

## Clinical Review

# How should we manage fatigue in on-call workers? A review of guidance materials and a systematic review of the evidence-base

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## ABSTRACT

On-call work is known to contribute to disrupted sleep, fatigue, and an increased risk of incident or injury. This review aimed to a) identify current on-call management strategies that are suggested or required by regulatory bodies, and b) determine if there is empirical evidence to support these strategies in managing the fatigue of on-call workers. A grey literature search produced 65 relevant guidance materials. A systematic inductive thematic process identified consistent strategies included in these materials: 1) regularity/predictability of shifts, 2) fatigue management policy, 3) prescriptive rule sets, 4) fitness for work assessment, 5) on-the-day control measures, 6) risk assessment, 7) training and education, and 8) call management. Subsequently, a systematic review identified 17 original studies on the effectiveness of fatigue management strategies in on-call workers. Very little research has been done on fatigue management strategies for on-call workers outside of some prescriptive hours of work limitations. These limitations generally reduced fatigue, but often had the unintended consequence of increasing workload, which may inadvertently increase overall risk. Training, education, and call management (e.g., protected naps during on-call periods) also had some supporting evidence. The current gap in evidence emphasises the critical need for research on tailored on-call fatigue management strategies.

## 1. Introduction

Many organisations use on-call or standby work, which are generally defined as work arrangements where workers are required to be available to respond to calls and/or attend the workplace on demand, to ensure workforce coverage, manage inconsistent workloads, or to respond to critical incidents [1–3]. Estimates indicate that between 19 and 23 % of workers undertake on-call work across the United States, Europe, and Australia [4–7]. Scheduled on-call periods may occur during the day or night – though on-call working arrangements are more common overnight in some industries (e.g., healthcare, emergency response) due to reduced or inconsistent workloads, or the need for emergency response [1].

Overnight on-call work is, by nature, associated with broken sleep, reduced time spent sleeping, and/or a perception of poor quality sleep [3,8]. Poor quality or shortened sleep typically results when workers are called but can also occur even when no calls are received [9,10]. As a result, on-call periods are likely to result in increased worker fatigue [11,

12], which is associated with an increased risk of incidents, both at work and while driving to and from work [13,14]. Moreover, on-call work is often linked with increased stress [8,15,16], which can also increase the likelihood of fatigue [17]. Consequently, in line with legislative obligations, workplaces typically have systems in place to manage fatigue in on-call workers, though systems vary between and within industries.

Advice provided by some regulatory bodies indicates that workers scheduled to be on-call continuously for longer than a 7-day period should be classified as ‘higher risk’ [18], while others suggest classifying all on-call schedules as equally high-risk, regardless of call volume or activities undertaken when called [19]. Additionally, some guidelines appear to indicate that fatigue should be managed in on-call workers, but do not provide specific advice on how this might be achieved (e.g., ‘mitigations should be in place if fatigue is experienced by on-call surgeons’ [20]). Beyond the apparent inconsistencies, it is unclear whether the strategies used to manage fatigue in on-call workers are evidence-based and/or effective in managing fatigue-related risk. As a result, this review aims to

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1. Identify current on-call management strategies that are suggested or required by regulatory bodies in Australia and internationally; and
2. Determine if there is empirical evidence to support the effectiveness of the suggested or required strategies in managing the fatigue of on-call workers.

## 2. Aim 1: guidance and regulatory material review methods

### 2.1. Eligibility criteria

To identify strategies for managing on-call work that are currently suggested or required by regulatory bodies, a grey literature search was undertaken. To be included, documents had to include specific guidance or regulation on how industries and/or organisations should manage fatigue associated with on-call work (i.e., it was not sufficient to describe a research study that investigated on-call work). Guidance materials and regulations from both Australian and international jurisdictions were eligible for inclusion.

### 2.2. Search strategy

Several steps were taken to identify relevant documents: 1) a systematic search of online grey literature databases, 2) hand search of targeted websites, and 3) targeted searches via an online search engine (Google), in line with the systematic review of grey literature search strategy outlined by Godin et al. [21]. Four online grey literature databases (Informit, Analysis & Policy Organisation (APO), OpenGrey, OAIster) were searched using the following search terms: “on-call”, “standby”, “fatigue”, and “work”. The comprehensive search strategy can be seen in [Supplementary Table 1](#).

The second part of this search strategy was to search a range of regulatory and government websites to identify relevant on-call guidance/regulatory materials. These websites were searched based on the knowledge and experience of the research team who are subject matter experts in this area. Where guidance or regulation was given on the website directly (i.e., without redirecting to a specific document), the information was saved and included in this review.

Following the systematic website search, a targeted search was undertaken using an online search engine (Google, California, United States). Search terms can be seen in [Supplementary Table 2](#). For each set of search terms, the first ten pages of results (representing 100 hits) were searched, in line with existing search strategies [21]. Search terms included government URL components for Western jurisdictions that are similar to Australia in their regulatory frameworks, to ensure that all relevant guidance or regulatory materials that may be applicable to the Australian context were identified.

### 2.3. Document selection

All documents identified as part of the search strategy were evaluated by MS to identify materials that aligned with the pre-determined inclusion criteria, described above. Documents were then reviewed by KK to adjudicate inclusion.

