sources to different colour temperatures, and was reported as effective in reducing fatigue. [54] The other study utilised an intervention tailored to participants' work schedules that involved wearing a sleep mask, exposure to bright lights, light avoidance, and suggestions regarding sleep time based on shift, and was reported to be effective. [55]

Two quasi experimental studies addressed general fatigue. [44,51] One intervention comprised exposure to bright or dim red light. [44] The other intervention was installation of software to alter the light spectrum of screens. [51] Both were reported to be ineffective.

One study used a hybrid effectiveness-implementation approach to address general fatigue. The intervention comprised changed lighting, use of an eye mask and blue light blocking glasses, and was reported to be effective. [48]

One study used a non-randomised open label trial in which the intervention was dark or bright room lighting on the desk to address general fatigue. The intervention was reported as effective. [49]

One study combined lighting with the provision of exercise equipment to address general fatigue. [109] In this RCT study, workers were provided access to a breakout room with passive exposure to blue-enriched fluorescent lamps and exercise equipment they were encouraged to use. This intervention was reported as effective.

Summary of effective interventions with RCT designs (5 studies)

General fatigue

- Evening light exposure and avoidance of morning light effective at reducing fatigue[45]
- Increased illuminance over workstations for night shift workers reduced fatigue [47]
- Lighting provided in the nurses station and optional behavioural components including a lightbox, blue-blocker glasses and eye masks were associated with reduced fatigue [48]

Visual fatigue

- LED Task lighting effective at reducing visual fatigue [50]
- Blue light filter software effective at reducing visual fatigue [52]

Education

Seven studies used education as an intervention [69-72,74,75,114] and all were designed to address general fatigue. Four studies were RCTs, two of which involved sending workers text messages with strategies to reduce fatigue. [72,115] One of these studies was reported to be effective. [72] Workers in another RCT study participated in education modules that included fatigue mitigation topics, but this was not reported to be effective. [74] In another RCT study, airline pilots were provided with access to a mobile app that provided advice about switching time zones, sleep and daylight exposure, nutrition and physical activity. This intervention was reported to be effective. [75]

One study used a prospective study design [70] and two a pre/post test design. [69,71] Two of these studies provided sleep coaching, [69,70] with one study [70] reporting the intervention to be effective. One study provided an online training course on sleep and fatigue management strategies and reported the intervention as effective. [71]

An additional four interventions were multifaceted, combining education and shift rostering, [102,103] education and napping [110] and education and exercise [106] to address general fatigue. One of the interventions comprising education and shift rostering used a cross over study design [102] while the other used a pre/post test design. [103] Both reported the interventions to be effective. The study incorporating education and napping was a quasi experiment and reported the intervention as ineffective. [110] A quasi experimental design was also used for the education and exercise intervention, and this intervention was reported to be effective. [106]

Summary of effective interventions with RCT designs (2 studies)

- Online education models addressing fatigue mitigation strategies was associated with reduced fatigue levels [115]
- Use of a mobile app with tailored advice and associated website with information was found to be effective in reducing fatigue levels[75]

Napping

Six studies used napping as an intervention to address general fatigue. [76-81] Interventions included introduction of at least one nap, sometimes of a prescribed duration and at a prescribed time. Two studies were RCTs, [76,77] one of which reported the intervention (nap of 15 or 45 minutes compared to no nap) to be effective. [77] The other four studies used a range of study designs and three reported the interventions were effective. [78,80,81]

One multifaceted intervention aimed to address general fatigue. A quasi experimental study combining napping and education reported the intervention to be ineffective. [110]

Summary of effective interventions with RCT designs (1 study)

- A 15 minute nap at 3pm effective in reducing fatigue, following night shift work [77]

Relaxation/meditation

Five studies used relaxation or meditation techniques as an intervention to reduce general fatigue. [82-86] Of the two RCTs, both of which were reported to be effective, one intervention involved using virtual reality and relaxation techniques [83] and the other a relaxation program. [86] In two studies the intervention comprised a yoga program [82,85] and this was reported to be effective. One study intervention was a meditation program that was reported as ineffective. [84]

Summary of RCT interventions reported to be effective (2 studies)

- 8 minute VR session providing s choice of different natural environments was effective in reducing fatigue levels[83]
- A 20 minute session of muscular relaxation combined with music for 8 weeks in a group was associated with reduced fatigue levels [86]

Mindfulness

Three studies utilised mindfulness interventions. Two were pre/post-test designs that aimed to reduce compassion fatigue, [91,93] one of which was reported to be effective. [91] The other was a quasi-experiment that aimed to reduce general fatigue and was reported to be effective. [92]

Rest breaks

Two studies, one a parallel-group randomised trial [101] and one a pre/post-test study, [100] investigated the use of rest breaks to reduce general fatigue. One compared rest breaks of 2 or 6–8 hours for seafarers before undertaking additional tasks [100] and reported the longer rest breaks significantly reduced sleepiness, to note is that the sleepiness accumulates across consecutive shifts which needs to be taken into account. The other compared long rest breaks (2 x 15 minutes) with short rest breaks (1–2 minutes per hour) and reported no significant difference in fatigue levels. [101] No RCT designs were undertaken with rest breaks

Exercise

Two studies examined the use of exercise as an intervention to address fatigue. One was an RCT that aimed to reduce general fatigue through a progressive resistance exercise program. This intervention was reported to be ineffective. [99] The other study used a pre/post-test design with the intervention comprising mento-physical exercise (involving stretching, relaxation and breathing exercises) and was reported to be effective in reducing visual, mental and physical fatigue. [98]

An additional intervention was multifaceted, combining exercise and education to address general fatigue. This quasi experiment was reported to be effective. [106]

Aromatherapy

Two RCTs involved inhalation of essential oils to address general fatigue [96] and compassion fatigue. [97] One intervention was reported to be effective. [96]

Summary of RCT interventions reported to be effective (1 study)

- During night shift one drop of rosemary essential oil was poured on gauze and put inside a simple fabric mask (surgical mask), used for 5–10 min during work and found to be effective in reducing fatigue levels [96]

Temperature

One cross over study varied temperature (23-26 degrees) as an intervention to reduce general fatigue, the intervention was not effective at reducing fatigue but the authors state there is some indication that the cooler temperature may be of benefit in reducing fatigue. [112]

Provision of office equipment

One quasi experimental study involved the provision of office equipment (e.g. foot rests, monitor stand). The study reported no significant change in visual fatigue. [107]

A multifaceted intervention used a pre/post-test design with provision of equipment as a part of an ergonomics intervention program (primarily designed to address manual handling hazards). This intervention was reported as effective in reducing general fatigue. [111]

Food/nutrition

One randomised cross over study involved provision of pre-packed meals to improve general fatigue and reported that the intervention reduced fatigue levels for shift workers. [108]

Summary of RCT interventions reported to be effective (1 study)

- Provision of healthy meals during shift work was associated with reduced fatigue levels [108]

Lighting/exercise equipment

One RCT used a multifaceted intervention comprising a breakroom with blue-enriched lamps and exercise equipment that staff were encouraged to use. [109] The intervention was reported to be effective.

Summary of RCT interventions reported to be effective (1 study)

- Passive exposure to blue-enriched polychromatic lighting for three 20-minute intervals, which included 10 minutes of exercise and occurred before and twice during their shifts was associated with reduced general fatigue [109]

Interventions targeting job design

Participatory process to support redesign

Two RCT studies used a participatory process. [104,105] One of these addressed exhaustion but reported the intervention was not effective. [104] The other aimed to address general fatigue and reported the intervention as effective. [105]

One study, with a multifaceted intervention, used a pre/post-test design with an ergonomics intervention program (primarily designed to address manual handling hazards) that incorporated provision of equipment. This intervention was reported as effective in reducing general fatigue. [111]

Summary of RCT interventions reported to be effective (1 study)

- Using a participatory ergonomics process to redesign physical workload tasks was effective at reducing general fatigue [105]

Shift rostering

The 12 studies that used shift rostering as an intervention to address general fatigue [57-68] incorporated one or more of the following:

- variation in shift length [57,59,63,65-68]
- variation in number of nights worked consecutively [59-61]
- variation in time off before return to work. [58,60-62,68]

Four studies were quasi experimental, [58,61,64,116] three used a pre/post design, [60,65,67] three were case control studies, [57,66,68] one was an RCT [63] and one used a cross over design. [62] Five of the 12 studies reported the interventions to be effective, with one noting that is challenging to isolate the distinct characteristics of different rosters and their relative effects, and that individual differences in adaptation to shift work may also affect outcomes. [66]

From the five studies that reported effectiveness, Cheng[58] found that nurses working 2 nights then 24 hours off reported higher levels of fatigue than the off-duty group. The authors reported that a single day off after night shift was insufficient to adapt back to a day-time shift.

