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# Fatigue risk management in healthcare: A scoping literature review

Stephanie Fox[a,*], Chiara Dall'Ora[b], Mark Young[a]

[a] Transportation Research Group, School of Engineering, University of Southampton, Southampton, UK
[b] NIHR Applied Research Collaboration Wessex, School of Health Sciences, University of Southampton, Southampton, UK

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ABSTRACT

*Background:* Occupational fatigue among healthcare professionals is a complex, multifaceted issue associated with increased likelihood of medical error, compromised patient safety and negative impacts on staff mental and physical health. While safety-critical sectors such as aviation and rail have implemented formal systems to manage fatigue-related risks, it remains unclear whether similarly structured approaches exist or operate effectively within healthcare.

*Objective:* This scoping literature review aimed to examine the current state of knowledge regarding fatigue risk management strategies and countermeasures in healthcare and explore the barriers and facilitators to their implementation. This review sought to highlight gaps and provide insights into advancing fatigue risk management practices within the healthcare context.

*Methods:* A systematic literature search to June 2025 was conducted across Medline, CINAHL Ultimate, and Scopus databases. Search terms were developed based on key concepts related to healthcare professions and fatigue risk management. Studies were included if they examined fatigue risk management strategies, countermeasures or organisational perceptions of fatigue in healthcare.

*Results:* Thirty-two studies met the inclusion criteria, including quantitative (n = 18), qualitative (n = 9), and mixed-methods (n = 5) designs. Findings were grouped into conceptual categories based on the study focus and/or intervention type. The majority of studies (n = 18) evaluated isolated interventions including informal/individual fatigue management strategies, napping, use of biomathematical models to predict fatigue risk, fatigue education, and the impact of scheduling practices. Only two studies reported on comprehensive, multi-component programmes. Nine studies explored staff perceptions and attitudes towards fatigue-related strategies, and three examined broader organisational understanding or design principles related to fatigue management. Key barriers to implementation included normalised cultural attitudes towards fatigue, limited managerial support, and inadequate infrastructure. Facilitators included improved staffing levels, better workload distribution, supportive leadership, and the development of non-punitive safety cultures that encouraged fatigue reporting.

*Conclusions:* Despite growing awareness of the risks associated with occupational fatigue, healthcare systems continue to rely on fragmented, informal, and largely individual approaches to fatigue management. In contrast to other high-risk industries, healthcare has yet to embed fatigue management within formal safety governance structures. Advancing practice in this area requires a shift towards system-level thinking that is supported by organisational leadership, effective fatigue monitoring, and workforce education. Additionally, this shift also demands a cultural reorientation that recognises fatigue as a predictable and manageable safety risk that necessitates organisational accountability rather than individual resilience to prioritise both staff wellbeing and patient safety.

* Corresponding author at: University of Southampton, Building 178, Boldrewood Innovation Campus, Burgess Road, Southampton, Hampshire, SO16 7QF, UK.
*E-mail address:* S.L.J.Fox@soton.ac.uk (S. Fox).

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**What is already known**

- Evidence indicates that staff fatigue in healthcare can adversely affect patient safety and has a detrimental impact on the physical and mental health and wellbeing of healthcare professionals.
- Safety-critical industries, such as aviation and rail, have successfully implemented fatigue risk management systems to identify, assess, and mitigate fatigue-related risks.
- Although the negative consequences of fatigue in healthcare settings are well-documented, the adoption of systematic and comprehensive approaches to mitigate these risks remains unknown.

**What this paper adds**

- Findings highlight a significant gap between the well-documented risks associated with fatigue in healthcare and the systematic approaches required to mitigate these risks effectively.
- A major barrier to effective fatigue risk management in healthcare is cultural and the normalisation of fatigue, alongside challenges such as resourcing, workload, and inadequate rest environments.
- Although evidence-based solutions to address these barriers are currently limited, potential strategies are likely to include collaborative efforts, educational initiatives, ongoing monitoring, and organisational support.

## 1. Introduction

Occupational fatigue is a multifaceted and complex construct that lacks a universally accepted definition. Within safety-critical industries, the International Civil Aviation Organization (ICAO, 2015, p. 6) provides a widely recognised definition of fatigue as "a physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety-related operational duties." Healthcare professionals frequently experience long working hours, shift work, unpredictable scheduling, and high workloads, all of which are contributors to occupational fatigue (Arsintescu et al., 2020; McClelland et al., 2019; Podesta et al., 2024; Steege et al., 2015). Fatigue not only increases the likelihood of medical error, thereby negatively impacting patient safety and care, but can also affect an individual's physical and mental health and wellbeing leading to reduced productivity and higher rates of staff burnout and turnover (Abramovich et al., 2023; Dent et al., 2024; McClelland et al., 2019; Ozkaynak et al., 2025). Despite these risks, fatigue is often normalised within healthcare culture with professionals expected to persevere and remain resilient (Cochran et al., 2021; Farquhar, 2017; Greig and Snow, 2017; Steege and Rainbow, 2017).

In recognition of the risks associated with fatigue and the need to address it systematically, safety-critical industries such as aviation and rail have adopted fatigue risk management (FRM) strategies to identify, assess and mitigate fatigue related risks (International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024). Collectively, these strategies can be implemented as part of a fatigue risk management system (FRMS) and as a component of the wider safety management system (SMS) (International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024). A fatigue risk management system integrates evidence-based and scientific principles of fatigue into operational practice, enabling organisations to proactively monitor fatigue levels, implement countermeasures, and evaluate the effectiveness of interventions to mitigate fatigue related risks (International Civil Aviation Organization, 2016). Key components of a fatigue risk management system include the use of fatigue data to guide decision making, adopting scheduling practices that align with circadian rhythms, education and training for staff, and a culture of non-punitive reporting (Dawson and McCulloch, 2005; International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024).

Understanding and systematically addressing occupational fatigue in healthcare is essential for maintaining patient safety, delivering high-quality care, and safeguarding the health and wellbeing of healthcare professionals (Farquhar, 2017; Greig and Snow, 2017; Pickup et al., 2025; Querstret et al., 2020). Whilst the adverse effects of fatigue in healthcare settings are well documented, it remains unclear whether structured fatigue risk management systems, such as those successfully implemented in aviation and rail (International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024; Sprajcer et al., 2022), exist or function effectively within healthcare, or to what extent such systematic approaches have been adapted and applied in this context. This scoping literature review seeks to explore the current state of knowledge regarding fatigue risk management strategies and countermeasures in healthcare. Fatigue risk management strategies include any proactive measures or policy designed to identify and mitigate fatigue-related risks, while countermeasures are targeted interventions implemented to minimise the impact of fatigue on performance and safety, even if not explicitly recognised as part of fatigue risk management. Additionally, this review aims to identify the barriers and facilitators to the successful implementation of fatigue risk management strategies in healthcare. By synthesising existing evidence, this review seeks to highlight gaps and provide insights into advancing fatigue risk management practices within the healthcare context.

## 2. Methods

This review was conducted in accordance with the framework for scoping reviews outlined by Peters et al. (2020) in the *JBI Manual for Evidence Synthesis*. This approach was used to map the existing literature on fatigue risk management in healthcare, identify barriers and facilitators to fatigue risk management implementation, and to identify gaps for future research.

### 2.1. Identifying relevant studies

A comprehensive search strategy was employed to identify relevant studies published in English language peer-reviewed academic journals. Searches were conducted in June 2025 on Medline, CINAHL Ultimate, and Scopus databases. Search terms were developed based on key concepts related to healthcare professions (e.g., "nurse," "physician," "paramedic") and fatigue risk management (e.g., "fatigue risk management," "fatigue intervention," "fatigue mitigation"). The search of the Scopus database was also limited by subject area to medicine, nursing and health professions. As shift work is a key risk factor for occupational fatigue, the search strategy targeted healthcare professionals for whom shift work is most prevalent and frequently reported in the literature. Given that much of the fatigue-related research focuses on specialised groups within healthcare, such as anaesthetists and obstetricians, these professions were included in the search terms. Details of the search terms used for each concept are presented in Table 1.

### 2.2. Study selection

The study inclusion criteria encompassed research on fatigue risk management implementation or investigation across any healthcare demographic, including studies on specific fatigue risk management strategies or countermeasures aimed at managing and reducing fatigue risk, even if not explicitly identified as fatigue risk management. Studies investigating worker or organisational perceptions of fatigue risk management and associated strategies were also included. No specific timeframe was specified during the literature search.