### 2.4. Data items

The following data were extracted from all included guidance and regulatory materials: the specific on-call management guidance or regulation (note that some documents had several on-call management suggestions or requirements), document title, document jurisdiction, target industry (e.g., aviation, emergency services, healthcare) and any evidence (e.g., citations) used to support the information provided.

### 2.5. Data extraction process

Once the grey literature search was completed, data were extracted

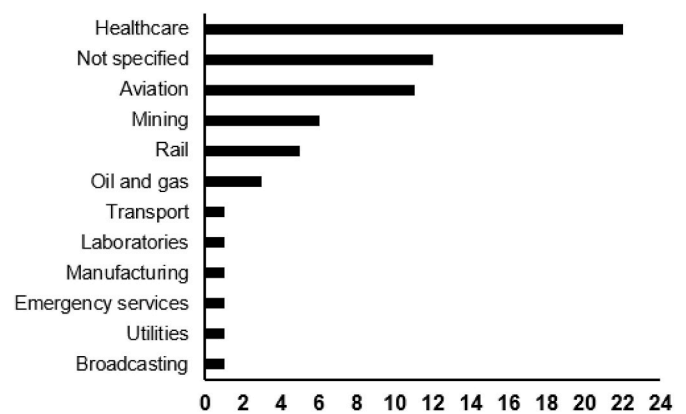


Fig. 1. Industries targeted by included documents.

from all relevant documents and organised into a data extraction table. MS and KK then systematically assessed each on-call fatigue management suggestion or recommendation and collaboratively identified consistent themes. This inductive process was undertaken by first identifying each of the separate on-call fatigue management strategies recommended by each document (often more than one per document). For example, one verbatim recommendation was ‘Minimise continuous hours of wakefulness before and during duty periods that are unscheduled. When being called-in is highly likely, establishing minimal notification periods before the individual can be asked to report for duty allows the opportunity for some sleep’ [22]. These suggestions and recommendations were then open coded at the first stage to identify strategies (e.g., ‘minimise time spent awake before and during on-call periods’, ‘minimise calls during the biological night’). Following this process, codes were clustered to identify overarching themes across all included materials.

## 3. Aim 1: guidance and regulatory material review results

### 3.1. Guidance and regulatory material selection

The first step of the search strategy included a search of four online grey literature databases. While these searches produced a number of documents (Informit: 267 results; APO: 3; OpenGrey: 5; OAIster: 910), no regulatory or industry guidelines met the inclusion criteria. The second step involved a targeted search of regulatory and government websites to identify relevant on-call guidelines. Key websites from relevant regulatory international bodies were identified (see [Supplementary Table 3](#)). These websites were identified to capture key governmental regulators that apply across industries (e.g., SafeWork Australia) in addition to specific regulators for industries that traditionally use on-call work (e.g., Office of the National Rail Safety Regulator [rail], Royal College of Physicians and Surgeons Canada [healthcare], European Union Aviation Safety Agency [aviation]), producing a total of 19 relevant documents that provided guidance or regulation on managing on-call work, which were included in this review. The third step in the review process, a systematic online search, produced a total of 600 documents or webpages (i.e., the top 100 items for each of the six search queries used; see [Supplementary Table 2](#)). Following a review of each item returned by the search, 89 items were deemed relevant. Once duplicates were removed, 65 documents were included in the final review.

### 3.2. Guidance and regulatory material characteristics

Included guidance and regulatory materials were from a range of jurisdictions including Australia (n = 25), Canada (n = 9), United States (n = 6), New Zealand (n = 7), United Kingdom (n = 5), multiple

**Table 1**  
On-call management themes emerging from grey literature search.

On-call management theme	Example guidance
1. Regularity and predictability of shifts	<i>Work time should be regular and predictable to support adequate sleep where possible.</i>
2. Fatigue management policy development	<i>Organisations should have, or consider, a working hours policy for on-call work.</i>
3. Prescriptive rule sets	<i>Maximum number or duration of on-call periods.</i>
4. Fitness for work assessment	<i>On-call responsibility should consider subjective assessment of fatigue.</i>
5. On-the-day control measures	<i>Consider providing transport home after on-call periods.</i>
6. Risk assessment	<i>Undertake a risk assessment before waking an on-call worker.</i>
7. Training and education	<i>Ensure workers are aware of the risks associated with fatigue through provision of training and information.</i>
8. Call management	<i>The on-call worker who has responded to the fewest previous calls should be called first.</i>

**Table 2**  
Overview of fatigue management recommendations in on-call workers.

Fatigue Management Strategy	Total Documents	Documents with Scientific Evidence	Documents with Reference List	Documents with No Evidence
Regularity and predictability of shifts	9	4	1	4
Fitness for work assessments	3	2	0	1
On-the-day control measures	15	3	4	8
Call management	11	4	2	5
Fatigue management policy development	34	12	0	22
Prescriptive rule sets	32	14	0	18
Risk assessment	13	3	2	8
Training and education	8	3	1	4

"Documents with Scientific Evidence" refers to those containing specific citations or references to scientific studies. "Documents with Reference List" indicates documents that provided a general list of references at the end. "Documents with No Evidence" denotes documents that did not include any scientific references or evidence.

jurisdictions/appliable internationally (n = 4), Unknown (n = 3), both Australia and New Zealand (n = 2), the European Union (n = 1), Malaysia (n = 1), Britain and Ireland (n = 1) and South Africa (n = 1). A range of different industries were represented, with included documents primarily making suggestions or recommendations for fatigue management in on-call workers working in healthcare or across multiple industries (see Fig. 1). The full data extraction table can be found in Supplementary Table 4.