Costa[59] examined two "3 x 8hour" shift rotas with backward rotation and quick return (morning and night shift in the same day) in a 5 or 6-day shift cycle, and a "2 x 12 hour" shift rota with forward rotation in a 5 day shift cycle. The counter-clockwise shift rotation and quick return of "3 x 8 hour" schedules reduce possibility of sleep and recovery. The insertion of a morning shift before the day with quick return increases night sleep by about one hour. Nurses who take a nap during the night shift require 40% less sleep in the morning after. Sleepiness increased more during the night than day shifts in all rosters, but without significant difference between 8-hour and 12-hour rosters. However, the significantly higher level of fatigue at the start of the night shift in the "3 x 8 hour" rosters suggests that the fast backward rotation with a quick return means that workers are not as effective as they could be with a different shift pattern.

Kubo[62] found after a month long intervention study which examined extended restart breaks from 31 h to 55 h after consecutive night shifts that fatigue levels (measured as vital exhaustion) were significantly reduced.

Shochat[66] examined a change from 8 to 12 hour rosters, but the results are challenging to interpret, although some reduction in fatigue was noted after the change to 12 hours, this needs to be interpreted carefully as there were other workplace changes which are not clearly documented.

Zakariassen[68] reported on strategies to combat sleepiness in pilots, napping was an important strategy to prevent sleepiness, no details on the duration or timing of naps was provided.

An additional two interventions were multifaceted, combining shift rostering with education. [102,103] One of the interventions comprising shift roster and education used a cross over study design [102] in which the groups were randomised to a morning (0900-1700) or evening (1500-2300) sleep schedule. The evening schedule was found to associated with reduced fatigue compared to the morning. The other used a pre/post design [103] and examined the implementation of Work Health Promotion guidelines, and found that a fast forward rotating shift was more protective that other scheduling (slow or intermediate rotating shifts or back-rotating) and rest periods of > 11 hours between shifts and a rest day after a night shift was protective against fatigue. The authors suggest that 30 days notice of shift allocations was advisable.

No RCT designs were used to examine shift rostering.

Workload

Workload was modified as an intervention in four studies and effects on general fatigue were assessed. [87-90] One RCT reduced working hours by 25% while preserving salary for 18 months and reported the intervention to be effective. [89] A study using a pre/post design reduced workload by implementing an additional staff member during night shift but the intervention was reported as ineffective. [88] Another study using a retrospective design altered shift rosters to increase staff numbers but reported the intervention was not effective. [87] One study using a pre/post test design reduced staff numbers and reported that fatigue worsened. [90]

Summary of RCT interventions reported to be effective (1 study)

- Reduction of work time by 25% was associated with reduced fatigue levels[89]

Work time flexibility

Three studies included interventions on work time flexibility to address general fatigue. [94,95,117] Two were pre/post-test studies, one involving the use of participatory working time scheduling software [94] and the other was a comparison of work time control levels. [117] The other study was a quasi experiment utilising "new ways of working" involving temporal and spatial flexibility. [95] All interventions were reported to be effective.

Karhula[94] examined the use of participatory working time scheduling software and found that in comparison to traditional scheduling, the perceived control over scheduling of shifts excessive sleepiness in connection with evening shifts decreased.

Nijp[95] found that with the new ways of working (NWW) implementation there was a large and significant shift from hours worked at the office to hours worked at home after implementation of NWW with significant reductions in fatigue.

Kubo[117] investigate the impact of increase work time control and reported reduced fatigue levels.

None of the studies utilised RCT designs.

Risk controls taking a systems-based approach and the hierarchy of risk controls

Coding of the level at which the intervention was targeted, identified that most were at the organisational level (n=28) level, followed by individual level (n=20), then physical work environment level (n=6) and task/equipment level (n=6), with seven interventions targeting multiple systems levels. Table 7 shows the breakdown for each of the levels.

Interventions that were organisationally focused included, for example, adjustments to shift rostering sequencing. Where the intervention was individually targeted, interventions included education programs for employees on improving sleep hygiene. Where interventions were targeted at the physical work environment, interventions included, for example, adjustments to ambient lighting.

TABLE 7 Level of intervention targeted

Systems level of intervention	No of studies
Organisational	29
Individual	20
Physical work environment	6
Task/equipment	6
Multiple level interventions	
Individual; Organisational	3
Individual; Physical work environment	1
Individual; Task/equipment	2
Individual; Task/equipment; Physical work environment	1
Task/equipment; Physical work environment	1
Not clear	1
Total	**70**

Table 8 shows interventions coded in relation to the hierarchy of risk controls. Most were at the substitution level (n=40), followed by administration (n=21). Substitution involved shift rostering, lighting and napping. Administration involved education, mindfulness and exercise programs as examples. The table of evidence (Appendix 4) shows the full details of the studies and the interventions (risk controls).

TABLE 8 Hierarchy of risk controls

Hierarchy of risk control	No of studies
Substitution	40
Administration	21
Administration; Substitution	5
Administration; PPE	2
Substitution; PPE	1
Not clear	1
Total	**70**

Grey literature

Evidence gathered from the grey literature documents as it related to fatigue and workplace health and safety was identified from eight websites. Four state OHS/WHS regulators referred directly to the SWA 2013 fatigue guidance materials (ACT, NSW, TAS, WA). Appendix 6 shows a summary of the identified documents.

The included grey literature provided guidance on management of workplace fatigue, with consistency in definition of fatigue and possible risk factors for it. Documents that were industry-specific (railways and maritime industries), guidance documents provided by regulators tended to include a checklist for risk factors to aid in assessment and management of fatigue. There was substantial overlap in the documents with the SWA 2013 guidelines on managing the risk of fatigue in the workplace.

Grey literature was accessed from the following sites.

- Australian Maritime and Safety Authority
- NSW Health
- NT WorkSafe
- Office of the National Rail Safety Regulator
- SafeWork NSW
- SafeWork SA
- Workplace Health and Safety Queensland
- WorkSafe Victoria

Review and maintenance of risk controls

The studies reviewed for this reported have utilised a range of interventions aimed at reducing the risk of fatigue in various work populations, as highlighted in the above sections. For the purpose of this report, these interventions can be considered risk controls; that is, they are aimed at reducing fatigue levels in their respective occupational groups. However, in none of the evidence reviewed did we identify a review and revision process. While review and revision of risk controls is part of a risk management approach and is needed to meet legislative requirements, it is unlikely to be described in academic publications. This was consistent with our findings in this review.

Section 2

Tools for managing and monitoring the risks of fatigue

The tools identified in the review presented here are focused on monitoring of workers' fatigue levels. The more comprehensive tools identify fatigue levels and the associated risk, through the identification of hazardous workplace conditions. The tools identified do not specifically monitor workers' health which, in the context of fatigue, is challenging. The focus of fatigue risk management tools is the identification then control of the hazardous workplace conditions.

In total, 63 tools were identified as measuring fatigue. They are included in Appendix 7. Six tools (see Table 9) were classified as fatigue risk management tools, as they were designed for use by organisations to both assess worker fatigue then manage risks arising from it. As shown in Table 9, three of the fatigue risk management tools identified were proprietary tools, one was a tool in development, and two were guidelines that were applied to improve fatigue risk management.