Exclusion criteria covered studies focusing on compassion or alarm fatigue as these are conceptually distinct from occupational fatigue and would not typically be addressed by conventional fatigue risk management systems or strategies. Studies examining fatigue risk management

**Table 1**
Search terms.

| Concept | | Search terms |
|---|---|---|
| Healthcare | General | "Healthcare (worker* OR professional* OR practitioner* OR staff)" |
| | Nurse | Nurs* |
| | Midwife | Midwi* |
| | Doctor | Doctor* OR physician* OR clinician* OR residen* |
| | Paramedic | Paramedic* OR emergency OR EMT OR EMS |
| | Specialism | Anaesthe* OR anesthe* OR obgyn OR obstetric* OR gynecolog* |
| Fatigue | | Fatigue AND "risk management" |
| | | "Fatigue intervention*" |
| | | "Fatigue mitigation*" |
| | | "Fatigue strateg*" |
| | | "Fatigue countermeasure*" |

* denotes truncation.

in non-healthcare contexts were also excluded. Two authors independently undertook the screening process. One reviewer conducted an initial rapid exclusion of non-relevant papers and screened the titles, abstracts, and full texts of potentially eligible studies, while the second reviewer assessed a subset of these papers to evaluate consistency and agreement. Any disagreements were resolved through discussion.

### 2.3. Data extraction and synthesis of results

We extracted the following from included studies: occupational context, participant characteristics, country, study design, fatigue risk management intervention/strategy details, outcomes and key findings relating to the research questions. The extracted data were organised into thematic groups per intervention or strategy. The findings are presented narratively and summarise the key themes and trends identified across the included studies.

## 3. Results

A total of 572 references were retrieved from the database searches. After removal of duplicates, 189 references were selected for title and abstract screening. Many of these records were rapidly excluded as they regarded either patient fatigue and alarm or compassion fatigue. A total of 111 references were identified as relevant to fatigue risk management, strategies pertaining to fatigue risk management, or organisational perceptions of such. After reading the full text of these 111 references, a further 79 were excluded. The reference lists of included studies were also scanned and no additional papers were identified through this process. Thirty-two papers met the criteria for inclusion in the final review (see Fig. 1 for reference screening flow chart).

Although no timeframe was imposed during the search, all the included studies were published from 2005 onwards, with half (n = 17) published since 2019. The sample comprised quantitative (n = 18), qualitative (n = 9), and mixed-method (n = 5) studies. Most research was conducted in the United States and Canada (n = 23), with the remainder from China (n = 2), Belgium (n = 2), Australia and New Zealand (n = 2), South Korea (n = 1), Bhutan (n = 1), and the United Kingdom (n = 1). Nurses were the most frequently studied demographic (n = 20), followed by medical residents/interns (n = 8), emergency physicians (n = 2), and emergency medical service (EMS) clinicians (n = 2).

Given the broad scope of this review, the search yielded a diverse range of studies addressing different aspects of fatigue risk management. To support a structured analysis, the findings are grouped into conceptual categories based on the study's focus and/or intervention type. Five studies examined individual and informal fatigue mitigation strategies, while two focused on fatigue awareness and education initiatives. Napping as a countermeasure was explored in six studies, one study assessed the impact of scheduling practices, and four investigated the use of biomathematical models in staff rostering. Only two studies (Scott et al., 2010a, 2010b) adopted a holistic fatigue risk management approach by integrating multiple strategies. Additionally, nine studies explored healthcare workers' perceptions and attitudes towards fatigue

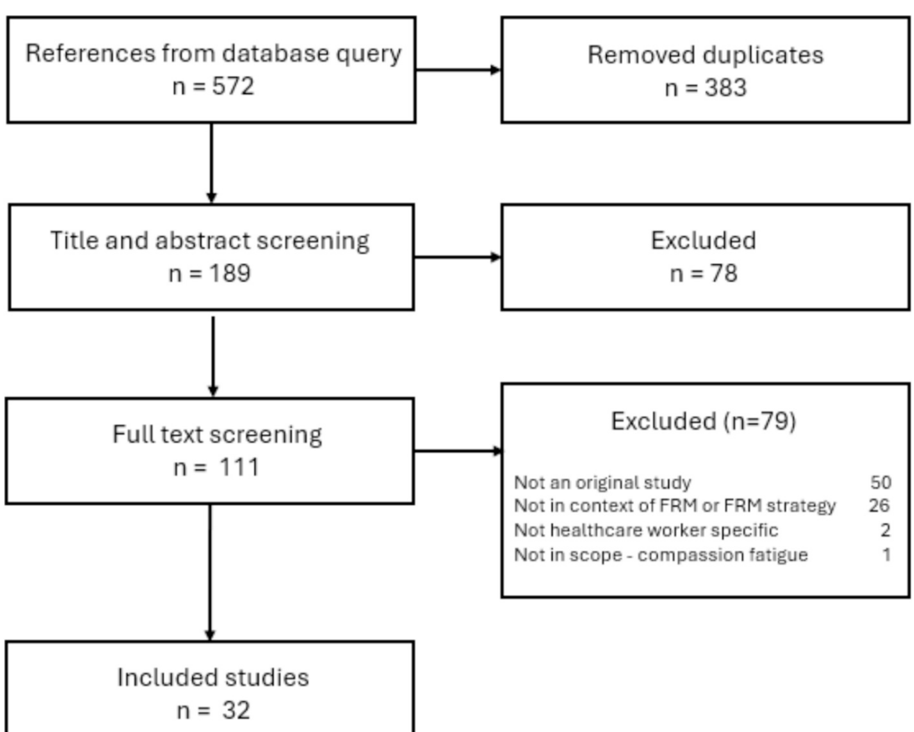


**Fig. 1.** Reference screening flowchart.

risk management, one proposed fatigue risk management design principles based on nurses' perspectives, and two examined the broader understanding and implementation of fatigue risk management within a hospital setting in the United States. A summary of the extracted data from the included studies is presented in Table 2.

### 3.1. Fatigue mitigation strategies

#### 3.1.1. Individual and informal strategies

Several studies have examined informal strategies employed by healthcare professionals in an effort to manage their fatigue. Bérastégui et al. (2018, 2020) categorised these strategies into fatigue reduction and fatigue-proofing methods. Fatigue reduction strategies, primarily aimed at alleviating fatigue symptoms, included consuming refreshments, engaging in physical activity, and seeking fresh air. Fatigue-proofing strategies focused on sustaining performance through self-regulation, task reallocation, and error monitoring.

He et al. (2025), Lawson Carney (2013), and Stoller et al. (2005) reported that healthcare workers employed a broad range of self-initiated fatigue management strategies. These included chemical aids (e.g., caffeine, medications), dietary adjustments, sleep-related practices (e.g., napping, adjusting sleep schedules), and behavioural methods (e.g., physical stimulation). Some individuals also resorted to extreme coping mechanisms, such as remaining awake for over 24 h or sleeping in vehicles. Despite the diversity of these approaches, their effectiveness was generally limited and often misaligned with established best practices.

Bérastégui et al. (2020) further assessed the effectiveness of informal approaches, finding that fatigue-proofing strategies moderated the impact of fatigue on performance but were associated with higher emotional exhaustion, potentially leading to burnout. In contrast, fatigue reduction strategies improved reaction times without increasing burnout risk.

Despite the widespread reliance on these informal methods, the studies highlight that healthcare professionals, including both nurses and physicians, often adopted strategies through a trial-and-error approach shaped by a lack of formal training, with participants receiving little to no guidance or education on managing sleep loss or circadian disruption (Bérastégui et al., 2020; Stoller et al., 2005; Lawson Carney, 2013; He et al., 2025).

#### 3.1.2. Napping

Several studies have investigated the use of naps as a fatigue countermeasure. Research demonstrated that scheduled naps can increase sleep duration and reduce fatigue, although uptake was inconsistent. Arora et al. (2006) found that medical interns who adhered to a nap schedule during a 30-hour shift slept longer and reported less fatigue. However, even though nap coverage was provided, interns often chose not to use it and preferred to keep continuity and deliver care to their own patients, even to the detriment to their own welfare. This finding is consistent with that of Shnayder et al. (2017) who found that most resident interns perceived their work environment to be unsupportive of a napping culture.