### 3.3. Guidance and regulatory material themes

Through the collaborative process used to identify key themes within the included documents, eight common themes emerged from the data (see Table 1).

The themes that were included most within the included documents were: the development of fatigue management policy (n = 34), prescriptive rules sets (n = 32), on-the-day control measures (n = 15), call management (n = 11), risk assessment (n = 13), training and education (n = 8), shift regularity and predictability (n = 9) and fitness for work assessments (n = 3), see Table 2. At least one of the eight themes was

**Table 3**  
Search terms based on PIO outline.

Population	AND	Fatigue management theme	AND	Eligible Outcome
On-call OR On call OR Call back		Fatigue management OR Rule Sets OR Risk control OR Fitness for work OR Fitness for duty OR Control measure OR Training OR Education OR Call management OR Risk assessment OR		Sleep Error Safety Performance Fatigue symptoms

Note: Table 3 shows the search criteria that will be used with Boolean operators "And" and "Or". The use of "Or" between populations and themes will be used to broaden the search, while "And" will be used to narrow down results to those that match both populations and themes.

recommended 125 times across the included 65 documents. Of 125 recommendations, 72 did not report any supporting evidence, 21 recommendations were made in documents that had a reference list at the end of the document (though no specific links were made to on-call guidance or regulation), and 32 recommendations included citations supporting their recommendations.

There was a moderate degree of variability between the included documents within each theme, though much of the guidance provided was general in nature and did not provide specific information (e.g., number of days or hours off required between on-call periods, number or duration of 'calls' that should be permitted, etc.). For example, documents that provided recommendations around the regularity and predictability of shifts included reasonably consistent guidance such as 'Reduce uncertainty – build some predictability around on-call periods such as a no-contact period' [23], 'build in some level of schedule predictability [22],' and 'on call duties should be planned to avoid variations of more than 2 h' [24]. Conversely, other themes were more specific in nature, and therefore resulted in a greater degree of between-document variability. For example, within the prescriptive rule sets theme, recommendations ranged from 'being on-call more than 24 h of the minimum 88 h free from work in a 7 day period is a risk' [25] to 'on call workers shall monitor the number of cumulative hours worked (including on-call responses) to ensure that they do not exceed the twelve (12) cumulative hours limit' [26], to 'on-call periods should be separated by an off duty night to allow for recovery' [27]. Of the documents containing recommendations for fatigue management in on-call workers, most (58 %) were not supported by, or did not refer to, the current on-call evidence base (see Table 2).

Given the sizeable differences between included materials in the degree of evidence used to underpin the guidance or regulation provided, a systematic review was undertaken to identify the scientific evidence base supporting the effectiveness of the recommended strategies for managing fatigue-related risk in on-call workers.

## 4. Aim 2: systematic review methods

### 4.1. Eligibility criteria

To be included in the systematic review of the evidence underpinning on-call fatigue management strategies, articles had to be original studies meeting the targeted Population, Intervention, and Outcome (PIO) [28]. The target population included any on-call worker population (including standby and/or reserve in any industry). As the aim of the systematic review was to evaluate the effectiveness of the fatigue management strategies recommended by guidance and regulatory materials, the search strategy was designed to capture studies that used these interventions. However, studies were eligible for inclusion if they evaluated fatigue management strategies that were not originally