TABLE 9 Fatigue risk management tools

Tool	url	Tool status
Fatigue Audit InterDyne (FAID) software	https://www.interdynamics.com/fatigue-risk-management-solutions/fatigue-risk-management-products/faid-quantum-software/	Proprietary tool
Fatigue Avoidance Scheduling Tool (FAST) software	https://fatiguescience.com/fast-scheduling/	Proprietary tool
Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model (used with FAST)	https://www.saftefast.com/overview	Proprietary tool
Risk assessment guide from the Australian Medical Association's National Code of Practice – Hours of work, shift work and rostering for hospital doctors	2016 version available from https://www.ama.com.au/search?q=shiftwork+and+rostering	Guidelines
Evidence-based guideline for fatigue risk management in emergency medical services	Patterson et al. (2018). Evidence-based guidelines for fatigue risk management in emergency medical services. https://doi.org/10.1080/10903127.2017.1376137	Guidelines
Fatigue Risk Management Systems Diagnostic Tool a	Maisey et al. (2022). Fatigue Risk Management Systems Diagnostic Tool: Validation of an organizational assessment tool for shift work organizations. https://doi.org/10.1016/j.shaw.2022.08.002	Tool in development

The other tools were mostly questionnaires designed to assess individuals' subjective assessment of fatigue (e.g. Swedish Occupational Fatigue Inventory, Occupational Fatigue Exhaustion Recovery Scale [see Rostami et al. [111]]); that is, their own fatigue levels. There was limited evidence of objective measures of fatigue (e.g. the Psychomotor Vigilance Task, physiological measures obtained via smartwatches or other technology [see Anund et al., [57] Ftouni et al. [118]]). Twenty-seven tools were identified that had been developed to specifically measure occupational fatigue, four of which were tools or apps that had been recently developed and needed further testing and potentially refinement (see McCrary et al., Nosker et al, Dorrian et al., Klyve et al. [119-122]). Fourteen of these tools had been used in intervention studies to assess fatigue.

Sixteen tools used to measure fatigue in an occupational setting were designed to measure a variety of symptoms associated with fatigue in a range of settings. Examples of such tools include those designed to measure sleepiness, drowsiness or objective measures of fatigue such as changes in gait (see Anund et al. [57] for examples). Thirteen of these tools had been used in intervention studies.

Eleven tools used to measure fatigue in the included studies were originally developed for use or validated with clinical populations. Six of these tools had been used to measure fatigue in intervention studies.

Three tools were identified that were developed to measure a construct other than fatigue (see Crestelo Moreno et al. [123]), none of which were tested for effectiveness in an intervention study. Borg's Rating of Perceived Exertion and the NASA Task Load Index, although developed for occupational use, are usually used to assess workload. The self-assessment manikin is a tool that measures aspects of emotional responses.

Discussion

This review identified interventions targeted at reducing fatigue levels and potential tools for use in industry. Seventy studies were identified which used interventions aimed at reducing fatigue levels, as outlined in Appendix 4. For the purpose of this review, these interventions were considered as potential risk controls. Second, we identified 63 tools for the reduction of fatigue, from analysis of 41 articles.

Intervention studies

In summary, healthcare was the most common sector in which the interventions were undertaken (n=38), with aviation the next most common (n=7). Study designs were mixed (see Appendix 5). Nineteen of the studies were RCTs, with 18 pre/post studies the next most common design. Interventions included 15 different types of single faceted interventions and 5 multifaced interventions.

Interventions were then considered using a systems model to identify the level at which the intervention was targeted. Twenty-nine of the interventions were targeted at the organisational level, 20 at individuals, six at the physical environment and six at task/equipment level. Only a limited number of studies (n=6) used multilevel interventions.

The hierarchy of risk controls was also used to identify the level at which the intervention was targeted. Most of the interventions were considered as substitution as they involved changes to lighting, or shift design. Some challenges arose in coding; for example, napping could be considered an administrative control but because it was mandated and included in the shift design it was considered at the substitution level. The hierarchy of risk controls is challenging to use where the need is for optimisation versus elimination of hazards, and so results should be interpreted with caution.

Type of intervention and effectiveness

Lighting was the most commonly reported intervention and it demonstrated a reduction in fatigue in 10 of the 13 studies. Shift rostering was identified in 12 studies, with five reporting effectiveness, education was used in seven studies with four reporting effectiveness, napping in six studies with four effective and relaxation in five studies with four found to be effective. Appendix 5 provides a comprehensive summary of the intervention type and effectiveness by study design.

Given the comprehensive nature of hazards relating to fatigue risk, the number of interventions which could be considered multifactorial was very limited. Further, in relation to interventions which addressed hazards relating to the psychosocial work environment, four studies addressed workload, with only one reporting effectiveness, and three studies focused on work time flexibility, all of which were found to be effective. An extensive range of psychosocial hazards has been identified as associated with increased fatigue risk, but very few interventions to reflect this range of hazards were identified.

Results on the effectiveness of interventions should be interpreted with caution, given the wide range in study design and measures.

Tools for managing the risks of fatigue

While a large number of tools were identified in the review process, many were not appropriate for workplace use by WHS/OHS practitioners. In taking a comprehensive approach to risk management only six tools were identified. Three were proprietary tools that required payment for use and one was a tool still in development (see Appendix 7 for the full list of tools).

Most of the other tools were research tools and did not offer organisations sufficient information or guidance to support identification then development of risk controls to reduce fatigue risk in their respective workplaces.

Future opportunities

Based on the findings from this review, a number of gaps were identified in the range and target level of interventions used to reduce fatigue risk and in the tools available for use by workplaces to reduce fatigue risk.

We have outlined these gaps or opportunities below.

Regulatory/guidance

- Development of practitioner tools, available for use by organisations to assist with identification of hazards and development of effective risk controls for fatigue risk management to address the gap in freely available tools.
- Promote systems approaches to managing fatigue that take into account the multifactorial nature of fatigue and the range of hazards that impact workers, arising from different levels within the workplace.

Organisational

- Improved integration of fatigue risk management into other OHS/WHS programs. Fatigue risk management should be part of ongoing risk management approaches with regular hazard identification, risk assessment and development of controls.
- Ensure there is a focus on the health and performance aspects of fatigue. There can be a tendency to focus on the high-risk safety events that arise from fatigue. While these are important, the long-term health impacts of fatigue should be considered. In addition, the impacts on productivity caused by fatigue should be considered in risk management planning.

Research

- Develop a research framework to evaluate new fatigue detection technologies and enable findings to be shared.
- Greater focus on the health and performance aspects of fatigue. Research has focused more comprehensively on the area of safety than on health and productivity in the area of fatigue.
- Further expansion of research in populations beyond the healthcare sector is required, as evidenced in this review which found the majority of research has been undertaken in this one field.
- A focus beyond shift work is needed, to include workers who are exposed to high job demands, long hours or working multiple jobs, to examine the impact of these on fatigue levels and to inform the development of appropriate controls.
- Research to identify the effects of work-related fatigue levels on domestic and community activities that are important in maintaining social capital should be conducted, to provide an adequate basis on which our society can develop appropriate policies concerning the balance between work and other activities.

OHS/WHS practitioners

- OHS/WHS practitioners need to have adequate knowledge about the implications of fatigue, which supports them in adopting a systems approach to the identification and development of risk controls.

- Practitioners must ensure risk management programs are multifaceted and take into account hazards at all levels within the workplace, avoiding a sole focus on individual risk controls.

