The effect of working on-call on stress physiology and sleep: A systematic review

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SUMMARY

On-call work is becoming an increasingly common work pattern, yet the human impacts of this type of work are not well established. Given the likelihood of calls to occur outside regular work hours, it is important to consider the potential impact of working on-call on stress physiology and sleep. The aims of this review were to collate and evaluate evidence on the effects of working on-call from home on stress physiology and sleep. A systematic search of Ebsco Host, Embase, Web of Science, Scopus and ScienceDirect was conducted. Search terms included: *on-call*, *on call*, *standby*, *sleep*, *cortisol*, *heart rate*, *adrenaline*, *noradrenaline*, *nor-adrenaline*, *epinephrine*, *norepinephrine*, *nor-epinephrine*, *salivary alpha amylase* and *alpha amylase*. Eight studies met the inclusion criteria, with only one study investigating the effect of working on-call from home on stress physiology. All eight studies investigated the effect of working on-call from home on sleep. Working on-call from home appears to adversely affect sleep quantity, and in most cases, sleep quality. However, studies did not differentiate between night's on-call from home with and without calls. Data examining the effect of working on-call from home on stress physiology were not sufficient to draw meaningful conclusions.

KEYWORDS

On-call; standby; sleep quality; sleep quantity; hypothalamo-pituitary adrenal axis; cortisol; sympatho-adrenal medullary system; sleep.

ABBREVIATIONS

EPHPP: Effective public health practice project

PRISMA: Preferred reporting items for systematic reviews and meta-analyses

SD: Standard deviation

1. INTRODUCTION

Prolonged and irregular work hours are becoming increasingly common in modern society [1-4]. Although there is a large body of research investigating irregular work patterns, such as shift work, one form of irregular work scheduling that has received relatively limited attention to date is 'on-call' (or standby) work [5]. During on-call periods, workers must be available at short notice, and are often called to work outside 'regular hours' [6]. This type of scheduling is typically used to provide 24-hour coverage, seven days a week and is utilised when the workload is such that there is no need for personnel to be 'present' for an entire shift [5]. Recent data show that approximately 25% of the Australian workforce [7], approximately 50% of German organisations [8] and 20% of the European Union [2] regularly operate with on-call or standby as part of their normal work schedule.

On-call work scheduling varies between occupations, with two main types defined in the literature [5]. One form is where employees remain on site whilst on-call and are usually provided a place to sleep [5, 9, 10]. Studies have investigated the effect of working on-call on site in doctors [11-13], ships' engineers [14], railroad engineers [15], medical helicopter pilots [4], and salaried firefighters [16]. In the second form of on-call work, employees are able to leave their place of employment and are called if required [5, 6, 17]. For brevity, this form of on-call work will be termed 'on-call from home' in this review, although it should be noted that personnel may not be physically at home whilst on-call, and may in fact be at a site of other employment. This form of on-call work is particularly relevant to fire and emergency service workers [17] and maintenance utility workers [18, 19], as well as some doctors [20-23], nurses [24] and midwives [5]. This second form of on-call work is the focus of this review.

Although on-call from home scheduling is less expensive for employers than providing full shift coverage on site, it may still come at a human cost [25]. Given that on-call work occurs

‘around the clock’, it is likely that sleep and circadian disruptions occur in populations working on-call from home. One inherent difference between on-call work and other forms of shift work is the unpredictability of when a call may occur. This unpredictability poses a unique work environment that is not faced by those working set shifts and has been identified as a factor that may inhibit workers’ ability to “switch off” and attain a cognitive distance from work when on-call from home [6, 17]. This has the potential to affect the lives of on-call workers by adversely impacting on their family time, social life, stress levels [5, 17, 25, 26], and consequently, further disrupting their sleep.