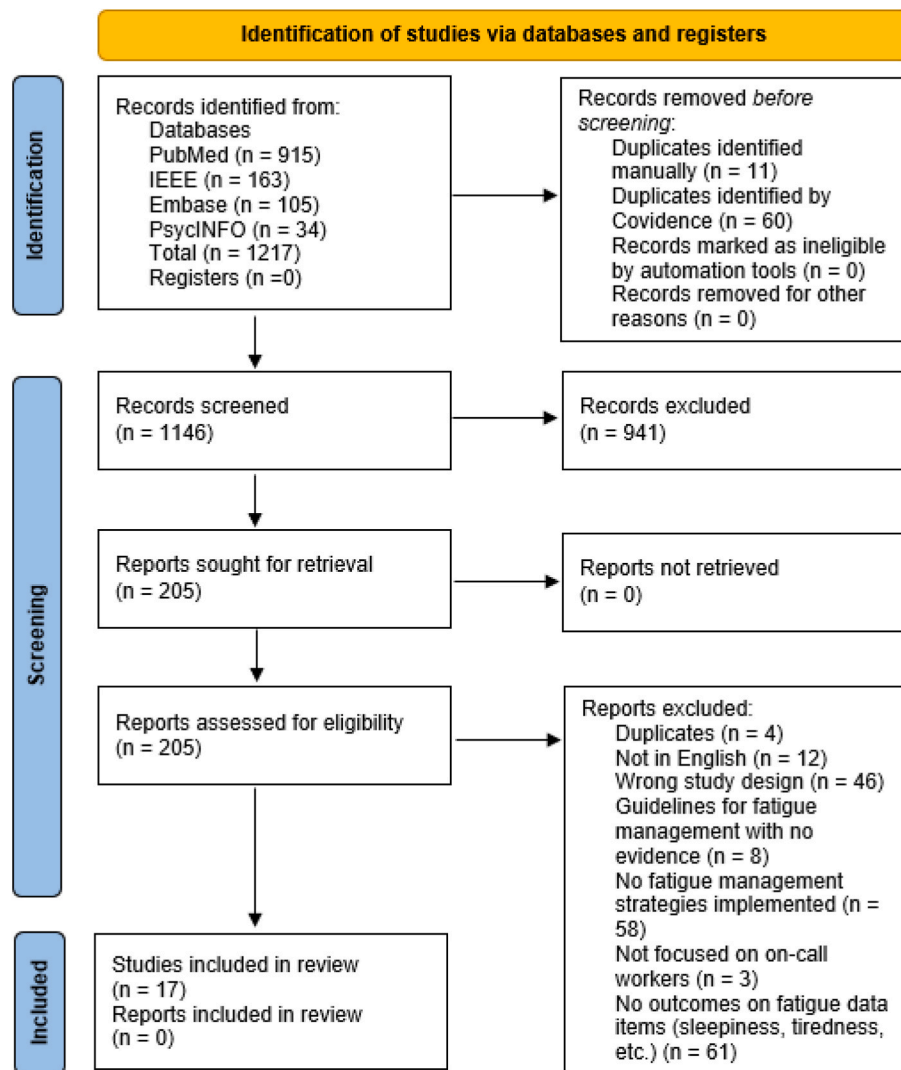


Fig. 2. PRISMA flowchart for database search.

identified in the guidance and regulatory material review.

Outcome measures had to include one of the following: fatigue, sleep, error, safety, or performance. The search terms were based on the PIO definitions (see Table 3). Studies had to be published between the year 1990 – present and written in the English language. The study date range was selected to align with when fatigue began to be acknowledged as a hazard in industry [29].

Excluded was any literature containing reviews, meta-analyses, personal accounts, reflections, and studies with no empirical scientific data collected. Studies that did not include the chosen population or did not measure the effects of fatigue management strategies on the identified outcome measures were excluded.

#### 4.2. Design

This systematic review aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and framework [30]. This review is registered with the international prospective register of systematic reviews (PROSPERO) as it meets the inclusion criteria of a systematic review with health-related results ID CRD42023470498.

#### 4.3. Information sources

A search was conducted using four academic databases: IEEE Xplore, Medline, PsycINFO, and PubMed. The last source search and consult was conducted on the October 7, 2023. These databases were chosen due to their inclusion of a broad range of quality studies relevant to the topic fatigue management strategies on on-call workers.

#### 4.4. Search strategy

The four databases were searched using the terms described above. Medical Subject Headings (MeSH) were not used unless the database provided automatic term mapping and so text words were used that related to PIO and outcomes. Through the use of a prior “dummy” search, the search terms were adjusted to account for variations in the PIO terms. This included the exclusion of terms that resulted in irrelevant search results. Search terms were formatted for each individual database requirements using field tags, filters, and truncations. Actual search terms used can be seen in Supplementary Table 5.

#### 4.5. Selection process

The results of the search were uploaded into Covidence (Covidence, Melbourne, Australia), a web-based platform that allows collaboration

in the data collection process of systematic reviews. Once the results of the search were transferred into Covidence, duplicates were removed and the article title and abstract reviewed for inclusion and exclusion criteria by two reviewers (HB and MS). Conflicts were resolved by discussions with a third reviewer (KK). The included studies from the review of the title and abstract then underwent a second screening process whereby the full texts were reviewed by HB and MS, with conflicts resolved by consensus discussion with KK.

#### 4.6. Data extraction process

Data extraction was conducted by HB and reviewed by MS and KK. Data were transposed from each study to the data extraction table under the headings: author and year, country, participant number, aims, type of design, fatigue management strategy used, and outcome.

#### 4.7. Data items

Data items included study demographics (authors, date of publication, location, the design of the study, participant details, participant number), fatigue management strategy implemented, and the results relating to the effect of fatigue management strategies on fatigue and associated outcomes in on-call workers. The results section of the data extraction table contained the definition of the relevant outcome that was studied and the result of the fatigue management strategy on the outcome.

#### 4.8. Synthesis methods

Given the limited studies on the effectiveness of fatigue management strategies for on-call workers, a qualitative systematic review of the included studies was conducted. Meta-analysis was not possible due to heterogeneity in study contexts, type of on-call work undertaken, and the broad range of outcome variables. It is also important to note that fatigue management strategies and outcomes are often not comparable statistically. There are several factors (sleep quality, sleep quantity, stress) that can influence fatigue, making it difficult to directly compare outcomes.

Qualitative synthesis was conducted by extracting relevant data from the methods and results. Statistical results were included where provided and qualitative data was summarised. Results indicating the effectiveness of fatigue management strategies were collated, compared, and contrasted. Conclusions were drawn for each identified outcome and any conflicting results were explored (i.e., points of difference between included studies that addressed the same fatigue management strategies were identified and evaluated).

#### 4.9. Study risk of bias assessment

The Joanna Briggs Institute (JBI) standardised critical appraisal tool was used to assess the quality and risk of bias of eligible studies [31]. One reviewer conducted the assessments (HB), and any differences were discussed with MS and KK to reduce the risk of error.