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Appendix 1 – Search terms

Concept 1	*Concept 2*	*Concept 3*
• Muscle fatigue (MeSH) • Fatigue (MeSH) • Mental fatigue (MeSH) • Fatigue* • Tiredness • Weariness OR sleepiness • Exhausted OR exhaustion	• Worker* • Employe* • “shift work*” OR shiftwork* • “night shift*” OR • Workplace (MeSH) • Workplace* OR “work place*” • Staff • Occupational health (MeSH) • OHS OR WHS • ((occupational OR work*) ADJ3 (health OR safety OR accident* OR injur* OR illness* OR related))	• Risk assessment (MeSH) • Risk reduction behavior (MeSH) • Risk management (MeSH) • ((risk* OR harm* OR hazard*) ADJ3 (manag* OR reduc* OR assess* OR factor* OR control* OR analys* OR eliminat* OR monitor* OR prevent* OR relat* OR review*)) • Harm reduction (MeSH) • Tools • “organi#ational factors” • Roster* • Schedul* • “organi#tional intervention*” • “fatigue management”

Note: MeSH terms cover a category of concepts and include alternative spellings

Appendix 2 – Data extraction tool

Study details

Author details

Article title

Year of publication

Country of study

Study design

Intervention type

Intervention details (e.g. change shift, education)

Type of fatigue measured

Participant breakdown

Industry

Occupation

Total number included in analysis

Gender breakdown (baseline)

Mean age/SD (baseline)

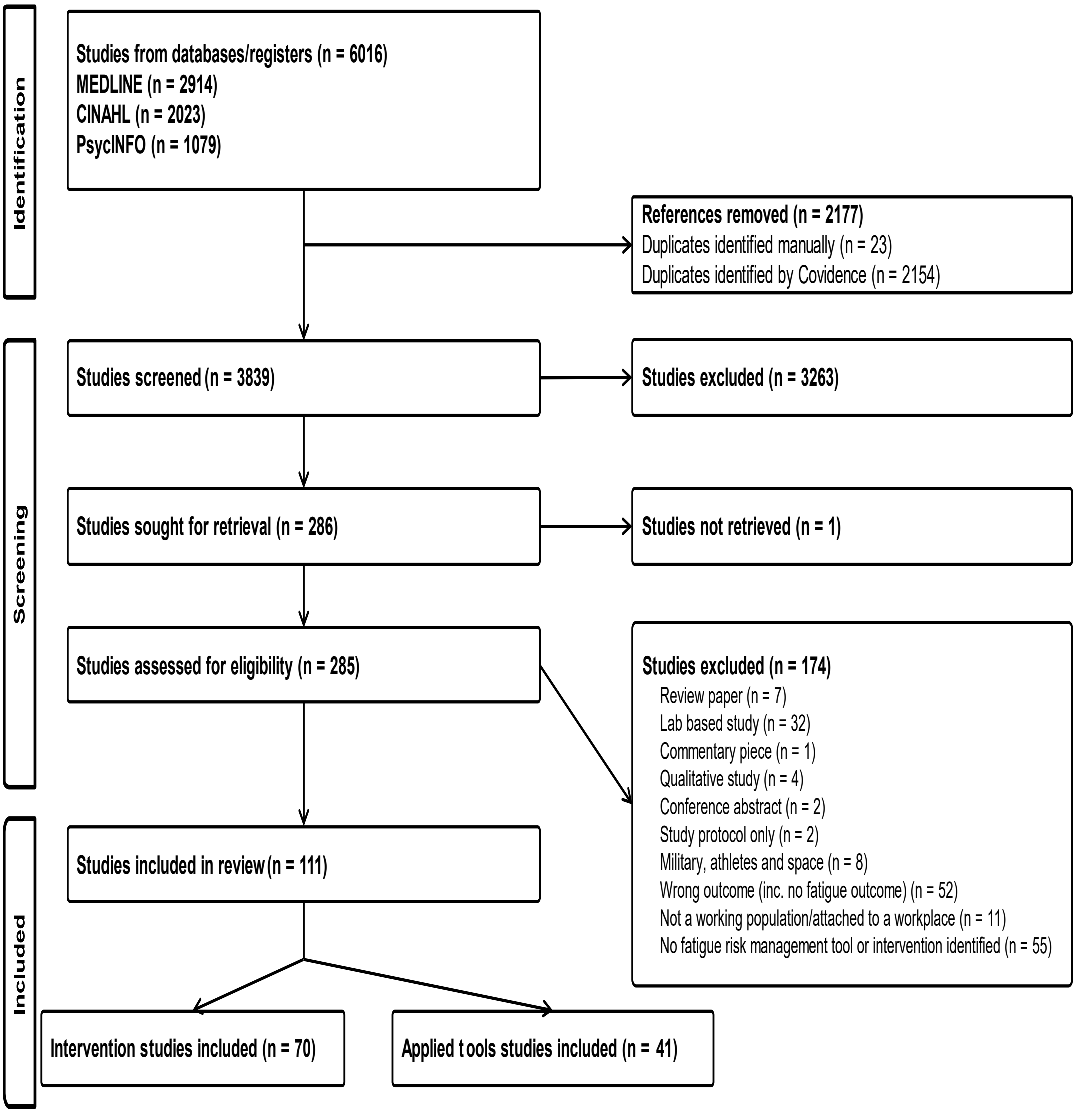
Name of tool/measure used

Level system intervention targeted

Did the intervention work or not? Y/N notes

Notes

Appendix 3 – PRISMA diagram



Appendix 4 – Table of evidence: Peer reviewed literature

Author Year/Country of study	Study design	Intervention type	Type of fatigue measured	Occupation	Number of participants	Fatigue tools used	Systems level of intervention	Hierarchy of risk control	Intervention effective
Lighting									
Bjorvatn 2021 [44] Norway	Quasi experimental	Lighting	General fatigue	Registered nurses	35	KSS; Accumulated Time with Sleepiness Scale	Task/ equipment	Substitution	No
Cyr 2023 [45] Canada	RCT	Lighting	General fatigue	Nurses	57	KSS	Individual; Task/equipment; Physical work environment	Administration ; PPE	Yes
Figueiro 2020 [46] USA	Cross over	Lighting	General fatigue	Hospital Shift workers (various)	70	KSS	Task/equipment	Substitution	Mixed
Griepentrog 2018 [47] USA	RCT cross over	Lighting	General fatigue	Nurses	43	SSS	Physical work environment	Substitution	Yes
Harrison 2020 [48]	Hybrid effectiveness-implementation approach	Lighting	General fatigue	Nurses & corpsmen	19	KSS	Task/equipment; Physical work environment	Substitution; PPE	Yes
Hoshi 2022 [49] Japan	Non-randomised open label trial	Lighting	General fatigue	Nurses	17 dark condition; 10 light condition	Subjective symptoms	Physical work environment	Substitution	Yes
Joines 2015 [50] USA	RCT	Lighting	Visual fatigue	Office workers	95	Eye fatigue questions	Task/ equipment	Substitution	Yes
Kazemi 2019 [51] Iran	Quasi experimental	Lighting	General fatigue	Emergency control centre workers	30	SSS	Task/ equipment	Substitution	No
Makateb 2023 [52] Iran	RCT	Lighting	General fatigue; Visual fatigue	Hospital employees (occupations not specified)	80	ESS Visual Function	Task/ equipment	Substitution	Yes

						Questionnair e			
Martin 2021 [53] Canada	Cross over	Lighting	General fatigue	Police officers	15 summer; 25 winter	KSS	Physical work environment	Substitution	No
Motamedzadeh 2017 [54] Iran	Pre/post test	Lighting	General fatigue	Control room workers	30	KSS	Physical work environment	Substitution	Yes
Olson 2020 [55] Canada	Pre/post test	Lighting	General fatigue	Nurses	33	MF; DFSF; KSS	Individual; Task/ equipment	Administration ; PPE	Yes
Sletten 2021[113] Australia	Cross over	Lighting	General fatigue	Chemical plant shift workers	28	ESS; PVT; KSS	Physical work environment	Substitution	Yes
Shift rostering									
Anund 2018 [57] Sweden	Case control	Shift rostering	General fatigue	Bus drivers	18 (9 females)	KSS; KDS; PVT; EEG & EOG (MATLAB)	Organisational	Substitution	No
Chang 2018 [58] Taiwan	Quasi experimental	Shift rostering	General fatigue	Nurses	42	SSS	Organisational	Substitution	Yes
Costa 2014 [59] Italy	Quasi experimental	Shift rostering	General fatigue	Nurses	294	KSS	Organisational	Substitution	Yes
Haidarimoghadam 2017 [60] Iran	Pre/post test	Shift rostering	General fatigue	Control room operators	60	KSS	Organisational	Substitution	No
Jensen 2022 [61] Denmark	Quasi experimental	Shift rostering	General fatigue	Police officers	73	KSS	Organisational	Substitution	No
Kubo 2022 [62] Japan	Cross over	Shift rostering	General fatigue	Nurses	30	Maastricht Questionnair e + objective measures (PVT & mattress sensor)	Organisational	Substitution	Yes
Parshuram 2015 [63] Canada	RCT	Shift rostering	General fatigue	Medical residents	47	SSS	Organisational	Substitution	No
Puttonen 2022 [64] Finland	Quasi experimental	Shift rostering	General fatigue	Shift workers	178	KSS	Organisational	Substitution	No
Shirreff 2014 [65] Canada	Pre/post test	Shift rostering	General fatigue	Residents, consultants, nurses	20 residents; 24 consultants; 47 nurses	Single item used	Organisational	Substitution	Yes
Shochat 2019 [66] Israel	Case control	Shift rostering	General fatigue	Ground crew	39	Shirom-Melamed	Organisational	Substitution	Not clear

