BMJ Open

Sleep- and wake-promoting drug use and health and safety outcomes in police officers

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022041
Article Type:	Research
Date Submitted by the Author:	31-Jan-2018
Complete List of Authors:	Ogeil, Rowan; Monash University, Eastern Health Clinical School; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Barger, Laura; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Lockley, Steven; Monash University, Monash Institute of Cognitive and Clinical Neurosciences and School of Psychological Sciences; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine O'Brien, Conor; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Sullivan, Jason; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Qadri, Salim; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Lubman, D; Monash University, Eastern Health Clinical School Czeisler, Charles; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Rajaratnam, Shantha M. W.; Monash University, Monash Institute of Cognitive and Clinical Neurosciences and School of Psychological Sciences; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women\'s Hospital; Division of Sleep Medicine
Keywords:	MENTAL HEALTH, shift work, drug use, health, performance, safety

Sleep- and wake-promoting drug use and health and safety outcomes in police officers

Rowan P. Ogeil, Ph.D.[1,2,3], Laura K. Barger, Ph.D.[1,2], Steven W. Lockley, Ph.D.[1,2,4], Conor S. O'Brien, B.A.[1], Jason P. Sullivan, B.S.[1], Salim Qadri, B.S.[1], Dan I. Lubman, MB ChB, Ph.D.[3], Charles A. Czeisler, Ph.D., M.D.[1,2], Shantha M.W. Rajaratnam, Ph.D.[1,2,4]

[1] Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital, Boston MA, USA.

[2] Division of Sleep Medicine, Harvard Medical School, Boston MA, USA.

[3] Eastern Health Clinical School, Monash University, Box Hill VIC, Australia and Turning Point, Eastern Health, Fitzroy VIC, Australia.

[4] Monash Institute of Cognitive and Clinical Neurosciences, School of Psychological Sciences, Monash University, Clayton VIC, Australia.

Address for Correspondence:

Rowan P. Ogeil, Ph.D.

Turning Point, 54-62 Gertrude St., Fitzroy 3065 VIC, Australia

Telephone: +613 8413 8469

Fax: +613 9416 3420

Email: Rowan.Ogeil@monash.edu

Word Count: 3168

Abstract

Objectives: To examine sleep- and wake-promoting drug use in police officers, and associations between use of these drugs and health, performance, and safety outcomes, both alone and in combination with night-shift work.

Design: Cross-sectional survey.

Setting: Police officers from North America completed the survey either on-line or on-site.

Participants: 4957 police participated in the survey, 3693 online and 1264 on-site.

Main outcome measures: Sleep and wake-promoting drug use, self-reported excessive sleepiness, near-miss motor vehicle crashes, dozing while driving, errors made while at work, stress, and burnout.

Results: Over the past month, 20% of police officers reported using sleep-promoting drugs and drugs causing sleepiness, while wake-promoting agents were used by 28% of police (5% used wake-promoting drugs, 23% used high levels of caffeine, and 4% smoked to stay awake). Use of sleep-promoting drugs was associated with increased near-crashes (OR=1.61; 95% confidence interval [CI]: 1.21 to 2.13), work-related errors (OR=1.75; 95% CI: 1.32 to 2.79), higher stress (OR=1.41; 95% CI: 1.10 to 1.82) and higher burnout (OR=1.83; 95% CI: 1.40 to 2.38). Wake-promoting medication use, high caffeine use and smoking to stay awake were associated with increased odds of a fatigue-related error, stress and burnout (ORs ranging from 1.68 to 2.56). Caffeine consumption was common, and while smoking was not, of those participants who did smoke, one-in-three did so to remain awake. Night-shift work was associated with independent increases in risk for excessive sleepiness, near-crashes and fatigue-related errors. Interactions between night-shift work and wake-promoting drug use were also found for excessive sleepiness.

Conclusions: Police who use sleep- and wake-promoting drugs, especially when working night shifts, are most vulnerable to adverse health, performance and safety outcomes. Future research should examine temporal relationships between shift-work, drug use and adverse outcomes, in order to develop optimal alertness management strategies combining behavioural and pharmacological countermeasures.

Keywords: Mental health; shift work; drug use, health, performance, safety.

Strengths and limitations of this study:

- Examines the contribution of both use of sleep- and wake-promoting drugs and shift schedules on health, performance and safety outcomes.
- Data were obtained from a large sample of North American police officers.
- Self-assessment of health, performance and safety outcomes was used, which may be subject to a bias not to report.
- The retrospective design employed may have been affected by recall or social desirability bias.