### 5. Aim 2: systematic review results

#### 5.1. Study selection

The study selection process is displayed in Fig. 2. The search resulted in 1217 articles, from which 71 duplicates were removed. The remaining 1146 articles were screened based on their title and abstract, and 205 progressed to full text screening. At the full text stage, 192 articles were excluded due to ineligible article type (e.g., review articles, case studies), not written in English, lack of evidence on the effectiveness of fatigue management strategies, the study sample not including on-call workers, or outcomes that were outside the scope of this study.

Seventeen studies were included in the final systematic review.

#### 5.2. Study characteristics

Key characteristics of the 17 studies included for synthesis are presented in [Supplementary Table 6](#). Studies were observational (n = 7), or cross-sectional (n = 10) and conducted between 2000 and 2022. They took place in the United States of America (n = 9), Canada (n = 2), Qatar (n = 1), Finland (n = 1), Australia (n = 1), Netherlands (n = 1), Taiwan (n = 1) and United Kingdom (n = 1).

#### 5.3. Population

Participants had a variety of occupations, including surgeons (n = 7841), other professionals (unspecified; n = 1865), medical employees (n = 1407), nurses (n = 969), midwives (n = 720), rail workers (n = 198), anesthesiologists (n = 55), paediatric residents (n = 51) psychiatrists (n = 45) and medical registrars (n = 5). Participant ages ranged from 23 to 69 years old, however, 11 studies did not disclose the age of the participants.

#### 5.4. Intervention

Most included studies evaluated prescriptive rule sets (n = 15). Prescriptive rule sets that were evaluated included restrictions on both on-call hours and total work hours each week (n = 11), restrictions on consecutive work hours during each 24-h period (n = 10), and minimum rest periods post call prior to next shift (n = 4). Call management strategies were evaluated by three studies, which included protected sleep while on-call (n = 2) and workload management (n = 2) (note one study evaluated both protected sleep while on-call and workload management). One study evaluated training and education by providing virtual on-call training (i.e., educating participants on what to expect from on-call, with the aim of alleviating anxiety around unpredictable work). Six studies implemented more than one intervention.

#### 5.5. Outcome measures

A range of outcome measures were used in included studies, including:

**Objective Sleep.** Sleep was objectively measured using actigraph watches reporting the number of hours slept for each 24-h period (n = 1).

**Subjective Sleepiness.** Subjective sleepiness was measured by self-reports, the Spiegel questionnaire and Karolinska Sleepiness Scale (KSS) (n = 4).

**Stress.** Stress was measured by the Quality-of-Life self-report questionnaire (n = 3) and heart rate measurements by electrocardiographic (ECG) recording over a 4 day on-call period (n = 1).

**Fatigue.** Fatigue was measured using a Quality-of-Life questionnaire, qualitative surveys, and the Profile of Mood States questionnaire; n = 6). Six studies examined the effect of fatigue management strategies on multiple outcomes that can be a factor resulting in fatigue.

**Error.** Error was measured by self-reported major medical errors in a 3-month period (n = 1).

**Quality of Life (QoL).** QoL was measured by a 5-point Likert scale.

**Cognitive Performance.** Cognitive performance was measured by response speed using the Psychomotor Vigilance Test (PVT) and Endoscopic Sinus Surgery Simulator (ES3) (n = 2).

[Supplementary Table 6](#) summarises the outcomes of on-call fatigue management strategies.

#### 5.6. Risk of bias

The risk of bias for each study can be found in [Table 4](#). The JBI checklist highlighted risk of bias for all but three studies [32–34]. The



### 5.13. Training and education

Virtual on-call training was used to prepare participants for the tasks they might complete when on-call, and how best to manage workload prioritization, with the aim of removing the unpredictability of work tasks that may result in stress, anxiety, and poor sleep. Doctors who received on-call training reported being able to cope better with fatigue and stress [46].

### 5.14. Call management

Three studies evaluated call management strategies for on-call workers. Shea et al. [47] examined the effects of taking a protected nap during on-call hours and found no difference between the control group and intervention (nap) group in subjective sleepiness. However, it was found that response speed on a psychomotor vigilance task was faster after on-call nights when participants napped compared to the control group who did not nap. Similarly, Parida et al. [38] investigated the impact of requiring protected nap opportunities if on-call hospital shifts exceeded 16 h, in addition to reduced on-call workloads (i.e., number of patients and associated calls). These strategies appeared to improve performance and attention, while reducing fatigue. However, it must be noted that these strategies were implemented at the same time as prescriptive rule sets limiting hours of work. Lindfors et al. [40] also investigated the impact of managing call workload, via increasing the use of technology, limiting calls to emergencies only, and increasing the number of scheduled staff in comparison to on-call staff. When these workload measures were implemented, worker stress decreased.

## 6. Discussion

The aim of this review was to a) identify guidance and regulation currently provided to organisations about managing fatigue in on-call workers, and b) determine if there is empirical evidence to support the effectiveness of the recommended strategies in managing the fatigue of on-call workers. Sixty-five documents were identified that provided guidance or regulation on fatigue management strategies for on-call work. Broadly, eight different types of on-call fatigue management strategies were identified based on current guidance/regulatory materials: 1) regularity and predictability of shifts, 2) fatigue management policy development, 3) prescriptive rule sets, 4) fitness for work assessment, 5) on-the-day control measures, 6) risk assessment, 7) training and education, and 8) call management. Few of the included documents provided a rationale for, or scientific evidence underpinning, these recommendations. As a result, a systematic review was undertaken to evaluate scientific evidence for how fatigue could be managed in on-call workers.