						Burnout measure; KSS			
Yi 2013 [67] USA	Pre/post test	Shift rostering	General fatigue	General surgery residents	9	ESS; Task performance measures	Organisational	Substitution	No
Zakariassen 2019 [68] Norway; Austria	Case control	Shift rostering	General fatigue	Pilots	45 (21 Norway; 24 Austria)	KSS; ESS	Organisational	Substitution	Yes
Education									
Holzinger 2019 [70] Austria	Prospective study	Education	General fatigue	Shift workers (various occupations)	30	ESS	Individual	Administration	Yes
Holzinger 2020 [69] Austria	Pre/post test	Education	General fatigue	Shift workers (occupations not specified)	30	ESS	Individual	Administration	No
James 2022 [71] USA	Pre/post test	Education	General fatigue	Police officers	57	ESS	Individual	Administration	Yes
Patterson 2015 [72] USA	RCT	Education	General fatigue	Emergency medical services clinicians	85	ESS; CFQ; OFER	Individual	Administration	Yes
Patterson 2019 [115] USA	RCT	Education	General fatigue	Emergency medical services clinicians	43	CFQ; ESS; OFER; Sleep, Fatigue, Alertness, Behavior Survey	Individual	Administration	No
Patterson 2023 [124] USA	RCT	Education	General fatigue	Emergency medical services clinicians	650	CFQ; ESS; OFER	Individual	Administration	No
van Drongelen 2014 [75] Netherlands	RCT	Education	General fatigue	Pilots	502	Checklist Individual Strength	Individual	Administration	Yes
Chang 2015 [76] Taiwan	RCT	Napping	General fatigue	Nurses	63	SSS	Organisational	Substitution	No
Fan 2022 [77] China	RCT	Napping	General fatigue	Doctors (interns)	105	SSS	Organisational	Substitution	Yes
Geiger-Brown 2021 [78] USA	Pre/post test	Napping	General fatigue	Nurses	177	General questions on	Organisational	Substitution	Yes

						drowsiness at work			
Oriyama 2014 [79] Japan	Quasi experimental	Napping	General fatigue	Nurses	15	VAS	Organisational	Substitution	No
Tempesta 2013 [80] Italy	Case control	Napping	General fatigue	Residents	54 (32 intervention: 22 control	KSS; POMS short version	Organisational	Substitution	Yes
Zion 2019 [81] Israel	Prospective, within subjects	Napping	General fatigue	Registered nurses	119	KSS	Organisational	Substitution	Yes
Relaxation/meditation									
Biman 2021 [82] India	Case control	Relaxation/ meditation	General fatigue	Diamond industry employees	166	FSS	Individual	Administration	Yes
Bodet-Contentin 2023 [83] France	RCT	Relaxation/ meditation	General fatigue	ICU caregivers	88	VAS	Individual	Administration	Yes
Gregoire 2015 [84] Canada	Pre/post test control group switching-replication design	Relaxation/ meditation	General fatigue	Call centre employees	102	CFQ	Individual	Administration	No
Menon 2023 [85] India	Quasi experimental	Relaxation/ meditation	General fatigue	Nurses	200	Multidimensi onal Fatigue Symptom Inventory (MDFSI-SF); OFER	Individual	Administration	Yes
Ozgundondu 2019 [86] Turkey	RCT	Relaxation/ meditation	General fatigue	Nurses	56	FSS	Individual	Administration	Yes
Workload									
Mélan 2022 [87] France	Retrospectiv e	Workload	General fatigue	Air traffic controllers	57	Single item used	Organisational	Substitution	No
Moore 2015 [88] Canada	Pre/post test	Workload	General fatigue	Medical residents	24	Two items developed for study	Organisational	Substitution	No
Schiller 2017 [89] Sweden	RCT	Workload	General fatigue	Public sector employees	580 (IG: 354)	KSS	Organisational	Substitution	Yes
Tadakuma 2021 [90] Japan	Pre/post test	Workload	General fatigue	Electronics parts production employees	42	PVT; KSS; JICOSH with an additional item	Organisational	Substitution	No

Arapovic-Johansson 2018 [104] Sweden	RCT	Participatory process	Exhaustion (not emotional)	Health care employees (mixed)	89 (baseline)	OLBI	Organisational	Substitution	No
Brandt 2018 [105] Denmark	RCT	Participatory process	General fatigue	Construction workers	80	Not stated, at least 1 item on fatigue	Organisational	Substitution	Yes
Work time flexibility									
Karhula 2020 [94] Finland	Pre/post test	Work time flexibility	General fatigue	Hospital employees	677	Item on sleepiness	Organisational	Substitution	Yes
Nijp 2016 [95] Netherlands	Quasi experimental	Work time flexibility	General fatigue	Various occupational groups (IT, managers, sales, financial personnel, administrative personnel, customer service workers)	962–977	FAS	Organisational	Substitution	Yes
Kubo 2016 [117] Japan	Pre/post test	Work time flexibility	General fatigue	Employees	39	PVT-192; JO	Not clear	Not clear	Yes
Mindfulness									
Kinman 2020 [91] UK	Pre/post test	Mindfulness	Compassion fatigue	Social workers	26	ProQOL	Individual	Administration	Yes
Klee 2024 [92] USA	Quasi experimental	Mindfulness	General fatigue	Oncology nurses	26	Patient-Reported Outcomes Measurement Information System-29 (PROMIS-29)	Individual	Administration	Yes
Marquez 2021 [93] Spain	Pre/post test	Mindfulness	Compassion fatigue	Police officers	20	ProQOL	Individual	Administration	No
Rest breaks									
Azimi Yancheshmeh 2021 [100] Iran	Pre/post test	Rest breaks	General fatigue	Seafarers	139	KSS	Organisational	Substitution	Yes
Mailey 2017 [101] USA	Parallel-group randomized trial	Rest breaks	General fatigue	Sedentary workers	49	FSI	Organisational	Administration	No
Exercise									

Nezhad 2022 [98] Iran	Pre/post test	Exercise	Mental fatigue; Visual fatigue; Physical fatigue	Control room personnel	18	Fatigue severity scale developed for study	Individual	Administration	Yes
Santos 2020 [99] Brazil	RCT	Exercise	General fatigue	Industrial workers	204	NRS	Individual	Administration	No
Aromatherapy									
Nasiri 2021 [96] Iran	RCT	Aromatherap y	General fatigue	Nurses	80	KSS; ESS	Individual	Administration	Yes
Shin 2020 [97] Republic of Korea	RCT	Aromatherap y	Compassio n fatigue	Registered nurses	50 (25 intervention)	ProQOL	Individual	Administration	No
Kim 2020 [112] Republic of Korea	Cross over	Temperature	General fatigue	Nurses	20	Subjective Symptoms of Fatigue Test (SSFT)	Physical work environment	Substitution	No
Equipment									
Barkhordarzadeh 2022 [107] Iran	Quasi experimental	Equipment	Visual fatigue	Emergency medical dispatchers	55	Visual Fatigue Questionnair e	Task/equipment	Substitution	No
Food / Nutrition									
Leedo 2017 [108] Denmark	Randomised cross over design	Food/nutritio n	General fatigue	Physicians, nurses and nursing assistants	59	POMS	Organisational	Substitution	Yes
Cheng 2022 [102] China	Cross over	Shift rostering; Education	General fatigue	Rotating shift workers: nurses, hospital transporters, manufacturing employees, security guards, convenience store service workers	60	KSS	Individual; Organisational	Administration ; Substitution	Yes
d'Ettorre 2020 [103] Italy	Pre/post test	Shift rostering; Education	General fatigue	Nurses	475	ESS	Individual; Organisational	Administration ; Substitution	Yes
Napping; Education									