In nursing, Centofanti et al. (2018) reported that nearly 70 % of nurses and midwives used naps to maintain alertness or compensate for sleep debt, with benefits including improved patient safety and reduced commuting risks. Gyeltshen et al. (2023) demonstrated that nurses who napped for at least 45 min during night shifts experienced lower fatigue levels and reported higher quality of care, though no significant psychological benefits were observed. Efforts to implement structured nap schedules in nursing units yielded mixed results. While Han et al. (2021) found that ICU nurses in Korea benefited from scheduled naps, reporting lower fatigue and improved care quality, Geiger-Brown et al. (2016) noted that successful implementation was limited to only one of six participating nursing units. Han et al. (2021) also collected objective drowsiness data using infrared reflectance oculography. Although only 13 nurses participated in the ocular data collection, the findings suggest that, as with subjective measures, high levels of drowsiness declined after the napping intervention.

However, across studies involving both nurses and resident physicians, several implementation challenges were highlighted including leadership resistance, staffing concerns, and inadequate facilities (Geiger-Brown et al., 2016; Gyeltshen et al., 2023; Groves et al., 2020; Han et al., 2021).

#### 3.1.3. Fatigue awareness and education

Patterson et al. (2019, 2023) conducted studies on mobile phone-based interventions and educational modules to address fatigue and sleep quality among emergency medical service (EMS) workers. Text messaging interventions can be effective in reducing fatigue, sleepiness, and concentration difficulties during 12-hour shifts, but their efficacy is reduced for longer shifts. Educational modules on sleep health and fatigue management showed mixed results. Per-protocol analysis indicated improvements in sleep quality and fatigue reduction that correlated with increased engagement in the modules. However, intention-to-treat analysis revealed no significant differences between intervention and control groups.

#### 3.1.4. Scheduling practices

Smith-Miller et al. (2016) examined the impact of a 12-week scheduling management intervention in nursing units that included breaks from duty and limitations on consecutive work hours and shifts. Although acute and chronic fatigue levels did not change significantly, the percentage of nurses with high levels of inter-shift recovery increased and persistent fatigue scores also showed improvement.

Pre-intervention culture included not taking breaks and staying beyond shift end, but nurse managers played a key role in ensuring breaks occurred through communication and proactive prompting. However, nurses were resistant to the change and hesitant to let float nurses cover their assigned patients.

#### 3.1.5. Biomathematical models

Biomathematical fatigue models predict fatigue under various work schedules, identifying periods of increased risk for performance decline, impairment, and error (McCormick et al., 2013).

Four studies assessed the feasibility of such models in healthcare and found significant fatigue risks associated with medical rotas. Cumber and Greig (2019) found that nearly half of all shifts assessed using an existing Health and Safety Executive fatigue risk calculator (Folkard et al., 2006) carried elevated fatigue-related risks, with general medicine rotas being the most affected. Research utilising other models, such as the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model and the Fatigue Avoidance Scheduling Tool (FAST) (Hursh et al., 2004a, 2004b) further confirmed that night shifts and extended shifts (16–24+ hours) contributed to critical fatigue levels (Schwartz et al., 2021; McCormick et al., 2013). Both studies demonstrated that integrating countermeasures, such as naps, improved modelled performance and reduced time spent working while critically fatigued.

Gander et al. (2020) developed a scheduling matrix incorporating factors such as total hours worked, shift extensions, break and nap opportunities, and rest days. Higher matrix scores significantly predicted extreme sleepiness, fatigue-related errors, drowsy driving, and social or personal difficulties.

#### 3.1.6. Use of multiple strategies

Scott et al. (2010a, 2010b) implemented the only comprehensive fatigue risk management programme combining unit-level interventions (adequate staffing for breaks, encouraging rest periods, permitting strategic napping) with individual-level measures (sleep hygiene education, sleep quality strategies, vigilance techniques). Significant improvements in sleep duration, quality, alertness, and error prevention were observed following programme implementation. However, the

**Table 2**
Summary of results.

| Author & year | Design | Aims | Participants & setting | Key findings |
|---|---|---|---|---|
| Individual & informal strategies | | | | |
| Bérastégui et al. (2018) | Qualitative, focus group | Explore Emergency Physicians (EP) experience of fatigue and informal strategies used to manage fatigue-related risk. | 25 emergency physicians. University hospital, Belgium | - Emergency physicians reported 28 specific effects of fatigue, including physical, cognitive, emotional, and motivational symptoms.<br>- Described 12 fatigue reduction strategies (FRS) and 21 fatigue proofing strategies (FPS). The proofing strategies were further classified into self-regulation, task re-allocation, and error monitoring strategies. |
| Bérastégui et al. (2020) | Longitudinal | Assess effectiveness and long-term well-being costs of informal fatigue risk management strategies used by emergency physicians. | 28 emergency physicians, over a total of 182 shifts. University hospital, Belgium | - Use of fatigue proofing strategies moderated the relationship between fatigue-related impairments and performance in the areas of patient interaction ($F = 4.91$, $p = 0.03$) and self-management ($F = 5.92$, $p = 0.02$).<br>- Frequent use of fatigue proofing strategies was associated with higher levels of emotional exhaustion, an early indicator of burnout ($\beta = 0.79$, $p < 0.001$).<br>- Use of fatigue reduction strategies was associated with reduced fatigue-related impairments (reaction time) without increased risk of burnout ($F = 8.02$, $p = 0.01$). |
| He et al. (2025) | Cross-sectional | To assess fatigue levels among Chinese night-shift nurses and identify commonly used anti-fatigue strategies. | 371 nurses from 18 hospitals, China. | - Common fatigue-coping strategies included napping (63.9 %) and consuming stimulating beverages such as coffee (45.4 %) and milk tea (23.3 %). |
| Lawson Carney (2013) | Cross-sectional | Understand how night shift nurses learn fatigue coping techniques they use to adapt to the disruption of their circadian rhythm. | 42 night shift nurses, USA. | - Night shift nurses use a variety of sleep/wake routines to cope with the disruption to their circadian rhythm.<br>- Many of these techniques, such as remaining awake for 24 h or more, do not align with recommended best practices.<br>- Nurses reported a wide range of behaviours related to driving while fatigued, including pulling over to sleep in their vehicles.<br>- None of the nurses had received any employer-provided education or training on managing the risks of shift work. |
| Stoller et al. (2005) | Mixed-methods | Examine sleep loss and fatigue countermeasures among resident physicians. | 149 medical residents. 5 university hospitals, USA. | - Residents used a wide range of strategies to manage sleep loss and fatigue, including chemical, dietary, sleep management, behavioural and cognitive strategies.<br>- Trial-and-error approach common despite awareness of negative effects. |
| Napping | | | | |
| Arora et al. (2006) | 1-year, within-participant, paired trial | To determine whether the provision of a nap during a 30-hour shift would increase sleep and decrease fatigue among medical interns. | 38 medical interns. University hospital, USA | - Interns on nap schedule slept 41 more minutes on average compared to the standard schedule (185 min vs. 144 min; $P < 0.001$).<br>- When interns used nap coverage, they slept 68 more minutes (210 min vs. 142 min; $P < 0.001$).<br>- Interns on nap schedule also reported less overall fatigue and significantly less fatigue on the post call day (1.74 vs. 2.26; $P = 0.017$).<br>- However, interns often chose not to use the nap coverage, preferring to care for their own patients. |
| Centofanti et al. (2018) | Mixed-methods | Investigate nurses' use of napping and caffeine for fatigue, and how these strategies relate to their sleep, physical health, and mental health. | 130 shift-working nurses and midwives surveyed, 22 interviewed.<br>2 metropolitan hospitals, Australia. | - Nearly 70 % participants reported taking naps, either during night shifts or as a preventative measure before night shifts.<br>- Those who napped during night shifts had less total sleep time compared to those who did not nap or took preventative naps ($F_{2,85} = 97.2$, $p < 0.001$).<br>- Increased caffeine consumption was linked to more sleep disturbance ($r = 0.26$, $p < 0.05$), psychological distress ($r = 0.37$, $p < 0.001$), abdomen pain ($r = 0.27$, $p < 0.05$) and weight gain since starting shift work ($r = 0.25$, $p < 0.05$). |
| Geiger-Brown et al. (2016) | Pilot study | 1) Identify barriers to successful implementation of napping on the night shift. | Nurses from 6 hospital units, USA. | - Napping successfully implemented in only one of the six units. |