Findings of the systematic review of the scientific literature suggest that there is a moderate to low level of evidence for many on-call fatigue management strategies, and many of the strategies described by guidance and regulatory materials (e.g., regularity and predictability of on-call shifts, fatigue management policy development, fitness for work assessment, on-the-day control measures, risk assessment, or call management) have not been evaluated. That is, no scientific studies have been undertaken to investigate the fatigue, sleep, performance, or safety outcomes of these strategies. The majority of studies instead addressed prescriptive rule sets for hours of work, with strong evidence indicating that restricting either the number of consecutive hours that can be worked on-call during each 24-h period, or weekly on-call work hours (particularly at night), increases the opportunity for sleep, which may reduce fatigue. Moreover, some studies indicated that work performance improved, and work error decreased, when the amount of time spent on-call was restricted. Interestingly, workload was found to increase when fewer hours were worked, suggesting that work hour restrictions may be associated with work intensification (i.e., workers have fewer hours in which to perform tasks that they would usually have a longer period of

time to complete). Thus, while work hour restrictions may have been designed to improve worker sleep, the increase in workload during these hours may negate these benefits. Training, work organisation, and work control were found to reduce stress and improve the ability to cope with fatigue in on-call workers. Surprisingly, a small number of studies found subjective reports of fatigue were not affected by the implementation of fatigue management strategies, with two studies indicating that these strategies negatively impacted on-call workers [41,42]. Broadly, it appeared that where scientific evidence exists, there was a moderate degree of agreement between the evidence and associated recommendations – though for most strategies there simply wasn't a large enough body of supporting evidence to draw strong conclusions about agreement. However, many prescriptive rule sets would be considered very permissive from a risk-based standpoint (i.e., there is a high likelihood of fatigue even when hours of work may fall within the recommended upper limits) [29,49].

Overall, it appears that much of the guidance on how to manage fatigue in on-call workers is lacking a strong evidence-base. Instead, it seems that organisations and industry bodies are 'making do' with the best information they have available – i.e., evidence that is based on research done on shiftworkers or those with standard working time arrangements, or based on what may appear to be 'common sense' that has limited scientific backing. It seems from the systematic review component of the present study that this limitation of the current guidance likely stems from a lack of specific research into on-call workers as a distinct population.

### 6.1. Prescriptive rule sets

Limitations to on-call hours of work (including restricted weekly hours, minimum rest periods, and restricted consecutive hours of work) generally resulted in improved sleep and reduced fatigue. In addition, a reduction in error rates, improved performance, and an increase in on-call workers' feelings of safety when driving home from on-call shifts were also noted when there were limitations on on-call hours. Of note, the studies that found these outcomes were generally those conducted in workplaces where weekly work hours were originally very high (e.g., hospital doctors working on-call). This aligns with the literature, which generally indicates that fewer weekly/monthly work hours, in addition to fewer consecutive hours are associated with a reduction in fatigue (e.g., the risk of a fatigue-related error increasing significantly beyond the 8th consecutive work hour [48]). However, this previous literature is generally based on the shiftwork context, and there is limited evidence to suggest how such a paradigm may apply in the on-call space.

While the outcomes described above are certainly positive consequences of work-hour restrictions, these findings were not consistent in all included studies. For example, Pilcher and Coplen [41] found participants who worked shorter (<24-h) on-call periods felt less rested and struggled to stay asleep in comparison to those that worked >24-h on-call periods. These findings appear to be linked with the impact of work-hour restrictions on workload, whereby limiting the number of hours of work can increase work intensity. This work intensity occurs because the same amount of work must be completed, but during a shorter period of time. This is supported by other included studies, which found that work-hour restrictions increased workload [37,50]. Moreover, higher workloads can mean less time to sleep for on-call workers – in a healthcare context, each patient added to residents' workload resulted in the loss of approximately 38 min of sleep [50]. Not only can an increase in on-call workload lead to reduced sleep, but it can also result in increased stress – both of which are associated with worker fatigue. Thus, while there are clearly some benefits associated with reducing the amount of time a worker can spend on-call, organisations should consider the potential ramifications of such reductions on workload and plan resourcing accordingly.

## 6.2. Training and education

One study evaluated the impact of training on fatigue in on-call workers [51], and found that training increased participants' capacity to cope with stress and fatigue as they were better prepared for what on-call work may entail. In this study, a simulation-based educational intervention was trialled, where students were given 'experience' in being on-call, with a particular focus on workload prioritization while on-call. While training and education was beneficial in this setting, further research is needed to determine training effectiveness, the specific element(s) of training contributing to the positive outcomes, and how this type of training may apply outside of the medical education context.