Several studies have shown that being on-call from home results in higher subjective stress levels than when not on-call [6, 27-31]. For example, Sutherland and Cooper [32] showed that doctors found night calls and interruption to family life highly stressful. Similarly, French et al. [28] found that doctors’ subjective stress levels were higher when on-call than when off duty and Rout [30] discovered that the uncertainty of being on-call and the on-call commitment was a source of unhappiness for on-call doctors. It is possible that the uncertainty associated with the unpredictability of calls may increase physiological stress. Repeated exposure to elevated physiological stress could ultimately impair the health of on-call workers. When a stressor occurs, two main physiological stress systems are activated: the sympatho-adrenal medullary system and the hypothalamo-pituitary adrenal axis. If the stressor is prolonged, repeated or uncontrollable the physiological stress response may become inadequate, and ultimately, result in adverse health problems. For example, stress-induced cortisol dysregulation has been positively associated clinical depression [33, 34], cardiovascular disease [35, 36], Type 2 diabetes and stroke [35], and dysregulation of the sympatho-adrenal medullary system has been positively associated with asthma [37] and atherosclerosis [38]. Therefore, it is important to establish whether the sympatho-adrenal medullary system and/or the hypothalamo-pituitary adrenal axis are affected when working on-call from home.

Calls may occur at any time of the day or night, and have the potential to impact sleep (Figure 1). The curtailment and/or interruption of sleep may potentially affect the safety of on-call workers. Research shows that a reduction in sleep of just 30 min per night may result in acute performance decrements, such as a slower reaction time and reduced vigilance over time [39]. Furthermore, chronic sleep deprivation and sleep restriction have been shown to have adverse effects on health. Deleterious effects include increased neurobehavioral deficits, blood pressure, body mass index and obesity, adverse cardiovascular events, elevated inflammatory markers and impaired glucose tolerance [40, 41]. Consequently, it is important to understand the effect of working on-call from home on sleep.

Studies investigating performance during/following on-call from home provide further evidence for why this topic is important. A retrospective analysis by Benson et al. [42], demonstrated significantly lower adenoma detection rates in procedures performed by gastroenterologists who had been “called in” (we assume on-call from home) for emergency procedures the previous night, compared to when procedures were performed by gastroenterologists who had not been on-call the previous night. Another study, not specifically investigating on-call work, found that there were more complications in cases the day after a night with a sleep opportunity of six hours or less compared to when doctors had a sleep opportunity of more than six hours [43]. Although measurement of performance is outside the scope of this review, this research highlights why it is important to understand the sleep and stress of workers operating on-call from home.

There is some evidence to suggest that there is a bidirectional interaction between sleep and stress physiology [44, 45]. A review of the interaction between stress and sleep suggests that hyperactivity of the hypothalamo-pituitary adrenal axis can result in sleep fragmentation, decreased slow wave sleep and reduced total sleep time [46]. Sleep disturbances may also

contribute to hypothalamo-pituitary adrenal axis dysfunction [46]. Several studies investigating the effect of working on-call on site have shown that sleep is adversely affected prior to a call occurring [14, 47-49]. It has been purported that the poorer sleep is due to the stress or anticipation of a call [6, 14, 17, 47, 48]. We contend that a similar relationship exists between sleep and stress when operating on-call from home (Figure 1). Other external factors such as wakefulness at inappropriate biological times, may disturb the synchrony of the circadian rhythm and result in impaired cognitive function [50, 51]. However, these factors are outside the scope of the review and are not included in the model.

Given, the potential interaction between sleep and stress and the possible adverse health and safety outcomes that could occur as the results of on-call work, it is important to establish whether working on-call from home is detrimental to stress physiology and sleep. To this end, this review systematically critiqued previous research investigating the effect of working on-call from home on the stress physiology and sleep of workers. Describing the evidence-base for the consequences of this increasingly prevalent work schedule will help to inform on-call practices and the health and safety systems that support on-call workers.