(continued on next page)

**Table 2** (*continued*)

| Author & year | Design | Aims | Participants & setting | Key findings |
|---|---|---|---|---|
| | | 2) Understand the experiences of nurses who take naps during the night shift. | | - Barriers included nurse managers declining to implement napping, lack of suitable napping spaces, and concerns about maintaining adequate nurse staffing.<br>- Nurses reported moderate sleepiness before the nap, with over 40 % having a high sleepiness level.<br>- Nurses found napping helpful, with an average helpfulness rating of 7.3 out of 10.<br>- Nurses that napped reported being less drowsy for their commute post shift. |
| Gyeltshen et al. (2023) | Cross-sectional | Understand night shift nurses' napping practices and the effects of napping on sleepiness, fatigue, well-being, and the quality of nursing care. | 305 nurses from 10 hospitals, Bhutan. | - About 40 % of nurses reported taking naps during their night shifts, with the majority (82.92 %) napping for more than 45 min.<br>- Napping was found to significantly reduce sleepiness ($P = 0.002$) and fatigue ($P = 0.001$) and improve the quality of nursing care ($P = 0.03$).<br>- Nurses who napped for more than 45 min reported significantly lower levels of sleepiness ($P = 0.02$) and fatigue ($P = 0.01$) compared to those who did not nap or napped for less than 45 min. |
| Han et al. (2021) | Quasi-experimental, one-group, pre- and post-test design | Implement a scheduled nap intervention for nurses and examine whether it would improve drowsiness and the quality of nursing care. | 38 nurses, (13 nurses continuously assessed using infrared reflectance oculography). Paediatric ICUs, South Korea. | - Nurses who were able to take naps reported improved levels of fatigue on the first night shift and better quality of nursing care on the second night and day shifts after the intervention, while those who did not take naps showed no significant improvements.<br>- Objective drowsiness data showed a decrease in the total cautionary and cautionary or higher levels of drowsiness after the intervention. |
| Shnayder et al. (2017) | Cross-sectional | Assess resident physicians' perception of their work environment's supportiveness for napping at work. | 858 resident physicians. University hospital, USA. | - 89 % residents reported access to an on-call room<br>- Only 20 % of residents felt their work environment supported a culture of napping. |
| Fatigue awareness & education | | | | |
| Patterson et al. (2019) | Randomised controlled trial | Assess impact of a mobile phone-based intervention (SleepTrackTXT2) on fatigue and sleep quality. | 83 Emergency Medical Service (EMS) clinicians (2828 shifts), USA. | - In the short-term, the intervention group reported less fatigue, sleepiness, and difficulty concentrating during 12-h shifts compared to the control group.<br>- Benefit was not seen for longer shifts over 12 h.<br>- No long-term sleep quality improvement |
| Patterson et al. (2023) | Cluster-randomised trial | Examine impact of an educational intervention on sleep and fatigue in Emergency Medical Service shift workers. | 678 emergency medical service clinicians across 36 agencies, USA. | - Intention-to-treat analyses showed no differences in sleep quality or fatigue between the intervention and wait-list control groups at 3 months.<br>- Per-protocol analyses revealed that the more education modules participants viewed, the greater the improvements in sleep quality and reductions in fatigue ($p < 0.05$). |
| Scheduling practices | | | | |
| Smith-Miller et al. (2016) | Mixed-methods | 1) Identify the barriers and facilitators in implementing a fatigue management plan.<br>2) Explore and evaluate the effects of a fatigue management intervention on nursing staff, time and attendance, and work culture. | 614 nurses across 4 nursing units, USA. | - Nurses' work habits related to breaks and staying past their shift were influenced by the unit culture.<br>- The percentage of staff with high levels of intershift recovery increased and persistent fatigue scores improved.<br>- Charge nurses played a key role in ensuring breaks occurred, and assistive personnel helped minimise interruptions during shift change. |
| Biomathematical models | | | | |
| Cumber and Greig (2019) | Observational | Assess the feasibility and ease of using a pre-existing health and safety executive fatigue risk calculator to assess doctors' rotas. | 95 anonymized rotas for foundation year 1 and 2 doctors in general medicine, general surgery, & emergency medicine, UK. | - Nearly half of all shifts showed increased risk of fatigue-related errors and high sleepiness levels.<br>- Significant variation between specialties, with the general medicine rotas having the highest fatigue risk. |

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**Table 2** (*continued*)

| Author & year | Design | Aims | Participants & setting | Key findings |
|---|---|---|---|---|
| | | | | - Results are based on rotas, not 'work as done' and therefore are likely to underestimate fatigue risks. |
| Gander et al. (2020) | Observational | 1. Develop and test a matrix that incorporates multiple aspects of rosters and recovery sleep, which are individually associated with three fatigue-related outcomes: fatigue-related clinical errors, excessive sleepiness, and sleepy driving. | Survey of 2358 nurses, New Zealand. | - The final matrix included 8 variables: total hours worked, shift extensions, night shifts, breaks under 9 h, breaks over 24 h, sleep opportunities from 11 pm-7 am, days feeling fully rested, and roster changes.<br>- Higher matrix scores were significant predictors of reported excessive sleepiness, fatigue-related errors, sleepy driving, and problems with social life, home life, personal relationships, and other commitments. |
| McCormick et al. (2013) | Observational | 1) Use a fatigue optimisation tool to calculate and compare the predicted fatigue impairment in surgical residents under different work schedules.<br>2) Identify specific times and rotations where residents were most affected by fatigue.<br>3) Test if implementing countermeasures could minimise the fatigue. | Computer simulation tool (Fatigue Avoidance Scheduling Tool (FAST) to analyse 4 different surgical rotations, USA. | - Simulations showed significant differences in predicted fatigue levels between the schedules.<br>- Night shift schedule had highest fatigue, with residents predicted to work more than 50 % of the time while critically fatigued.<br>- Implementing fatigue countermeasures for the night shift, such as naps and schedule changes, improved the predicted effectiveness to 87.1 % and reduced critical fatigue to only 1.9 % of the time ($P < 0.001$). |
| Schwartz et al. (2021) | Observational | 1) Analyse surgical residents' schedules and predict their fatigue levels and performance using a biomathematical model.<br>2) Assess the impact of hypothetical naps on predicted performance. | Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model used to analyse duty hours and schedules of 89 surgery residents, USA. | - Analysis showed that residents had moderate levels of fatigue risk, with at least 8 h of sleep debt during 24.36 % of their shifts.<br>- Longer shifts (16–24 h and over 24 h) were predicted to have significantly more time with reduced performance.<br>- Addition of hypothetical naps improved the predicted performance and reduced the time with fatigue risk. |
| Multiple fatigue risk management strategies | | | | |
| Scott et al. (2010a) | Qualitative, focus group | Describe the structural, organisational, and environmental factors associated with the implementation of a fatigue countermeasures program for nurses (FCMPN). | 46 staff nurses, 8 nurse manager. 3 large acute care hospitals, USA. | - Staff nurses identified benefits of the program such as increased awareness of sleep needs, feeling more rested, and being able to control their lifestyle factors.<br>- Challenges included hospital work culture and physical environment.<br>- Nurse managers reported benefits such as building partnerships with employees and engaging in research.<br>- Managerial challenges included lack of organisational support, professional culture and issues with staffing levels. |
| Scott et al. (2010b) | Pre-test post-test, repeated-measures. | Evaluate the feasibility of a fatigue countermeasures program for nurses (FCMPN) for improving sleep duration, sleep quality, reducing daytime sleepiness, and reducing patient care errors. | 47 staff nurses. 3 large acute care hospitals, USA. | - Most nurses experienced poor sleep quality, severe daytime sleepiness, and decreased alertness at work and while driving.<br>- After the program, nurses reported significant improvements in sleep duration, sleep quality, alertness, and error prevention.<br>- However, nurses still experienced some level of daytime sleepiness and felt guilty when engaging in fatigue countermeasures such as napping. |
| Perception & attitudes | | | | |
| Cochran et al. (2021) | Cross-sectional | Assess nurses' willingness to accept fatigue reduction strategies. | 279 nurses, USA. | - Nurses expressed acceptance of several workplace fatigue reduction strategies including taking duty-free breaks, working 9-hour shifts, and limiting consecutive 12-hour shifts. |
| Groves et al. (2020) | Qualitative, Semi-structured interviews | 1. What are the barriers to fatigue management by hospital nurses, both at work and at home?<br>2. What are the strategies for fatigue management used by hospital nurses, both at work and at home?<br>3. What do nurses suggest as potential solutions that hospitals could offer for managing fatigue? | 41 nurses. 8 hospital settings, USA. | - Barriers to fatigue management at work included workload, pace, schedule, and nutrition.<br>- Strategies for fatigue management at work included moving, drinking caffeine, keeping busy, eating, and taking breaks.<br>- Nurses suggested organisational approaches to support fatigue management, such as breaks, naps, and adjustments to schedules and shifts. |