## 6.3. Call management

One study included in this review investigated the effect of implementing a protected nap period, to ensure that on-call workers had the opportunity to obtain some sleep during on-call shifts [47]. Surprisingly, there were no significant differences found in subjective sleepiness between the control group (no protected nap period) and the group that had a 3-h protected nap during their on-call time, even though participants in the protected nap group were more likely to have slept while on-call. The sleep obtained in the nap may have been poor quality or short in duration due to sleeping at work/time available for sleep, and workload demands may have been altered. Studies have found that sleep quality can depend on where the on-call participant is sleeping i.e., home vs on-site [41] and thus protected nap strategies should take account of location. Further, while sleep quality and duration may differ based on location, other factors may have a greater impact (e.g., timing and duration of sleep periods) [52]. Importantly, psychomotor vigilance performance was improved in the protected nap condition, suggesting that while having a protected nap period did not impact subjective feelings of fatigue, there may be significant performance benefits. Just one other study investigated the impact of protected naps in on-call workers [38], though naps were only protected once in-hospital on-call shifts exceeded 16 h duration. While this strategy was associated with improved fatigue and performance outcomes, protected naps were accompanied by reduced workloads and prescriptive rule sets limiting hours of work. As such, it is difficult to identify the specific impact of protected naps under these conditions. Similarly, while a reduction in on-call workload was associated with reduced stress [40], it is difficult to identify the specific effects of this strategy as it was also accompanied by restricted hours of work. Interestingly, few recommendations explicitly related to napping were included in existing guidance materials, though many did describe the need for on-call schedules to accommodate worker sleep. While further research is needed, it appears that both protected naps and managing on-call workload may be useful fatigue management strategies.

## 6.4. Limitations of this review

There are several limitations of this two-part review that should be considered when interpreting outcomes. While the review of guidance and regulatory materials was done in accordance with accepted grey literature search strategies, it is possible that additional guidance or regulatory materials were missed, given the use of the search engine Google: search results from which may be impacted by underlying algorithms and paid advertising. However, given that a large number of guidance materials ( $n = 46$ ), particularly those from key industry bodies, were produced using this strategy, we believe the outcomes demonstrate the breadth of guidance and regulation currently provided to on-call organisations. A limitation of the systematic review component was that only English language studies were included, which may result in relevant data being missed.

## 6.5. Limitations of included studies

Limitations of the included studies should be considered when understanding the impact of on-call fatigue management strategies. Most included studies relied on self-report data to determine the impact of the fatigue management strategies. While self-report data is valuable (particularly in the context of fatigue management, where self-report is often used as part of systematic approaches to fitness for duty assessment [53]), there is often a disconnect between subjective and objective measures of fatigue. As a result, self-report data may either over- or under-estimate fatigue-related impairment [54]. Additionally, the publication date of included studies ranged from 1990 to present. As a result, it is possible that some working time arrangements and conditions from older publications may no longer be aligned with current regulations and guidelines. Moreover, the healthcare industry is vastly over-represented in the included studies, with just one study being undertaken in another industry [41]. As a result, the findings of this review may be limited in generalisability to other industries (e.g., transport).

## 6.6. Implications and future directions

The present review has a number of potential implications for organisations that use on-call working time arrangements, and regulatory bodies that provide guidelines or regulations for these organisations. Primarily, there was strong evidence that in cases where on-call work hours are very high, limiting the amount of time workers spend on-call is associated with a reduction in fatigue. While this may be unsurprising, this finding provides a strong evidence base for the prescriptive fatigue management strategies that are recommended in many current guidance or regulatory materials. However, it must be noted that while limiting the amount of time workers can spend on-call may be effective in reducing the overall amount of fatigue that is experienced, this strategy is unlikely to eliminate all fatigue in on-call workers. As such, it is critical that organisations also consider additional strategies designed to either reduce fatigue during the on-call periods that do occur, and control the risk associated with fatigue both at work and during commutes [49,53]. It is also likely that both the amount of time it is appropriate to spend on-call, and how fatigue risk is controlled, will differ depending on industry, organisation, worker, and/or tasks undertaken.

Organisations and regulators should also be aware that limitations on hours of on-call work may be associated with unintended consequences associated with workload (i.e., resulting in an increased workload during on-call time) – which may in turn increase fatigue. In future, guidelines should therefore consider this potential negative outcome. Similarly, if restrictions limit hours of work, then services may not be available during those times unless the number of workers increase, enabling fatigue to be managed while continuing service provision. This issue highlights the critical interaction between staffing levels and work allocation in on-call settings. Notably, there was scant reference in both the scientific and grey literature to appropriate frequency of on-call work, and the appropriate distribution of periods free of on-call commitments. Future research is needed to evaluate the impacts of the frequency of on-call allocations. For instance, is there a maximum appropriate frequency of on call work (one week in every two, three, or four weeks) and a minimum proportion of time spent free of on-call commitments?

Other fatigue management strategies that have some supporting evidence include training and education, and the use of protected naps during on-call periods. While both strategies appear to have positive outcomes for on-call workers (e.g., an increased ability to cope with fatigue and improved cognitive performance, respectively), more research is needed to clarify what elements of these potential interventions are impactful (e.g., optimum protected nap duration, type of training). However, it would likely be appropriate to incorporate both strategies into on-call fatigue management systems and guidance/

## Practice points

1. Most fatigue management guidance for on-call work has not yet been scientifically evaluated, though much of this advice appears reasonable when taken at face value.
2. Limitations to on-call hours of work (e.g., restricted weekly hours, minimum rest periods) may reduce fatigue, but can also be associated with work intensification and have the potential to increase overall risk if not managed appropriately.
3. Protected naps during on-call periods and worker training may be effective fatigue management strategies for on-call workers.