Han 2021 [110] Republic of Korea	Quasi experimental	Napping; Education	General fatigue	Nurses	38	Single-item measure developed for study; JDS	Individual; Organisational	Administration ; Substitution	No
Lighting; Exercise equipment									
Barger 2021 [109] USA	RCT	Lighting; Exercise equipment	General fatigue	Flight mission controllers	20	KSS	Individual; Physical work environment	Administration ; Substitution	Yes
Permatasari 2022 [106] Indonesia	Quasi experimental	Education; Exercise	General fatigue	Shift workers	116	FSS	Individual	Administration	Yes
Participatory process; Equipment									
Rostami 2022 [111] Iran	Pre/post test	Participatory process; Equipment	General fatigue	Shop floor workers, HR, IT	430 before intervention, 295 after intervention	SOFI; OFER	Individual; Task/equipment	Administration ; Substitution	Yes

Tool names and abbreviation used

CFQ: Chalder Fatigue Questionnaire
DFSF: Daily Fatigue Short Form
ESS: Epworth Sleepiness Scale
FSI Fatigue Symptom Inventory
EEG: Electroencephalogram
EOG: Electrooculogram
FSS: Fatigue Severity Scale
FAS: Fatigue Assessment Scale
JDS: Johns Drowsiness Scale
JICOSH: Self-Diagnosis Checklist of Worker's Accumulated Fatigue
KSS: Karolinska Sleepiness Scale
KDS: Karolinska Drowsiness Scale
MFI: Multidimensional Fatigue Inventory
NRS: Need for Recovery Scale
OFER: Occupational Fatigue, Exhaustion, Recovery Scale
OLBI: Oldenburg Burnout Inventory
POMS: Profile of Mood States
ProQOL: Professional Quality of Life Scale
PVT: Psychomotor Vigilance Task
SOFI: Swedish Occupational Fatigue Inventory
SSS: Stanford Sleepiness Scale
VAS: Visual Analogue Scale

Appendix 5 –Summary of study designs and reported intervention efficacy

	All study designs		RCT		RCT cross over		Parelle group randomised trial		Pre/post test		Quasi experimental		Case control		Cross over		Randomised cross over		Prospective study		Prospective, within participants		Retrospective		Pre/post test control group switching - replication design		Hybrid effectiveness-implementation approach		Non randomised open label trial	
	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective	No.	No. effective
Single-faceted interventions																																
Lighting	13	10 [a]	3	3	1	1			2	2	2	0			3	2 [a]											1	1	1	1
Shift rostering	12 [b]	5	1	0					3	1	4	2	3 [b]	1	1	1														
Education	7	4	4	2					2	1									1	1										
Napping	6	4	2	1					1	1	1	0	1	1							1	1								
Relaxation/ meditation	5	4	2	2							1	1	1	1											1	0				
Workload	4 [c]	1	1	1					2 [c]	0													1	0						
Participatory process	2	1	2	1																										
Work time flexibility	3	3							2	2	1	1																		
Mindfulness	3	2							2	1	1	1																		
Rest breaks	2	1					1	0	1	1																				
Exercise	2	1	1	0					1	1																				

Aromatherapy	2	1	2	1																										
Temperature	1	0													1	0														
Provision of office equipment	1	0									1	0																		
Food/nutrition	1	1															1	1												
Multifaceted interventions																														
Shift rostering & Education	2	2							1	1					1	1														
Napping & Education	1	0									1	0																		
Lighting & Exercise equipment	1	1	1	1																										
Education & Exercise	1	1									1	1																		
Participatory & equipment	1	1							1	1																				
Total	70	43	19	12	1	1	1	0	18 [c]	12	13	6	5 [b]	3	6	4 [a]	1	1	1	1	1	1	1	0	1	0	1	1	1	1

[a] Includes 1 study with mixed findings. [b] Includes 1 study where authors conclude results are unclear (has been counted as "ineffective"). [c] Includes 1 study in which staff numbers were reduced.

Appendix 6 – Table of evidence: Grey literature

Organisation, Author, Year	Document Title	Key themes	Link
Workplace Health and Safety Queensland, 2020	Preventing and managing fatigue-related risk in the workplace	Guidelines for employers in how to (1) identify hazards and risks relating to fatigue; (2) consult with workers; (3) eliminate and minimise the risks of fatigue; and (4) respond and learn from incidents involving fatigue to improve future efforts in preventing fatigue. Resource for managers, supervisors and health and safety representatives. Intended work contexts: drivers, shift workers, plant operators and jobs requiring high concentration. Includes definitions and causes of fatigue. Includes tools.	https://www.worksafe.qld.gov.au/news-and-events/newsletters/esafe-newsletters/esafe-editions/esafe/august-2020/new-guidance-on-managing-fatigue
WorkSafe Victoria, 2020	Work-related fatigue: A guide for employers	A guide for employers which includes: (1) causes of fatigue and its impact on employees; (2) how to identify fatigue as a hazard in the workplace; (3) how to consult with employees and health and safety representatives to prevent fatigue; (4) how to use risk management approaches to prevent fatigue; and (5) how to provide employees with training. Includes definitions and risk factors for fatigue. Risk management approach to fatigue. Includes case studies.	https://www.worksafe.vic.gov.au/resources/work-related-fatigue-guide-employers-pdf-version
WorkSafe Victoria, 2017	Fatigue in mines: A handbook for earth resources industry	A handbook providing guidance on how to conduct risk assessments, apply control measures and consult with employees in relation to managing fatigue. Also includes guidance for employees (recognising fatigue, understanding what factors contribute to fatigue, what is their role in the fatigue management plan and strategies in non-work time to reduce fatigue at work). Includes definitions of fatigue. Includes a fatigue hazards checklist.	https://www.worksafe.vic.gov.au/resources/fatigue-mines-handbook-earth-resources-industry
NT WorkSafe, 2023	Guide to fatigue management for heavy vehicle drivers Northern Territory	Guideline for the road transport industry in NT to develop, review and implement driver fatigue management systems to eliminate or minimise risks relating to fatigue. Includes definitions of fatigue. Includes tools.	https://worksafe.nt.gov.au/__data/assets/pdf_file/0019/1303831/guide-to-fatigue-management-for-heavy-vehicle-drivers.pdf
SafeWork SA, 2013	Emergency services: Guideline for risk managing fatigue	Guideline for emergency services to manage the risks of fatigue. The guide identifies measures which can be used to control the health and safety risks arising from fatigue. Includes a checklist (relating to work hours and fatigue).	https://www.safework.sa.gov.au/__data/assets/pdf_file/0005/140666/Emergency_services_guideline_for_risk_managing_fatigue.pdf

NSW Health, 2023	Fatigue management in NSW Health workplaces	Guideline provides a risk management approach for managing work-related fatigue. Includes definitions, factors which may cause fatigue and controls for reducing fatigue risk.	https://www1.health.nsw.gov.au/pds/ActivePDSDocuments/GL2023_012.pdf
Office of the National Rail Safety Regulator, 2020	ONRSR guideline fatigue risk management	Guideline for rail transport operators. Provides guidance on how to manage the fatigue-related risks associated with rail safety work. Includes definitions on fatigue. Includes examples.	https://nraspricms01.blob.core.windows.net/assets/documents/Guideline/Fatigue-Risk-Management-Guideline-1-July-2022.pdf
Australian Maritime and Safety Authority, 2020	Fatigue guidelines: Managing and reducing the risk of fatigue at sea	Guideline for those managing and operating Australian vessels and foreign vessels. Information on the causes, consequences and management of fatigue.	https://www.amsa.gov.au/sites/default/files/amsa-fatigue-guidelines-web.pdf

Appendix 7 – List of fatigue risk management tools and tools used to detect fatigue