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**Table 2** (*continued*)

| Author & year | Design | Aims | Participants & setting | Key findings |
|---|---|---|---|---|
| Hill et al. (2020) | Mixed-methods | Implement an evidence-based approach to identify, monitor, and reduce nurse-leader fatigue and increase retention rates within 12 months at a healthcare organisation. | 5 executive leaders, 56 nurse leaders, USA. | - Nurse leaders experienced moderate to high levels of fatigue, with scores in the 2nd and 3rd quartiles of the Occupational Fatigue and Exhaustion Recovery (OFER15) scale.<br>- Scores did not show a statistically significant change after roundtable intervention.<br>- However, positive feedback and reflections from nurse leaders indicate that the roundtable format was effective in creating a safe and collaborative environment, which helped to reduce stress and improve relationships between nurse leaders and executive leadership. |
| Kassam et al. (2019) | Qualitative, Semi-structured interviews | Explore the perceived impact of residents' experiences of fatigue and the mitigating strategies they identified as useful, which could be used to inform the development of Fatigue Risk Management Plans (FRMPs). | 57 resident physicians, Canada. | - Residents experienced fatigue in different ways, with impacts on their physical, cognitive, and emotional states.<br>- Fatigue was found to affect residents' personal/family life, work performance, patient care, and self-care.<br>- Residents reported using strategies at the individual (self), program, and system levels to manage their fatigue. |
| Konkol et al. (2024). | Cross-sectional | 1) Examine the perceived impact of shift work on work and personal life experiences.<br>2) Examine the use of fatigue countermeasures.<br>3) Examine potential interventions to minimise the effects of shift work stressors. | 186 inpatient nurses. University hospital, USA. | - Significant differences in nurses' perceptions between day and night shifts.<br>- Use of fatigue countermeasures, such as napping and using medication, more common during night shifts.<br>- Nurses most interested in using blackout curtains and an on-site exercise facility to address the effects of shift work.<br>- Nurse leaders should consider nurses' perspectives when implementing initiatives to mitigate the effects of shift work. |
| Pi et al. (2025) | Qualitative, Semi-structured interviews | To explore clinical nurses' lived experiences of work fatigue risk and identify factors that hinder or facilitate its management. | 25 nurses.<br>Tertiary hospital, China | - Hindering factors included staff shortages, poor workplace welfare, role mismatch, and weak organisational cohesion.<br>- Facilitating factors involved cognitive reframing, support systems, active coping, and behavioural change. |
| Steege and Dykstra (2016) | Qualitative, Semi-structured interviews | 1) What do hospital nurses identify as factors in the work system contributing to or preventing the development of occupational fatigue?<br>2) What do hospital nurses perceive as barriers and facilitators to coping with fatigue in their work system? | 22 nurses.<br>University hospital, USA. | - Analysis revealed multiple themes related to factors contributing to or preventing fatigue, as well as barriers and facilitators to coping, across the five components of the Systems Engineering Initiative for Patient Safety (SEIPS) model (physical environment, tasks, tools and technology, organisation, and person).<br>- Some themes had both positive and negative impacts on fatigue and coping. |
| Steege and Rainbow (2017) | Qualitative, Semi-structured interviews | Explore barriers and facilitators within the hospital nurse work system to nurse coping and fatigue. | 22 nurses.<br>University hospital, USA. | - All nurses experienced fatigue but had varying perspectives on the importance of addressing it compared to other health system challenges.<br>- Researchers identified a new construct related to nursing professional culture, defined as "Supernurse."<br>- These values, beliefs, and behaviours within nursing culture can act as barriers to fatigue risk management programs and achieving safety culture. |
| Taylor et al. (2019) | Qualitative, Semi-structured interviews | Understand medical students' perspectives on fatigue and explore how students cope with the workplace fatigue they face during their clinical training. | 22 third-year medical students.<br>University hospital, Canada. | - Participants described unprecedented levels of sleep deprivation and uncertainty during their training.<br>- Fatigue perceived as a threat to personal health, patient care, and professional reputation.<br>- To manage threats, students used strategies like perseverance, faith in the healthcare system, and stoicism. |
| Fatigue risk management design principles | | | | |
| Steege et al. (2022) | Qualitative, Semi-structured interviews | Understand hospital nurses' current fatigue risk management, identify design goals and | 21 nurses.<br>University hospital, USA. | - Nurses described fatigue risk management as a pursuit of balance between work demands and capacity to meet those demands at |

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Table 2 (*continued*)

| Author & year | Design | Aims | Participants & setting | Key findings |
|---|---|---|---|---|
| | | principles, and obtain feedback on fatigue risk management design concepts. | | multiple levels: individual, unit, hospital, over time.<br>- Seven design principles were identified and applied to two initial design concepts for fatigue risk management tools.<br>- Participants provided positive feedback on the designs including the ability to focus attention on fatigue, to communicate needs, guide interventions and to trend monitor. |
| Current understanding of fatigue risk management | | | | |
| Steege et al. (2017a) | Mixed-methods | Understanding the current state of fatigue risk management systems to address nurse fatigue in hospitals. | 21 nurse leaders interviewed, 189 survey respondents compromising of hospital nurse executives, directors, and managers, USA. | - Only 23 % of respondents indicated that they have an organisational fatigue management policy in place.<br>- 25 % respondents reported some level of fatigue management, e.g., Employee Assistance Programme (EAP), task reallocation, dedicated rest areas.<br>- Most organisations do not have adequate systems to monitor fatigue in individual nurses or nursing leaders.<br>- 90 % of participants report not having the tools to support decision-making about fatigue management. |
| Steege et al. (2017b) | Mixed-methods | 1) What is the state of adoption of evidence-based policies to address fatigue in nurses?<br>2) What is the current state of preparedness of hospitals to adopt fatigue risk management systems? | 21 nurse leaders interviewed, 189 survey respondents compromising of hospital nurse executives, directors, and managers, USA. | - Adoption of evidence-based policies to address fatigue is limited and variable.<br>- Only about half of the organisations had policies limiting nurse shift scheduling, and very few had policies supporting nurse napping or providing alternative transportation for fatigued nurses.<br>- Only 13 % of organisations provide fatigue risk management education to nurse managers and supervisors.<br>- Many organisations lack the necessary antecedents for change, such as making fatigue a priority and engaging key stakeholders. |

absence of a control group and adjustments for confounding factors limit the strength of these findings.

Qualitative findings (Scott et al., 2010a) highlighted cultural barriers with nurses expressing guilt over taking breaks or naps and struggling to mentally disengage from work, particularly during busy shifts. Despite reporting improvements and advantages including a better understanding of sleep needs, increased rest, and increased ability to control lifestyle factors, these cultural issues still arose after implementation of the programme. At the unit level, even though nurse managers initially anticipated implementation challenges, they reported that the programme was relatively easy to integrate and helped foster trust within teams. Nonetheless, barriers such as workplace culture, limited organisational support, and staffing constraints complicated implementation.

### 3.2. Perception and attitudes

Nine studies focused specifically on investigating the perceptions and acceptance of various fatigue risk management strategies and countermeasures, as well as identifying the barriers and facilitators to their implementation (Cochran et al., 2021; Groves et al., 2020; Hill et al., 2020; Kassam et al., 2019; Konkol et al., 2024; Pi et al., 2025; Steege and Dykstra, 2016; Steege and Rainbow, 2017; Taylor et al., 2019).