2. METHODOLOGY

2.1 Search strategy

This review was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [52]. A systematic search of the electronic databases Ebsco Host (searching Academic Search Complete, CINAHL, MEDLINE Complete, Psychology and Behavioral Sciences, PsycINFO and SPORTDiscus), Embase, Web of Science, Scopus and ScienceDirect was used to identify relevant English-language peer-reviewed studies published between January 1960 and April 2015. The key words used for the search were: *on-call*, *on call*, and *standby* searched together with *sleep* or with stress

physiology related terms that included: *cortisol, heart rate, adrenaline, noradrenaline, nor-adrenaline, epinephrine, norepinephrine, nor-epinephrine, salivary alpha amylase* and *alpha amylase*. Reference lists from retrieved articles were examined to identify any additional relevant articles and conference papers that were not discovered in the original search. Identification of relevant conference abstracts resulted in follow up searches to locate related full-text articles.

2.2 Eligibility criteria

To be included in this systematic review, studies were required to investigate workers who operate in an on-call environment and who are able to leave their site of employment whilst on-call (i.e. work on-call from home). Outcome variables of interest were objective measures of sleep, such as polysomnography or activity monitors, subjective measures of sleep, collected from sleep diaries or surveys and measures of stress physiology including cortisol, salivary alpha-amylase, epinephrine (adrenaline), norepinephrine (noradrenaline) and/or heart rate.

Titles and abstracts of search results were screened for relevance to on-call work and potentially relevant articles were accessed to review the full text. Articles were restricted to studies that identified workers as able to leave their site of employment whilst on-call. Studies were excluded if the on-call work was performed on site, if they did not state where the on-call period occurred, or if they were both on-call on site and from home but did not differentiate between the two forms of on-call work in their analysis. Conference abstracts were also excluded from the review. Screening, data extraction and quality assessment was performed independently by two authors (SJH and GEV), with discrepancies resolved through discussion between authors. If no agreement could be reached, differences were resolved by discussion and consensus with a third author (BA).

2.3 Data extraction

A data extraction sheet was developed based on the cochrane consumers and communication review group's data extraction template [53]. Extracted information included: 1) Characteristics of trial participants, including age, sex and occupation; 2) Type of study; 3) Outcome measure(s); and 4) Major findings of the study.

2.4 Quality assessment

The methodological quality of each study in the review was assessed using the Effective public health practice project (EPHPP) quality assessment tool for quantitative studies [54]. Based on the quality assessment, a global quality score was assigned to each study. The global score of a study was determined by the number of strong, moderate and weak scores in the subsections of the assessment tool (selection bias, study design, confounders, blinding, data collection method, withdrawal and dropout). To obtain a 'strong' global score a study needed to obtain four or more strong ratings and no weak ratings, a 'moderate' global score required less than four strong ratings and no more than one weak rating, and a 'weak' global score occurred when a study had two or more weak ratings.

3. RESULTS

3.1 Literature Selection Overview

A flow diagram summarising the selection process is shown in Figure 2. The original search yielded 3,173 English-language articles. Of these, 984 were identified as duplicates and removed. A further 1,896 were rejected during initial screening as they did not relate to on-call work. Of the remaining 293 articles, 112 were excluded for relating only to on-call on site, 147 were excluded because the study did not specifically state that workers were able to leave their place of employment whilst on-call, 11 were excluded because workers were both on-call on site and on-call from home, but the study did not differentiate between the two

forms of on-call work in the results and 13 were rejected for not reporting relevant outcomes (including review articles relating to on-call from home). Finally, two studies were rejected as they were conference abstracts and no corresponding full-text versions were available. Consequently, the final number of studies included in this systematic review was eight (Figure 2).

3.2 Study characteristics

Study characteristics and key findings of the eight studies are summarised in Table 1. In the four studies that reported age as a mean, participant age ranged from 39 to 44 years. Two other studies reported the percentage of participants in specified age ranges, in one, most (71%) participants were aged 30-49 years and in the other, most (59%) participants were aged 25-44 years. Two studies did not report the age of participants. Sample sizes ranged from 24 to 994. Imbernon et al. [19] conducted a case-control study, but also analysed the results within the on-call group separately. Results from both the case-control and the on-call cohort components of this study are included in this review.

The quality assessment scores given to each study based on the EPHPP quality assessment tool for quantitative studies [54] are presented in Table 2. The study by Imbernon et al. [19] was rated twice, both as a case-control and as a cohort study. The two arms of the study by Imbernon and colleagues [19] were rated ‘moderate,’ with the seven [6, 15, 18, 21-23, 26] remaining studies rated as ‘weak’.