## Research agenda

Future research should.

1. Establish the appropriate frequency of on-call work, and the appropriate distribution of periods free of on-call commitments.
2. Evaluate the effectiveness of fatigue management strategies for on-call workers beyond limitations to working time arrangements.
3. Assess the recovery value of the interrupted sleep frequently obtained by on-call workers.

regulatory materials.

Interestingly, no studies were found that investigated many on-call fatigue management strategies that are included in current guidance/regulatory materials (i.e., regularity and predictability of on-call shifts, use of fatigue management policy development, fitness for work assessment, on-the-day control measures, risk assessment, and call management strategies). While it may be logical to assume that many of these strategies are effective (as they have been demonstrated to be effective in other populations, such as shiftworkers [53]), more research is needed to investigate their specific applicability to on-call workers. For example, fatigue management strategies such as the use of fitness for work assessments, the use of on-the-day control measures to manage fatigue when it does occur at work, and standardised risk assessment processes [55,56] are highly effective in managing fatigue-related risk in shift workers. However, it is unclear what level of tailoring is needed to ensure these strategies are appropriate for the on-call context. For example, are fitness for work assessment strategies that rely on information about prior sleep wake behaviour (i.e., how much sleep the worker has had in the previous 24 h) appropriate for on-call workers, who – unlike shift workers – are likely to obtain interrupted, rather than consolidated sleep? Because much of the sleep they obtain while on-call is interrupted, it is likely that current fitness for work assessment strategies vastly underestimate fatigue-related risk in on-call workers. Critically, many fatigue management strategies that are tailored to on-call workers specifically (e.g., call management strategies), have received little or no attention in the published literature to date, reflecting a significant gap in our current understanding. Moreover, it is apparent that little is known about how on-call work could be designed or managed to support the physical, mental, and psychosocial health of on-call workers, or how on-call work design should be adjusted depending on the type of work undertaken (e.g., sedentary vs active). Similarly, there is a need for tailored advice for workers with non-standard work arrangements beyond the shift work/day work binary [57].

It is critical to note that the absence of published literature supporting current on-call guidelines or regulation does not necessarily mean that such guidance is incorrect or inappropriate. Indeed, much of the current guidance is logical and reasonable when taken at face value. However, it is critical for ‘face value’ strategies to be validated to both protect workers (from poor health and safety outcomes) and to allow organisations to meet their regulatory and/or legal obligations.

### 6.7. How should we manage fatigue in on-call workers?

Based on this comprehensive review of both guidance materials and the evidence-base, we can cautiously recommend that the following fatigue management strategies be applied for on-call workers.

1. Ensure that there are limitations around on-call periods, potentially including the number and frequency of on-call periods themselves, cumulative hours of work, length of time spent on-call, and rest periods after call-outs.
2. Ensure that limitations around on-call periods also consider potential impacts on social, recreational, community and family activities, to maintain psychosocial well-being across the on-call workforce. For example, the number of weekends and evenings (i.e., periods of time with high social value) spent on-call would ideally be limited.
3. Consider on-call workloads when scheduling, to ensure that work intensification does not result in increased fatigue, near misses, errors, or incidents. For example, in situations where on-call workloads are identified as being consistently high, it may be preferable to change on-call periods to regularly scheduled shifts. Similarly, where on-call workloads are high due to limitations on time spent on-call, it may be preferable to add additional staff during the identified on-call periods.
4. Consider implementing protected nap periods for on-call workers and consider impact of on-call periods on consolidated sleep opportunities.
5. Develop training for on-call workers on both how to cope with this working time arrangement both while at work and during non-work time.
6. Develop fatigue management policies and procedures that monitor and evaluate how the fatigue management system is functioning. This would ideally include a continual improvement process and would be informed by key information used to identify fatigue risk in on-call workers (e.g., self-reported fatigue, objectively measured sleep, performance measures, incident statistics, etc.).
7. As part of the monitoring and evaluation process, develop and critically – evaluate – any other measures that are developed for the industry, organisation, or workgroup. This would ideally include a formal evaluation of fitness for work assessment strategies, risk assessment procedures, control measure selection, and any other

features of the on-call fatigue management system (e.g., call management strategies).

8. Ensure that, as far as is practicable, any guidelines and policies that are developed are based on scientific evidence. Where this is not possible, endeavour to collect industry- or organisation-level data to support the use of other strategies recommended by guidance materials.

## 7. Conclusion

This review aimed to identify and evaluate on-call management strategies recommended within guidance and regulatory documents and assess their effectiveness in managing fatigue among on-call workers. While various strategies like shift regularity, fatigue management policy development, and work hour limitations were identified, the review found limited research specifically addressing their effectiveness in the on-call context. Furthermore, although work-hour limitations showed some efficacy in reducing fatigue, they did not fully mitigate fatigue-related risks during work time, indicating a need for more comprehensive fatigue management strategies. While organisations would ideally continue to align with current guidelines, for now, it is critical that future research be undertaken to determine how fatigue can be effectively managed for on-call workers beyond on-call work hour limitations.

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## Declaration of competing interest

The authors declare there is no conflict of interest.

## Appendix A. Supplementary data

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