#### 3.2.1. Acceptance of fatigue risk management strategies

Across studies, nurses demonstrated varying levels of acceptance towards fatigue risk management strategies, with an overall preference for interventions that aligned with their needs and workplace realities. For instance, Cochran et al. (2021) reported high acceptance of strategies such as breaks from duty (75 % participants), not adding extra shifts (80 % participants), and refraining from working beyond scheduled hours (87.4 % participants). However, only 41.5 % of participants expressed acceptance of shorter shifts (e.g., nine-hour shifts). Nurse participants in a study by Groves et al. (2020) had mixed views on whether napping was acceptable in their organisation, but they expressed interest in implementing structural changes like mandatory breaks and designated quiet areas to challenge existing norms and facilitate napping practices.

#### 3.2.2. Barriers to fatigue risk management

A key theme across studies was the prevalence of organisational and cultural barriers to fatigue risk management adoption. Studies highlighted a prevailing culture that prioritises patient care above healthcare worker needs and wellbeing, consequently hindering the recognition of fatigue as a critical concern for both patient and personal safety (Geiger-Brown et al., 2016; Smith-Miller et al., 2016). Steege and Rainbow (2017) conceptualised this cultural context as the “Supernurse” phenomenon, in which fatigue is normalised as an inherent part of the job, and admitting to it or seeking help is perceived as a sign of weakness (Steege and Rainbow, 2017; Taylor et al., 2019). This belief perpetuates a cycle in which fatigue is deprioritised, despite its known implications for safety (Arora et al., 2006; Bérastégui et al., 2018; Cumber and Greig, 2019; Groves et al., 2020; Scott et al., 2010a, 2010b; Steege and Rainbow, 2017; Stoller et al., 2005; Taylor et al., 2019).

Compounding cultural issues, significant organisational challenges such as excessive workloads driven by the complexity and intensity of patient care, resource constraints, understaffing, and physically demanding work environments, were frequently cited as obstacles to effective fatigue risk management implementation. Scheduling challenges, such as inconsistent shifts and rotations, also emerged as barriers, alongside inadequate break room facilities and management support (Centofanti et al., 2018; Geiger-Brown et al., 2016; Groves et al., 2020; Gyeltshen et al., 2023; Konkol et al., 2024; Pi et al., 2025; Smith-Miller et al., 2016; Steege et al., 2017a; Stoller et al., 2005). Additionally, a lack of education and awareness about the effects of fatigue contributes to its normalisation, as training in healthcare settings often emphasises other safety priorities, such as infection control and manual handling, over fatigue management (Bérastégui et al., 2018; Geiger-Brown et al., 2016; Lawson Carney, 2013; Smith-Miller et al., 2016; Steege and Dykstra, 2016; Steege and Rainbow, 2017).

### 3.2.3. Facilitators of fatigue risk management

The studies identified various facilitators for fatigue risk management implementation, often linked to structural and cultural improvements. At the organisational level, better staffing ratios and workload alignment, reduced administrative duties and non-nursing tasks, and improving processes such as handovers were recommended (Groves et al., 2020; Kassam et al., 2019; Pi et al., 2025). Technology was also seen as a facilitator when functional and accessible: for example, tools for electronic handovers, optimised scheduling, and real-time monitoring of fatigue (Pi et al., 2025; Steege and Rainbow, 2017). Moreover, creating a culture of safety and non-punitive support was seen as essential to encourage nurses to acknowledge fatigue and seek assistance (Konkol et al., 2024; Pi et al., 2025; Steege and Rainbow, 2017). However, one study reported mixed outcomes regarding the effectiveness of implementing a roundtable intervention to identify, monitor and reduce nurse fatigue (Hill et al., 2020). While nurse leaders expressed positive feedback about the roundtable for fostering trust and a safe space to discuss fatigue, self-reported fatigue scores did not show a statistically significant improvement after the intervention.

### 3.3. Fatigue risk management design goals and principles

Steege et al. (2022) identified four key design goals for fatigue risk management tools: 1) integrating data sources reflecting nursing role complexity, 2) enhancing existing processes without adding workload, 3) supporting proactive decision-making, and 4) ensuring stakeholder flexibility. However, cultural barriers and concerns about punitive use were identified as implementation challenges.

### 3.4. Current understanding of fatigue risk management

Steege et al. (2017a, 2017b) found that only 23 % of hospital nurses reported having any fatigue risk management policy, with most focusing solely on limiting work hours. Critical gaps included a lack of systematic fatigue monitoring (90 % lacked sufficient tools), absent mandated nurse-to-patient ratios (85 % of hospitals), and limited training (only 13 % provided education for nurse managers). Additionally, 44 % of nurses felt unsupported by their organisations in managing fatigue.

## 4. Discussion

This review aimed to assess the current state of knowledge regarding fatigue risk management strategies and countermeasures in healthcare, including the barriers and facilitators influencing their successful implementation. Based on an evaluation of 32 studies, this review identified a range of strategies used to address fatigue-related risks in healthcare, including reactive methods such as informal and individual coping, proactive strategies such as scheduling adjustments and fatigue education initiatives, and predictive tools such as biomathematical modelling. Despite an expanding evidence base evaluating a range of fatigue countermeasures, the research remains fragmented with the majority of studies examining fatigue risk management strategies in isolation and focusing on specific countermeasures rather than comprehensive and system-wide approaches.

Whilst many of the strategies outlined do demonstrate potential in reducing fatigue-related impairments and improving performance, their acceptance and effectiveness vary depending on factors such as resourcing, organisational support, and workplace culture. Furthermore, many of the studies utilised small sample sizes and lacked long-term follow-up, making it difficult to determine whether observed improvements in fatigue or performance were sustained over time. Interventions such as the holistic fatigue countermeasure programme (Scott et al., 2010a, 2010b) and scheduled napping (Geiger-Brown et al., 2016; Han et al., 2021) were also implemented in isolated units, with limited scope and evidence of system-wide scalability or cost-effectiveness.

The current adoption of fatigue risk management practices in hospitals also remains limited with few hospitals reporting any formal fatigue risk management policy, fatigue monitoring tools, or providing staff with awareness training. In contrast to more advanced approaches seen in other safety-critical industries such as aviation and rail, whereby these fatigue risk management elements are integrated within a formal framework and embedded in organisational governance, healthcare demonstrates a significant lag in implementation. This underlines the need for healthcare to shift from reactive, experience-based coping to structured and evidence-informed fatigue mitigation (Caruso et al., 2022; Pickup et al., 2025; Querstret et al., 2020).

### 4.1. The evidence-practice gap in fatigue risk management

Studies outlined in this review indicate the growing recognition of the need for fatigue risk management in healthcare. Interventions such as scheduled napping, fatigue education, and adjusted scheduling practices have demonstrated some potential as viable means of reducing fatigue-related risks and improving performance in healthcare settings. However, despite the evidence supporting the effectiveness of these fatigue risk management strategies, their implementation in real-world healthcare settings remains limited, informal, and inconsistently applied. This disconnect reflects a broader evidence–practice gap whereby interventions supported in research fail to translate into everyday clinical practice. In contrast, safety-critical industries such as aviation and rail have successfully embedded evidence-informed fatigue risk management strategies into organisational frameworks, supported by regulatory oversight and standardised protocols (International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024; Rangan et al., 2020). Healthcare, by comparison, has been slow to operationalise similar approaches. This gap between evidence and implementation reflects not only structural and resourcing challenges, but also a failure to embed fatigue risk management as a standard component of a wider organisational safety strategy (Caruso et al., 2022; Kellogg and Fairbanks, 2018; Pickup et al., 2025; Querstret et al., 2020).

Evidence from other safety-critical sectors demonstrates how evidence-based interventions can effectively reduce fatigue-related risks. For example, scheduling interventions designed to reduce extended shifts or allow sufficient rest periods have demonstrated positive outcomes in aviation and transport (Cabon et al., 2012; Gander et al., 2011; Rangan et al., 2020; Srivastava and Barton, 2012). A short-haul European airline demonstrated the effectiveness of a systematic approach by using operational data, predictive fatigue modelling, and pilot feedback to develop a fatigue risk management system that directly informed the redesign of crew rosters. This evidence-based approach not only reduced identified fatigue risks but also secured regulatory approval for more flexible scheduling beyond standard flight time limitations (Srivastava and Barton, 2012; Stewart et al., 2006). Such approaches are underpinned by regulatory mandates, standardised data collection practices, and a coherent framing of fatigue as a systemic safety hazard. In contrast, these elements are largely absent in healthcare systems (Pickup et al., 2025).