3.3 Stress physiology of on-call from home workers

Only Bamberg et al. [6] investigated the effect of working on-call from home on stress physiology. These authors observed no significant effects of being on-call from home on evening cortisol levels in a single cohort of 31 information technology workers (30 male and one female) compared to when not on-call, regardless of whether or not workers were called

to work [6]. The saliva sample for cortisol analysis was taken in the evening, prior to bed [6]. Only samples collected between 2100 h and 0100 h were included in the analysis, representing 88.3% of the samples [6]. Although this study controlled for potential confounders and reported withdrawals and dropouts, it did not report the validity or reliability of collection methods, resulting in a 'weak' rating based on the EPHPP quality assessment tool for quantitative studies [54; Table 2].

3.4 Sleep quantity of on-call from home workers

Six studies investigated the effect of working on-call from home on sleep quantity [15, 18, 19, 21-23]. Of these, three studies investigated the effect of working on-call from home compared to when not on-call [15, 18, 19]. The remaining three studies investigated the sleep quantity of workers operating on-call from home, but did not make comparisons to when not on-call [21-23].

Two of the three studies that compared sleep quantity when on-call from home to when not on-call found reductions in sleep quantity when on-call from home [15, 19]. Pilcher and Coplen [15] found that when utilising self-report activity logs, railroad engineers total sleep time was approximately 1 h shorter when on-call from home compared to workers on regular work assignments (i.e. not on-call). Similarly, Imbernon et al. [19] found that gas and electricity supply company supervisors slept an average of 36 min less when on-call compared to when not on-call. In contrast, Cebola and colleagues [18] detected no difference in the sleep quantity of Network Rail infrastructure maintenance managerial staff when on-call from home compared to when not on-call. It should be noted that Imbernon et al. [19] also found no differences in overall sleep quantity when comparing the sleep of gas and electricity supply company supervisors who work on-call from home to a matched cohort

who did not work on-call [19]. None of these studies compared the sleep quantity of workers when on-call with a callout compared to when on-call without a call.

The remaining studies all investigated the sleep of on-call doctors. Schauberger et al. [23] found that 13% of obstetricians in Wisconsin who operated on-call from home felt that sleep deprivation was an occasional or frequent concern. O'Grady et al. [21] found that that surgical trainees in Australia and New Zealand self-reported a median total sleep time of 5-7 h per shift. Finally, Richter and colleagues [22] investigated the effect of the European Working Time Directive on physicians sleep. This directive resulted in a new policy that restricted the number of hours hospital physicians' in Germany could work to a maximum of 48 h (on average) per week [22]. This study found that doctors self-reported sleeping 1 h 36 min ± 2 h 16 min (mean ± standard deviation) less in 2007, after the implementation of the directive, compared to in 1997, before the directive was in place [22]. It is likely, that the implementation of the directive resulted in an increased in doctors operating on-call from home. All of the studies investigating the sleep quality of workers operating on-call from home relied exclusively upon subjective measures, such as sleep logs. In addition, only the study by Imbernon et al. [19] was rated 'moderate' using the EPHPP quality assessment tool for quantitative studies [54], with all other studies that investigated sleep quality [15, 18, 21-23] being assessed as 'weak' (Table 2).

3.5 Sleep quality of on-call from home workers

Six studies reported the sleep quality of on call from home workers [6, 18, 19, 21, 22, 26]. Three of these studies investigated the effect of working on-call from home compared to when not on-call [6, 18, 19]. Two of the three found that some aspects of sleep quality were worse when on-call from home [18, 19]. The final three studies investigated sleep difficulties or interruptions to sleep, but did not compare on-call from home to when not on-call [21, 22,

26].