Name of tool	Tool targets organisations / individuals	Fatigue detection tool only Y / N	Risk management tool Y / N	Intended use by researchers / organisations	Initially developed for clinical / general / occupational use	Used in intervention study	Example article demonstrating use
Fatigue risk management tools							
Fatigue Audit InterDyne (FAID) software	O	N	Y	O	O		Darwent et al. (2015). Managing fatigue: It really is about sleep. https://doi.org/10.1016/j.aap.2015.05.009 [36]
Fatigue Avoidance Scheduling Tool (FAST) software	O	N	Y	O	O		Cushman et al. (2023). Improving performance on night shift: A study of resident sleep strategies. https://doi.org/10.5664/jcsm.10480 [125]
Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model (used with FAST)	O	N	Y	O	O		Peng et al. (2018). An improved model to predict performance under mental fatigue. https://doi.org/10.1080/00140139.2017.1417641 [37]
Risk assessment guide from the Australian Medical Association's National Code of Practice – Hours of work, shift work and rostering for hospital doctors	O	N	Y	O	O		Dara et al. (2016). Fatigue risk in nurses performing rotating shift work in an intensive care unit in Singapore: Analysis of work rosters. [126]
Evidence-based guideline for fatigue risk management in emergency medical services	O	N	Y	O	O		Patterson et al. (2018). Evidence-based guidelines for fatigue risk management in emergency medical services. https://doi.org/10.1080/10903127.2017.1376137 [127]

Fatigue Risk Management Systems Diagnostic Tool [a]	O	N	Y	R	O		Maisey et al. (2022). Fatigue Risk Management Systems Diagnostic Tool: Validation of an organizational assessment tool for shift work organizations. https://doi.org/10.1016/j.shaw.2022.08.002 [128]
Fatigue detection tools developed for occupational use							
Cumulative Fatigue Symptoms Index (CFSI)	I	Y	N	R	O		Kagamiyama et al. (2019). Association between sleep and fatigue in nurses who are engaged in 16 h night shifts in Japan: Assessment using actigraphy. https://doi.org/10.1111/jjns.12246 [129]
Fatigue and risk index	I	Y	N	O	O		Kim et al. (2018). Evaluation for fatigue and accident risk of Korean commercial bus drivers. https://doi.org/10.1620/tjem.246.191 [130]
Jikaku-sho shirabe	I	Y	N	R	O		Kagamiyama et al. (2019). Association between sleep and fatigue in nurses who are engaged in 16 h night shifts in Japan: Assessment using actigraphy. https://doi.org/10.1111/jjns.12246 [129]
Maastricht Questionnaire	I	Y	N	R	O	Y	Kubo et al. (2022). Shift-work schedule intervention for extending restart breaks after consecutive night shifts: A non-randomized controlled cross-over study. https://doi.org/10.3390/ijerph192215042 [62]
Need for Recovery (NFR) Scale	I	Y	N	R	O	Y	Santos et al. (2022). Effectiveness of a progressive resistance exercise program for industrial workers during breaks on perceived fatigue control: A cluster randomized controlled trial. https://doi.org/10.1186/s12889-020-08994-x [99]
Occupational Fatigue Exhaustion Recovery (OFER) Scale	I	Y	N	R	O	Y	Rostami et al. (2022). Assessing the effectiveness of an ergonomics intervention program with a participatory approach: Ergonomics settlement in an Iranian steel industry. https://doi.org/10.1007/s00420-021-01811-x [111]
Oldenburg Burnout Inventory (OLBI)	I	Y	N	R	O	Y	Arapovic-Johansson et al. (2018). Participatory work place intervention for stress prevention in primary health care. A randomized controlled trial. https://doi.org/10.1080/1359432X.2018.1431883 [104]
Patient-Reported Outcomes Measurement Information System (PROMIS-29)	I	Y	N	R	O	Y	Klee et al. (2020). Zentangle pilot study: A mindfulness exercise for oncology nurses. https://doi.org/10.1188/24.CJON.173-180 [92]

Professional Quality of Life Scale	I	Y	N	R	O	Y	Kinman et al. (2020). 'It's my secret space': The benefits of mindfulness for social workers. https://doi.org/10.1093/bjsw/bcz07 3 [91]
Psychomotor Cognition Test	I	Y	N	R	O		Lee et al. (2023). The psychomotor cognition test for measurement of sleepiness/fatigue on a touch screen. https://doi.org/10.1109/EMBC40787.2023.10340988 [131]
Samn-Perelli Fatigue Scale	I	Y	N	R	O		Kazemi et al. (2016). Fatigue and workload in short and long-haul train driving. https://doi.org/10.3233/WOR-16232 8 [132]
Self-Diagnosis Checklist for Assessment of Worker's Accumulated Fatigue (JICOSH)	I	Y	N	R	O	Y	Tadakuma et al. (2021). Subjective and objective assessments after a change from a 4-crew, 12-h shift to a 3-crew, 12-h shift schedule: An observational study. https://doi.org/10.1007/s00420-020-01561-2 [90]
Shirom Melamed Burnout Measure	I	Y	N	R	O	Y	Shochat et al. (2019). Burnout, sleep, and sleepiness during day and night shifts in transition from 8- to 12-hour shift rosters among airline ground crew managers. https://doi.org/ 10.3390/clockssleep1020020 [66]
Sleep, Fatigue, Alertness, Behavior (SFAB) Survey	I	Y	N	R	O	Y	Patterson et al. (2019). Real-time fatigue mitigation with air-medical personnel: The SleepTrackTXT2 randomized trial. ttps://doi.org/10.1080/10903127.2018.1532476 [115]
Study-specific questions on fatigue / drowsiness at work	I	Y	N	R	O	Y	Geiger-Brown et al. (2021). Going beyond position statements: One hospital's successful initiative to implement napping for night shift nurses. https://doi.org/ https://doi.org/10.1177/216507992 [78]
Subjective symptoms	I	Y	N	R	O	Y	Hoshi et al. (2021). Effects of working environments with minimum night lighting on night-shift nurses' fatigue and sleep, and patient safety. https://doi.org/ 10.1136/bmjoq-2021-001638 [49]
Subjective Symptoms of Fatigue Test (SSFT)	I	Y	N	R	O	Y	Kim & Song. (2020). The effects of indoor ambient temperature at work on physiological adaptation in night shift nurses. https://doi.org/10.1111/jonm.13052 [112]
Survey of shiftwork – sleep disturbance concepts included	I	Y	N	R	O		Gupta et al. (2020). The impact of dayshifts and sleepover nightshifts on the eating and driving behaviours of residential support workers: An exploratory workplace study. https://doi.org/10.3233/WOR-203228 [133]
Swedish Occupational Fatigue Inventory (SOFI)	I	Y	N	R	O		Rostami et al. (2022). Assessing the effectiveness of an ergonomics intervention program with a participatory approach: Ergonomics settlement in an Iranian steel

							industry. https://doi.org/10.1007/s00420-021-01811-x [111]
Visual Fatigue Questionnaire	I	Y	N	R	O	Y	Barkhordarzadeh et al. (2022). Effects of an ergonomic intervention program based on the PRECEDE–PROCEED model for reducing work-related health problems and exposure risks among emergency medical dispatchers. https://doi.org/10.1007/s00420-022-01846-8 [107]
Visual Function Questionnaire	I	Y	N	R	O	Y	Makateb et al. (2023). Investigating the effects of a blue-blocking software on the daily rhythm of sleep, melatonin, cortisol, positive and negative emotions. https://doi.org/10.1080/07420528.2023.2222816 [52]
Transport Fatigue Assessment Tool	I	Y	N	O	O		Rose et al. (2023). Fatigue risk assessment of a helicopter emergency medical service crew working a 24/7 shift pattern: results of a prospective service evaluation. https://doi.org/10.1186/s13049-023-01143-4 [134]
Fatigue monitoring tool (app) for data collection [a]	I	Y	N	R	O		McCrary et al. (2022). Load and fatigue monitoring in musicians using an online app: A pilot study. https://doi.org/10.3389/fpsyg.2022.1056892 [119]
Flight Risk Assessment (FRA) [a]	I	Y	N	R	O		Nosker et al. (2020). Fatigue in aeromedicine: A validity study of the Flight Risk Assessment. https://doi.org/10.1080/24721840.2020.1735939 [120]
Sleep, fatigue and alertness behavior survey (SFAB)	I	Y	N	R	O		Patterson et al. (2014). Emergency healthcare worker sleep, fatigue, and alertness behavior survey (SFAB): Development and content validation of a survey tool. https://doi.org/10.1016/j.aap.2014.09.028 [135]
Sleep tank [a]	I	N	N	R	O		Dorrian et al. (2019). How much is left in your "sleep tank"? Proof of concept for a simple model for sleep history feedback. https://doi.org/10.1016/j.aap.2018.01.007 [33]
Nurse rostering problem with fatigue (fatigue modelling) [a]	O	N	Y	R	O		Klyve et al. (2023). Nurse rostering with fatigue modelling : Incorporating a validated sleep model with biological variations in nurse rostering. https://doi.org/10.1007/s10729-022-09613-4 [122]
Fatigue detection tools initially developed for general use							
2B-Alert Web	I	Y	N	P	G		Reifman et al. (2022). 2B-Alert Web 2.0, an open-access tool for predicting alertness and optimizing the benefits