The successful implementation of fatigue risk management in aviation can be attributed to structural features that are often lacking in healthcare, such as clear regulatory oversight, data collection and continuous monitoring, and a culture that prioritises proactive risk mitigation. Conversely, the absence of robust mechanisms for collecting and monitoring fatigue-related data or 'evidence' in healthcare impedes organisational awareness of the true scale and nature of fatigue risk and therefore presents a significant barrier to the development of targeted and system-wide interventions (Pickup et al., 2025). Such interventions are essential not only to reduce dependence on potentially harmful and unsustainable individual coping strategies, such as excessive caffeine consumption and poor dietary habits (Stoller et al., 2005; Bérastégui et al., 2020), but also to address other risks such as drowsy driving (Dawson and Thomas, 2019; Smith et al., 2020).

Normalisation Process Theory (NPT) (May and Finch, 2009; Murray et al., 2010) provides a valuable framework for understanding why such evidence-informed strategies may fail to translate effectively into healthcare practice. Normalisation Process Theory proposes that for a new practice or intervention to be successfully embedded or 'normalised' in the workplace, four key mechanisms are required. It must be understood and valued by stakeholders (coherence), be actively supported (cognitive participation), be operationally feasible (collective action), and be assessed and adjusted over time (reflexive monitoring). In healthcare, failures at one or more of these levels may explain the persistent gap between evidence and implementation of fatigue risk management strategies and countermeasures.

Bridging the evidence-practice gap will require coherent and coordinated engagement across all organisational levels, from frontline clinicians to senior leaders involved in policy, workforce planning, and investment decisions. Evidence suggests that collaborative approaches, central to cognitive participation, such as focus groups and roundtable discussions, are instrumental in fostering meaningful dialogue, identifying existing informal fatigue management strategies and co-creating tailored solutions that reflect the realities of everyday clinical work (Bérastégui et al., 2018; Geiger-Brown et al., 2016; Hill et al., 2020). Understanding the day-to-day perceptions, constraints, and practices of healthcare workers is essential to designing formal fatigue risk management procedures that are not only aligned with organisational goals but also reflect the realities of clinical practice, thereby supporting the mechanism of collective action (Kellogg and Fairbanks, 2018; Pickup et al., 2025; Redfern et al., 2023; Watts and Jackson, 2024). Furthermore, top-down behavioural change, with leadership demonstrating a commitment to fatigue management, is essential for shifting the prevailing culture (Steege and Rainbow, 2017; Redfern et al., 2023).

### 4.2. Cultural and systemic barriers: beyond individual responsibility

A consistent and critical theme across the literature reviewed is the deeply embedded cultural and systemic barriers that undermine the implementation of fatigue risk management strategies in healthcare. These challenges are not only contextual but are also rooted in professional norms and organisational structures that shape how fatigue is perceived, managed, and in many cases, overlooked in healthcare settings.

At the cultural level, healthcare institutions have historically placed the needs of patients above the health and wellbeing of staff, reinforcing a professional identity in which fatigue is viewed as an inherent and accepted aspect of healthcare practice. This normalisation of fatigue, exemplified by the "Supernurse" concept (Steege and Rainbow, 2017), positions fatigue as a marker of professional dedication rather than a legitimate safety risk and contributes to a widespread reluctance to address it as a systemic concern (Pickup et al., 2025; Redfern et al., 2023). This cultural framing is further compounded by a general lack of awareness and education regarding fatigue and its consequences, with training often prioritising other safety concerns such as disease prevention and manual handling over fatigue management (Steege and Dykstra, 2016; Steege and Rainbow, 2017).

Research using medical residents as participants has highlighted that this professional culture is instilled early in training (Taylor et al., 2019). Students often perceive enduring fatigue to be a normal part of training and a necessary sacrifice, a perception that is reinforced by superiors operating within the same cultural norms (Steege and Rainbow, 2017; Redfern et al., 2023). This ingrained acceptance of fatigue as 'normal' can impede the adoption of effective fatigue management strategies throughout a healthcare worker's career (Steege and Rainbow, 2017; Redfern et al., 2023; Taylor et al., 2019).

Compounding these cultural dynamics are systemic shortcomings that further hinder the implementation of any kind of fatigue risk management framework or system. The responsibility for managing fatigue is frequently placed on individual workers, with limited organisational accountability for work design, staffing, or scheduling practices that contribute to fatigue risk (Shnayder et al., 2017; Steege and Dykstra, 2016; Taylor et al., 2019). A shift towards shared responsibility between employee and employer is crucial (Groves et al., 2020; Ippolito et al., 2024; Steege and Rainbow, 2017). However, practices such as praising staff for working overtime or picking up extra shifts can reinforce counterproductive cultural norms (Steege and Dykstra, 2016; Steege and Rainbow, 2017; Taylor et al., 2019). Furthermore, laws and policy in some countries prohibit sleep during work hours and do not protect workers from being dismissed for refusal to work as a result of fatigue, further perpetuating these norms (Cochran et al., 2021; Gyeltshen et al., 2023; Ippolito et al., 2024; Scott et al., 2010a).

Other systemic barriers such as resourcing and lack of support can further exacerbate these cultural issues. For example, while short naps are recognised in the wider literature as effective in restoring alertness and cognitive performance (Caldwell et al., 2019; Querstret et al., 2020; Gregory et al., 2021; Zion and Shochat, 2019), their implementation in healthcare settings is often constrained by inadequate staffing, high workload, and the absence of suitable rest environments (Centofanti et al., 2018; Groves et al., 2020; Konkol et al., 2024; Zhang et al., 2023). Moreover, healthcare professionals often report feelings of guilt or stigma when using designated break time for rest, therefore undermining the effectiveness of such interventions (Landis et al., 2021; Sagherian et al., 2023; Shnayder et al., 2017; Smith-Miller et al., 2016). As a result, organisations must go beyond simply providing rest facilities by actively promoting and legitimising their use to facilitate the normalisation of practices like napping as a valid and necessary fatigue mitigation strategy (Konkol et al., 2024; Shnayder et al., 2017; Zion and Shochat, 2019).

Finally, unlike other safety-critical industries such as aviation or rail, healthcare has yet to consistently adopt a proactive and non-punitive approach to error reporting and fatigue disclosure. In these sectors, fatigue is treated as a reportable and mitigatable risk that is embedded within formalised safety management systems (Pickup et al., 2025; Steege et al., 2017a, 2022). Without a fundamental shift in safety culture towards transparency, shared accountability and systemic learning, frontline healthcare workers may remain reluctant to report fatigue, challenge unsafe working conditions or fully engage with fatigue risk management processes, further hampering progress towards developing mature and sustainable fatigue risk management systems within healthcare.

### 4.3. The promise and limitations of technology-based solutions

Proactive and predictive tools, such as biomathematical fatigue models, have demonstrated potential in forecasting fatigue-related risk and informing safer scheduling practices across safety-critical sectors like aviation and rail (Dawson and McCulloch, 2005; International Civil Aviation Organization, 2015; Office of Rail and Road, 2024; Stewart et al., 2006). These models offer predictive insights into fatigue risk by simulating work–rest patterns and circadian rhythms and are used to support roster design, minimise cumulative fatigue, and ensure compliance with rest requirements (Civil Aviation Safety Authority, 2014; Folkard et al., 2007; Dawson et al., 2011; RSSB, 2019; Wilson et al., 2021).

Despite their use in other industries, the integration of biomathematical models into healthcare remains limited. One major barrier is the disconnect between the assumptions underpinning these models and the operational realities of clinical work. Predictive models are built around standardised duty and rest patterns and population averages that may align well with more structured environments such as aviation but are often not as well suited to the unpredictability of healthcare settings where staff often work beyond scheduled hours due to staffing shortages, emergent patient needs, and unpredictable workloads (Dawson et al., 2011, 2017). This results in a disconnect between 'work as imagined', or the theoretically planned schedule, and 'work as done', the reality of clinical operations (Dawson et al., 2011; Hollnagel, 2017). Moreover, biomathematical models typically fail to capture key contextual variables that significantly influence fatigue risk in healthcare, including workload intensity, individual resilience, decision-making complexity, staff grade differences, and the emotional demands of patient care (Cumber and Greig, 2019; Gander et al., 2020; McCormick et al., 2013). As such, while these models offer useful predictive insights, they provide only a partial view of actual fatigue risk.