Two studies used single-item scales to assess subjective sleep quality [6, 18]. Bamberg et al. [6] used the question "How did you sleep last night?" rated on a 5-point scale developed by Funck [55] to assess sleep quality. This study found that subjective sleep quality was no different when on-call from home compared to when not on-call. In contrast, Cebola et al. [18] found that subjective sleep quality, measured from 1 = “very good” to 5 = very poor”, was significantly worse during an on-call week (2.52 ± 0.6; mean ± SD) compared to a week when not on-call (2.01 ± 0.77; $p < 0.05$).

Two studies investigated self-report sleep latency when on-call from home compared to when not on-call [18, 19]. Cebola et al. [18] observed no differences in self-reported sleep latency of rail maintenance workers when on-call from home. These findings contrast those of Imbernon et al. [19], who found that 99% of the gas and electricity supply company supervisors that participated in the study reported that it took longer to fall asleep when on-call from home. Imbernon and colleagues [19] established that 28% of workers took more than 30 min to get to sleep when on-call from home compared to 14% during ‘normal’ weeks, when not on-call. The authors did not report whether this was significantly different, although chi square tests, performed by the authors of this review, reveal that these results are significantly different ($p = 0.008$). It should be noted that when Imbernon et al. [19] compared the overall sleep of workers who operate on-call from home (combining the on-call week with two weeks not on-call) to workers who do not operate on-call, no differences were observed in overall self-reported sleep latency.

One study also included measures that related to waking during the sleep period and feelings upon awakening [19]. Imbernon et al. [19] found that participants more frequently reported difficulty in getting back to sleep after being woken up and tiredness in the morning during

the on-call weeks compared to when not on-call. However, there was no difference in the difficulty in getting back to sleep after being woken up between workers who operate on-call from home and workers who do not operate on-call [19]. Imbernon et al. [19] also found that participants were more tired in the mornings whist on-call from home compared to when not on-call. Although, when workers on-call from home were compared to workers who did not operate on-call, no differences were observed [19]. Pilcher and Coplen [15] used a 4-point scale (1 = well rested to 4 = not at all rested) and also found no differences in how rested participants felt upon awakening when on-call from home compared when not on-call.

The remaining three studies compared sleep quality of on-call workers in 1997 to 2007 [22], sleep difficulties of working doctors to retired doctors [26], or the median uninterrupted sleep period of on-call doctors [21], but lacked comparisons to when not on-call. Chambers and Belcher [26] compared reported sleep difficulties of working and retired general practitioners. This study found that 47.6% of working general practitioners reported sleep difficulties compared to 27.3% of retired doctors [26]. While, the authors did not report whether this difference was significant, a chi square test, performed by the authors of this review, revealed that these results were significantly different ($p = 0.03$). The peak age for reported sleep difficulties in this study was 40-49 years, with 54.5% of 40-49 year-olds reporting difficulty sleeping [26]. Richter and colleagues [22] investigated the sleep quality of German hospital physicians while on-call from home and found that interruptions to sleep increased significantly from 0.7 ± 0.9 (mean ± SD) interruptions per sleep in 1997 to 1.0 ± 1.1 interruptions per sleep in 2007, following the implementation of the European Working Time Directive. Finally, O'Grady et al. [21] and colleagues reported that the median uninterrupted sleep of surgical trainees in Australia and New Zealand was 3-5 h/shift. However, no comparisons were made to when not on-call or to other populations.

4. DISCUSSION

This review highlights that there is limited research investigating the effect of working on-call from home on stress physiology and sleep. There is insufficient evidence to determine whether working on-call from home has detrimental effects on stress physiology. Consequently, further research is required before more meaningful conclusions can be made. The limited evidence suggests that working on-call from home impairs sleep and that individuals may perceive changes to both sleep quantity and quality when operating on-call from home.