							of caffeine: Utility study. https://doi.org/10.2196/29595 [136]
Accumulated Time with Sleepiness (ATS) Scale	I	Y	N	R	G	Y	Bjorvatn et al. (2021). The effects of bright light treatment on subjective and objective sleepiness during three consecutive night shifts among hospital nurses: A counter-balanced placebo-controlled crossover study. https://doi.org/10.5271/sjweh.3930 [44]
Convergence Insufficiency Symptom Survey	I	Y	N	R	G	Y	Joines et al. (2021). Adjustable task lighting: Field study assesses the benefits in an office environment. https://doi.org/10.3233/WOR-141879 [50]
Daily Fatigue Short Form	I	Y	N	R	G	Y	Olson et al. (2020). Developing a light-based intervention to reduce fatigue and improve sleep in rapidly rotating shift workers. https://doi.org/10.1080/07420528.2019.1698591 [55]
Johns Drowsiness Scale & oculography system	I	Y	N	R	G	Y	Ftouni et al. (2013). Objective and subjective measures of sleepiness, and their associations with on-road driving events in shift workers. https://doi.org/10.1111/j.1365-2869.2012.01038.x [118]
Karolinska Drowsiness Scale	I	Y	N	R	G	Y	Anund et al. (2018). An on-road study of sleepiness in split shifts among city bus drivers. http://doi.org/10.1016/j.aap.2017.05.005
Karolinska Sleepiness Scale (KSS)	I	Y	N	R	G	Y	Anund et al. (2018). An on-road study of sleepiness in split shifts among city bus drivers. http://doi.org/10.1016/j.aap.2017.05.005
Mattress sensor	I	Y	N	R	G	Y	Kubo et al. (2022). Shift-work schedule intervention for extending restart breaks after consecutive night shifts: A non-randomized controlled cross-over study. https://doi.org/10.3390/ijerph192215042 [62]
Multidimensional Fatigue Symptom Inventory (MDFSI-SF)	I	Y	N	R	G	Y	Menon & Abraham (2023). Exploring the factors of fatigue among nurses and effectiveness of fatigue countermeasure programme. [85]
Profile of Mood States (POMS) Questionnaire	I	Y	N	R	G	Y	Leedo et al. (2017). The effectiveness of healthy meals at work on reaction time, mood and dietary intake: A randomised cross-over study in daytime and shift workers at an (sic) university hospital. https://doi.org/10.1017/S000711451700191X [108]
Psychomotor Vigilance Task (PVT)	I	Y	N	R	G	Y	Anund et al. (2018). An on-road study of sleepiness in split shifts among city bus drivers. http://doi.org/10.1016/j.aap.2017.05.005 [57]

Stanford Sleepiness Scale (SSS)	I	Y	N	R	G	Y	Chang et al. (2018). Is one day off sufficient for re-adaptation to a daytime routine after two consecutive nights of work? https://doi.org/10.1080/00140139.2017.1330492 [58]
Visual Analog Scale (VAS)	I	Y	N	R	G	Y	Bodet-Contentin et al. (2023). Virtual reality during work breaks to reduce fatigue of intensive unit caregivers: A crossover, pilot, randomised trial. https://doi.org/10.1016/j.aucc.2022.01.009[83]
Self-Report Fatigue Scale	I	Y	N	R	G		Zhong et al. (2023). Fatigue assessment of sedentary office workers using smartphones: A preliminary study. https://doi.org/10.1080/10803548.2022.2077000 [137]
Postural control with a custom made force platform	I	Y	N	R	G		Forsman et al. (2014). Feasibility of force platform based roadside drowsiness screening: A pilot study. https://doi.org/10.1016/j.aap.2013.09.015 [138]
Physiological measures (via wearable devices or other; e.g., EEG)	I	Y	N	R	G	Y	Anund et al. (2018). An on-road study of sleepiness in split shifts among city bus drivers. http://doi.org/10.1016/j.aap.2017.05.005 [57]
Fatigue detection tools initially developed for clinical use							
Brief Fatigue Inventory (BFI) 17	I	Y	N	R	C		Cho et al. (2021). Changes in fatigue levels and sleep measures of hospital nurses during two 12-hour work shifts. https://doi.org/10.1097/NNA.0000000000000983 [139]
Chalder Fatigue Questionnaire (CFQ)	I	Y	N	R	C	Y	Grégoire and Lachance. (2015). Evaluation of a brief mindfulness-based intervention to reduce psychological distress in the workplace. https://doi.org/10.1007/s12671-014-0328-9[84]
Checklist Individual Strength	I	Y	N	R	C		van Drongelen et al. (2016). Evaluation of an mHealth intervention aiming to improve health-related behavior and sleep and reduce fatigue among airline pilots. https://doi.org/10.5271/sjweh.3447 [75]
Checklist Individual Strength 20-R (CIS20R)	I	Y	N	R	C		Habibi et al. (2015). A survey of the relationship between work schedule and its effect on the fatigue of rescue personnel in Isfahan with a standard method of CIS202. https://https://doi.org/10.4103/2277-9531.171812 [140]
Epworth Sleepiness Scale (ESS)	I	Y	N	R	C	Y	James et al. (2022). Pilot test of "NIOSH training for law enforcement on shift work and long work hours". https://doi.org/10.1097/JOM.0000000000002534 [71]
Fatigue Assessment Scale	I	Y	N	R	C	Y	Njip et al. (2016). Effects of new ways of working on work hours and work location, health and job-related

							outcomes. https://doi.org/10.3109/07420528.2016.1167731 [95]
Fatigue Severity Scale	I	Y	N	R	C	Y	Ozgundondu and Metin (2019). Effects of progressive muscle relaxation combined with music on stress, fatigue, and coping styles among intensive care nurses. https://doi.org/10.1016/j.iccn.2019.07.007 [86]
Fatigue Symptom Inventory (FSI)	I	Y	N	R	C	Y	Mailey et al. (2017). Effects of an intervention to reduce sitting at work on arousal, fatigue, and mood among sedentary female employees: A parallel-group randomized trial. https://doi.org/10.1097/JOM.0000000000001131 [101]
Multidimensional Fatigue Inventory (MFI)	I	Y	N	R	C	Y	Olson et al. (2020). Developing a light-based intervention to reduce fatigue and improve sleep in rapidly rotating shift workers. https://doi.org/10.1080/07420528.2019.1698591 [55]
Short Fatigue Questionnaire (SFQ)	I	Y	N	R	C		van Elk et al. (2022). Study design of PerfectFit@Night, a workplace health promotion program to improve sleep, fatigue, and recovery of night shift workers in the healthcare sector. https://doi.org.10.1186/s12889-022-13206-9 [141]
Excessive Sleep Scale [b]	-	-	-	-	-	-	Deng et al. (2024). Association of intra-shift nap duration with heart rate variability in medical night shift workers. https://doi.org/10.1111/jsr.13935 [142]
Tools developed to measure a construct other than fatigue							
Borg Rating of Perceived Exertion Scale (RPE)	I	Y	N	R	O		Crestelo Moreno et al. (2023). Fatigue as a key human factor in complex sociotechnical systems: Vessel traffic services. https://doi.org/10.3389/fpubh.2023.1160971 [123]
NASA-TLX (mental demand scale)	I	Y	N	R	O		Crestelo Moreno et al. (2023). Fatigue as a key human factor in complex sociotechnical systems: Vessel traffic services. https://doi.org/10.3389/fpubh.2023.1160971
Self-assessment manikin (pleasure and arousal dimensions)	I	Y	N	R	G		Crestelo Moreno et al. (2023). Fatigue as a key human factor in complex sociotechnical systems: Vessel traffic services. https://doi.org/10.3389/fpubh.2023.1160971

Note: [a] Tools in development or that require further pilot testing. [b] No information could be found on this scale.