Nevertheless, when used appropriately, biomathematical models can serve as a valuable component of a broader fatigue risk management system. They can support proactive scheduling decisions, inform real-time operational choices such as shift swapping, and can be used to identify optimal moments for employing targeted countermeasures such as napping or strategic breaks (Gander et al., 2020; McCormick et al., 2013; Schwartz et al., 2021). However, their utility in this regard will depend on how the outputs are interpreted and operationalised. A biomathematical model should not be used as a standalone or definitive assessment tool and numerical compliance with fatigue thresholds should never be treated as sufficient evidence of a safe system (Dawson et al., 2011, 2017). Predictive insights provided by the models should serve as a valuable component within a holistic and adaptive fatigue risk management system that reflects the complex and dynamic nature of healthcare work.

### 4.4. Towards a system-wide approach

Findings from this review highlight that fatigue risk management in healthcare is characterised by a fragmented and predominantly reactive approach, with interventions often limited to isolated, individual-level strategies shaped by workplace cultures that normalise and individualise fatigue (Caruso et al., 2022; Pickup et al., 2025; Steege and Dykstra, 2016). Whilst the current reliance on individual adaptability demonstrates workforce resilience, it ultimately fails to recognise fatigue as a systemic safety risk (Dawson and McCulloch, 2005; Farquhar, 2017; Pickup et al., 2025).

Moving towards a system-wide approach to fatigue risk management will require a significant cultural and structural shift from individual responsibility to organisational accountability. The International Civil Aviation Organization (2015) defines a fatigue risk management system as a data-driven framework for managing fatigue-related safety risks, grounded in scientific principles and operational experience. This definition underlines a shift from placing responsibility on individual workers to recognising fatigue as an organisational concern and emphasises the need for multi-level interventions, continuous monitoring and improvement, and integration within a broader safety management system. In healthcare settings, however, these elements remain largely absent and fatigue is still largely self-managed, unmeasured, and interventions are often isolated rather than coordinated (Pickup et al., 2025; Steege et al., 2017a, 2017b, 2022).

In comparison, high-reliability industries such as aviation and rail have successfully embedded fatigue risk management into mature, proactive safety management systems. These sectors have evolved from reactive, incident-driven safety responses (Safety-I) to more proactive, resilience-oriented models (Safety-II) that seek to anticipate and mitigate risk before harm occurs (Hollnagel et al., 2015). Features of these systems include continuous data monitoring, regular auditing, iterative policy refinement, and clearly defined accountability for managing fatigue risk (International Civil Aviation Organization, 2015, 2016; RSSB, 2019).

Several key structural and operational differences may explain why these industries have succeeded where healthcare has fallen behind. Aviation and rail are governed by centralised regulatory bodies, operate within more predictable scheduling environments, and benefit from more investment in resourcing, safety infrastructure and quality improvement (Macrae and Stewart, 2019; Pickup et al., 2025). Fatigue management in healthcare may be perceived as a secondary concern until supported by economic evaluations demonstrating long-term cost savings through improved staff retention, reduced absenteeism, and enhanced patient safety (Macrae and Stewart, 2019; Pickup et al., 2025).

Despite these challenges, the implementation of systemic fatigue risk management within healthcare is not beyond reach. Evidence from the one set of studies to evaluate a holistic fatigue risk management programme at both individual and unit levels suggests that a multi-component approach, including implementing structured breaks, strategic napping, and educational initiatives can lead to improvements in sleep quality, alertness, and job performance (Scott et al., 2010a, 2010b). Whilst these findings demonstrate the practical feasibility of applying a holistic fatigue risk management approach, the strength of this evidence is constrained by methodological limitations, including small sample size and pre-experimental design that restrict the generalisability of the results. Further research is needed to evaluate long-term effectiveness and sustainability across different healthcare environments. Furthermore, without integration into a broader organisational safety management system framework, these interventions risk remaining temporary and unsustainable, reinforcing the cycle of reactive and individualised fatigue management and therefore limiting their overall impact (Bérastégui et al., 2018, 2020; Dawson et al., 2012; Redfern et al., 2023).

Ultimately, advancing a system-wide approach to fatigue risk management in healthcare will require both structural reform and cultural change. Organisational leadership must take active ownership of fatigue as a shared safety risk. Whilst the complexity and unpredictability of healthcare will mean fatigue risk management models used in other sectors cannot be simply replicated, the sector can adapt core principles such as accountability, data collection, data monitoring, and continuous improvement to fit its unique operational context. This will involve embedding fatigue risk management within an organisational safety management system, allocating appropriate resources, and supporting a culture in which staff wellbeing is recognised as integral to patient safety.

### 4.5. Limitations

The broad search strategy used for this review returned varied results that encompassed various measures of fatigue, implementation outcomes, multiple populations, and varying sample sizes and therefore the depth of analysis within specific intervention types is limited. Conclusions about the effectiveness of a holistic fatigue risk management approach cannot be drawn, although potential factors influencing its implementation have been identified. Additionally, the lack of quality assessment in scoping reviews limits conclusions based on evidence strength (Peters et al., 2020). Despite these limitations, this review provides an overview of the current knowledge on fatigue risk management in healthcare, highlights research gaps, and serves as a guide for future study considerations.

### 4.6. Future steps and implications for research

The outlined research has documented how frontline healthcare staff develop and rely on informal experience-based strategies to manage their fatigue despite limited evidence of their effectiveness (Bérastégui et al., 2018, 2020; Kassam et al., 2019; Stoller et al., 2005; Taylor et al., 2019). The reliance on informal fatigue management strategies, while fostering individual resilience, can contribute to a disconnect between planned work policies and actual workplace practices, as management remains unaware of the mitigations implemented by staff (Bérastégui et al., 2018; Hollnagel, 2017). Furthermore, the perspective of senior managers and decision-makers and the extent to which their views align or conflict with those of frontline staff remains unexplored. The extent to which evidence-based fatigue risk management strategies and policies are implemented across healthcare organisations also remains unclear. Identifying and understanding both frontline and management perspectives together is critical for bridging the gap between policy and practice and for ensuring the development of a fatigue risk management framework (and ultimately a fatigue risk management system) that is both evidence-based and practical for real-world application (Bérastégui et al., 2018; Dawson et al., 2012; Groves et al., 2020; Kassam et al., 2019; Smith-Miller et al., 2016).

Furthermore, to align with the data-driven approach of fatigue risk management systems (International Civil Aviation Organization, 2015, 2016; Office of Rail and Road, 2024; Steege et al., 2022), fatigue risk needs to be measured. Only one study outlined in this review included an objective measure of fatigue (Han et al., 2021). Future research should include both subjective and objective measures of fatigue to bridge the gap between 'work as planned' and 'work as done' (Gander et al., 2020; Gyeltshen et al., 2023; Hollnagel, 2017; Schwartz et al., 2021). For example, the use of actigraphy data obtained from wearable devices, including smartwatches, could validate assumptions about work patterns and fatigue. Integrating both objective and subjective measures would enable the refinement of existing guidelines and fatigue models, thereby enhancing their accuracy and applicability (Han et al., 2021; Gander et al., 2020; Gyeltshen et al., 2023; Schwartz et al., 2021; Steege et al., 2022). Moreover, given the inherently data-driven nature of fatigue risk management systems, any effective system must include continuous data collection and monitoring to facilitate its ongoing improvement (Gander et al., 2020; Steege et al., 2022). Proactive monitoring of data ensures that the desired outcomes of implemented strategies are achieved while minimising the risk of unintended consequences (Gander et al., 2020).

## 5. Conclusion

This review highlights a significant maturity gap between fatigue risk management in healthcare and more advanced, systemic approaches established in other safety-critical industries. The path forward requires fundamental cultural and structural changes that recognise fatigue as a predictable and manageable systemic safety risk requiring organisational accountability rather than individual resilience. Lessons from sectors like aviation and rail demonstrate that the effective implementation of fatigue risk management systems is underpinned by clear governance, strong organisational commitment, technological solutions, and continuous improvement. Whilst the complexity and unpredictability of healthcare mean it cannot simply replicate the fatigue risk management models used in other domains, it can adapt core principles and take a similar systemic approach to close this gap to prioritise both staff wellbeing and patient safety.

## CRediT authorship contribution statement

**Stephanie Fox:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Chiara Dall'Ora:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Mark Young:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

## Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used generative AI (ChatGPT) in order to proof-read and copy-edit text. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Given her role as Senior Associate Editor of IJNS, Dr. Chiara Dall'Ora had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor.

The other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

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