In the only study that investigated the effect of working on-call from home on stress physiology [6], Bamberg et al. [6] reported that there were no differences in evening salivary cortisol levels when on-call from home compared to when not on-call. This lack of finding is surprising given the research suggesting subjective stress is heightened when on-call from home [27-31]. It is unclear whether this indicates that the hypothalamo-pituitary adrenal axis is not affected or whether, as the authors suggested, it is a consequence of the sampling time utilised in this study [6]. Interestingly, this study also found no difference in sleep quality when operating on-call from home [6]. Given the effect of sleep on hypothalamo-pituitary adrenal axis functioning [56, 57], it is possible that if sleep had been affected, as was the case in other studies identified in this review, the stress response may have also been altered. No study to date has investigated the effect of working on-call from home on the sympatho-adrenal medullary system. Given that sympatho-adrenal medullary system and hypothalamo-pituitary adrenal axis dysregulation are both positively associated with adverse health outcomes [33-36, 38], it is important that the effect of working on-call from home on both stress systems are investigated.

The major shortcoming of the study by Bamberg et al. [6] is that, given the diurnal rhythm of cortisol, having a 4-h window for saliva collection may have introduced variability into the results. The circadian rhythm of cortisol means that the timing of the saliva collection is critical in order to make comparisons between days. Typically, saliva samples are collected based on either time of awakening [58-61] or time of day [62-65]. The samples in this study were collected "before going to sleep" and, as such, may have been at different times on different days, limiting the conclusions that can be drawn. Another major shortcoming of this study is that it did not compare cortisol responses on days where workers were on-call with call outs to days when on-call without call outs. Future research, involving several measurement points across the day, and differentiation between on-call days with and without calls, will provide a more comprehensive understanding of the hypothalamo-pituitary adrenal axis response to operating on-call from home.

Although two studies found that workers report sleeping less when on-call from home compared to when not on-call [15, 19], none of the existing studies differentiated between nights on-call with and without calls [15, 18, 19]. It is possible that this can explain some of the inter-study differences in the reported sleep reduction when on-call. When calls occur during sleep, sleep is inevitably disrupted and there is less opportunity for sleep. However, even without calls, the duty of being on-call from home could still disrupt sleep [17]. Previous work investigating sleep quantity when on-call on site suggests that sleep is reduced even when no calls occur [14, 20]. It remains unclear whether this also occurs when on-call from home.

While Imbernon and colleagues [19] found that sleep was reduced when working on-call from home, when the overall sleep of workers who operate on-call from home (one week on-call and two weeks not on-call) was compared to workers who do not work on-call there was

no overall difference in sleep quantity. This suggests that workers may obtain more sleep during periods when not on-call to compensate for the loss of sleep during on-call periods. However, some workers who operate on-call from home, for example, volunteer fire and emergency service workers do not have periods where they are not on-call, which may have implications for health and safety. Alternatively, it is possible that the inclusion of the two weeks of data where on-call workers were not on-call in the comparison could have washed out the effects of the on-call week or that the differences were observed due to between subject differences in the rating of sleep.

Another surprising finding was that the sleep of German doctors had reduced since the implementation of the European Working Time Directive, which resulted in the restriction of work hours to a maximum of 48 h (on average) per week [22]. It is possible that this resulted in more time on-call from home, and increased transit time between the hospital and home. It may also be impacted by an increased number of people visiting emergency departments [66, 67] and therefore a likely increase in the number of calls. If call patterns or working arrangements change to increase call frequency or the proportion of time that workers are on-call, it is likely that sleep disruptions will also increase.

Research suggests that it is not only the quantity of sleep but also the quality of sleep that may adversely impact health [68]. While subjective sleep quality generally appears to be affected when working on-call from home compared to when not on-call, one study found no difference in sleep quality [6] and others found differences in some measures but not others [18, 19]. One possible explanation for the differences in the quality of sleep workers obtained in different studies is the inherent requirements of the job, which may vary across different occupations and locations. Factors that may affect the ability to sleep when on-call could include how likely it is for a call to occur, the method by which workers are notified of a call

(e.g., how loud the alert is) and what is required of the worker when called (e.g., providing a brief answer over the phone versus being called in to attend a large-scale emergency incident) [17, 49, 69]. These factors may have different influences on the components of sleep quality (e.g., sleep latency, ability to stay asleep, ability to return to sleep after waking) and may provide an explanation for variances in the results. Alternatively, the differences observed might be a result of the different tools utilised to collect data, with some not being validated measures of sleep quality. Future research should aim to investigate a range of occupations, using valid and reliable tools to determine whether sleep quality is affected when working on-call from home.

Importantly, none of the sleep studies in this review used objective measures of sleep and, as a result, rely solely on subjective measures of sleep quantity and quality. Although sleep diaries have been shown to provide similar data to actigraphy for sleep duration, and sleep timing, they are less accurate for the number and durations of night-time awakenings, reporting fewer and shorter awakenings [70]. Given that nocturnal awakenings are common in on-call work, rigorous studies, using objective measures are required to determine whether workers operating on-call from home do in fact sleep differently to when not on-call. Another limitation associated with the studies included in this review is their quality, rated using the EPHPP quality assessment tool for quantitative studies [54]. The review found that no studies were rated ‘strong’ and only the study by Imbernon et al. [19] was rated ‘moderate’, with all remaining studies [6, 15, 18, 21-23, 26] being assigned a ‘weak’ rating. Future studies should employ and report rigorous methodological designs, such as using valid and reliable measures and undertaking comprehensive statistical analyses, to improve the quality ratings of studies.

It should be noted that there are limitations associated with the review itself. The primary limitation is that the quality and value of the review is directly related to the quality of the primary research it covers. Given the studies were predominantly rated ‘weak’ using the EPHPP quality assessment tool for quantitative studies [54] framework, the quality of the research investigating the effect of working on-call from home prevents definitive conclusions from being drawn. In addition, the review may be affected by publication bias, as only published research in English language were included. Thus, some relevant research may not have been included in the review.

To date, there is not enough evidence to confirm or refute the proposed model in Figure 1. However, although the results are limited, it appears that sleep quantity and quality may be impaired when working on-call from home and that the ability to go to sleep, stay asleep and return to sleep after awakening are all reduced. There is a need for more in depth studies that focus on utilising objective measures of sleep and that differentiate between nights with and without calls. Furthermore, more rigorous studies are required to investigate the effect of working on-call from home on the sympatho-adrenal medullary system, to provide a more comprehensive understanding of the hypothalamo-pituitary adrenal axis and to establish if there is an interaction between sleep and stress when working on-call from home.

Practice Points

1. One study investigated the effect of working on-call from home on stress physiology;
2. There is insufficient evidence to determine whether working on-call from home affects stress physiology;
3. Eight studies examined the effect of working on-call from home on sleep;
4. It appears that working on-call from home may impair sleep quantity and quality.

Research Agenda

Future research should:

1. Use objective tools to evaluate the effect of working on-call from home on sleep quantity and quality;
2. Differentiate between nights when workers are on-call from home with and without calls in analyses;
3. Investigate the effects of working on-call from home on the sympatho-adrenal medullary system and diurnal profile of cortisol;
4. Establish whether there is an interaction between stress physiology and sleep when operating on-call from home.

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CONFLICTS OF INTEREST

The authors declare we are not aware of any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three (3) years of beginning the work submitted that could inappropriately influence, or be perceived to influence, their work.

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FIGURE LEGENDS AND CAPTIONS

Figure 1: Schematic representation of the proposed relationship between stress physiology and sleep when working on-call from home.

↑ = increase; ↓ = decrease

Figure 2: Flow diagram summarising the selection process

n = number

TABLES

Table 1: Characteristics and major findings of studies relating to stress physiology and sleep

Author (year)	**Sample size (*n*)**	**Population investigated**	**Age ± SD (years)**	**Sex**	**Method**	**Outcome measures**	**Key findings**
Chambers and Belcher, 1994 [26]	704 (674 practicing, 30 retired)	Doctors (general practitioners)	43.5 ± 11.0	M and F (81.2% M)	Questionnaire	Sleep difficulties	*Practicing vs. retired doctors* ↑ sleep difficulties
Pilcher and Coplen, 2000 [15]	198 (162 on-call, 36 regular work)	Locomotive engineers	44.01 ± 6.67	195 M, 3 F	14-day activity log	Sleep quantity, Sleep quality (ability to go to sleep, ability to stay asleep, feeling of	*On-call workers vs. regular assignments* ↓ sleep quantity ↑ difficulty going to sleep and difficulty staying asleep ↔ feeling of restedness upon awakening

						restedness on awakening)	
Imbernon et al., 2007 [19]	340 questionnaire, 282 weekly report form (115 exposed, 167 not exposed)	Gas and Electricity supply company supervisors	43.6 ± 0.4	M	Questionnaire 3 week sleep diary	Sleep quantity Sleep quality (interruptions, tiredness upon awakening, time to fall asleep)	*On-call exposed vs. not on-call not exposed* ↔ sleep quantity, interruptions, tiredness upon awakening *On-call vs. not on-call (exposed)* ↓ sleep time ↑ time to fall asleep, difficulty falling asleep after being woken and tiredness upon awakening
Schauberger et al., 2007 [23]	66	Obstetricians	Not reported	Not reported	Questionnaire	Sleep deprivation	*No comparisons were made* 13% occasional/frequent concern 87% seldom/never a concern

O'Grady et al., 2010 [21]	616	Surgical trainees	Not reported	M and F (% not reported)	Questionnaire	Sleep quantity Sleep quality (interruptions)	*No comparisons were made* Median total sleep: 5–7 h (54%), 38% 3–5 h, 3% ≤ 3 h Median uninterrupted sleep: 3–5 h (52%), 24% ≤ 3 h
Bamberg et al., 2012 [6]	31	Information Technology workers	71% aged 30-49	30 M, 1 F	4 days on-call, 4 days off-call. Daily survey Salivary cortisol	Salivary cortisol Sleep quality	*On-call vs. not on-call* ↔ sleep quality and evening salivary cortisol
Cebola et al., 2013 [18]	24	Network Rail infrastructure maintenance managerial staff	59% aged 25-44, 25% aged 45-56 6.9% aged > 56 or < 25	M	2-week sleep diary	Bed time Up time Sleep latency Sleep quantity Sleep quality	*On-call vs. not on-call* ↔ bed time, get up time, sleep latency and sleep quantity ↓ sleep quality

Richter et al., 2014 [22]	1997: 328 2007: 994	Hospital physicians	39.4 ± 9.1 1997; 39.8 ± 9.3 2007	M and F (1997: 70.6% M; 2007: 63.4% M)	Questionnaire	Sleep quantity Sleep quality (interruptions)	*2007 vs. 1997* ↓ sleep quantity ↓ sleep quality (↑interruptions)

↔ = no difference ($p > 0.05$); ↑ = significantly higher ($p < 0.05$); ↓ = significantly lower ($p < 0.05$); F = female; M = male; SD = standard deviation. All data presented as mean ± standard deviation unless otherwise indicated.

Table 2: Quality assessment of studies using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies.

Study	**Selection Bias**	**Study Design**	**Confounders**	**Blinding**	**Data Collection Method**	**Withdrawal and Dropout**	**Global Score**
Chambers and Belcher, 1994 [26]	1	3	1	3	3	1	Weak
Pilcher and Coplen, 2000 [15]	3	2	1	3	3	1	Weak
Imbernon et al., 2007 [19] – Case-control	2	2	1	3	2	1	Moderate
Imbernon et al., 2007 [19] – Cohort	2	2	1	3	2	1	Moderate
Schauberger et al., 2007 [23]	3	3	1	3	1	1	Weak
O'Grady et al., 2010 [21]	3	3	1	3	3	3	Weak
Bamberg et al., 2012 [6]	2	2	1	3	3	1	Weak
Cebola et al., 2013 [18]	3	2	1	3	1	2	Weak
Richter et al., 2014 [22]	1	3	1	3	3	2	Weak

‘1’ = strong; ‘2’ = moderate; ‘3’ = weak. Global scores were determined by the number of strong, moderate and weak scores for each paper. To obtain a ‘strong’ global score a study needed four or more strong ratings and no weak ratings, a ‘moderate’ global score required less than four strong ratings and no more than one weak rating, and a ‘weak’ global score occurred when a study had two or more weak ratings.