Introduction

Sleep problems adversely impact the physical and mental health of individuals, and place a high economic and health care burden on the community. [1] Poorer health outcomes among those who work non-standard shifts include an increased prevalence of chronic sleep disorders, mood disturbance, cardiovascular disease, and diabetes. [2]

Shift-work disorder is characterised by insomnia and/or excessive daytime sleepiness associated with work schedules.[3] Between 8 and 14% of shift workers meet the clinical criteria for a diagnosis of shift-work disorder, with rates as high as 26% reported in those working rotating shifts. [2] The incidence of shift-work disorder is likely underestimated, however, given that the symptoms which define the disorder are common to many sleep disorders, and most shift workers will experience some adverse consequences as a result of opposing circadian physiology to sleep at night, and to be awake during the day. [2] As an occupational group, police provide services 24-hours a day, with officers required to work overnight shifts. Shift-work disorder in both police and other professionals is associated with adverse consequences including an increased propensity for work related errors, decrements in performance and increase incidence of motor vehicle crashes or near-crashes. [3, 4]

The majority of shift workers do not adapt to the shifted sleep-wake schedule required for their work,[5] and our understanding of those workers who may be more vulnerable or resistant to shift-work disorder is limited.[6] Circadian misalignment between internally driven physiological processes and the light-dark cycle has been proposed as the mechanism which underlies poorer physical and mental health observed in shift workers.[7] Kalmbach et al. [8] reported that those who develop shift-work disorder report greater levels of anxiety and depression compared to shift workers who do not. These negative effects were further compounded in shift workers with circadian systems that were slower to adapt to changes associated with work-shifts, suggesting that while the biological clock is unable to adapt to the demands imposed by shift-work, that there are likely trait and state characteristics of individuals that are associated with greater impairment or resilience to health and performance effects following night-shift work.

Hitherto, research examining shift schedules and effects on health and performance outcomes has generally not considered the use of sleep- and wake-promoting drugs. While 1 in 10 adults in the general population have used alcohol as a sleep aid, recent data suggest higher rates of consumption in shift workers with one in six consuming alcohol to help initiate sleep between shifts.[9] Indeed, following prescription sleep medications (e.g., benzodiazepines), alcohol is also commonly used as sleeping aid by shift workers. [10] High alcohol or continued use of prescription sleeping aids is of concern given that their long-term use is associated with poor health and public health outcomes. [11, 12] For example, Roche et al. [13] reported that high-risk drinkers are 22 times more likely than low-risk drinkers to be absent from work due to alcohol use, placing a large burden on the economy due to lost productivity.

Common wake-promoting medications used by shift workers include freely available stimulants (e.g., caffeine and nicotine), [14] in addition to medication obtained via prescription, over-the-counter or as a supplement. A Cochrane review that examined pharmacological product efficacy for shift work disorder found mixed to limited efficacy of wake-promoting agents including modafinil and caffeine. [15] As with sleep-promoting medication, there may be negative consequences that accompany continued use of stimulants. For example, reliance on caffeine has been associated with poorer sleep quality, increased levels of daytime dysfunction, and increased

levels of night time disturbance, whereas nicotine dependence has been associated with poorer sleep quality and increased use of sleep medication and sleep disturbances. [14]

This study investigated the use of the sleep- and wake-promoting drugs and their associations with night shift work and performance and safety indices, including errors made at work and near-crash events.

Methods

Participants

Police officers in North America were recruited to participate in a cross-sectional study either online (*n*=3693) or on-site (*n*=1264). A total of 4957 officers completed the survey, a cooperation rate of 63.1% in the on-site cohort and a 91.9%, participation rate in the online sample. Further details of the sample have been described previously.[4]

The protocol was approved by the Partners and Monash Human Research Ethics Committees. Participants provided written or electronic informed consent and were not informed about study hypotheses.

Materials and Survey Instruments

In the survey, participants completed sections on demographics, sleep-promoting drug use (alcohol, prescription sleep medication, over the counter (OTC) or herbal medication, medication that listed sleepiness as a side-effect), and wake-promoting drug use (caffeine, cigarettes, prescribed medication, OTC/herbal medication).

The survey also contained questions about health, performance and safety outcomes over the past month. Stress was assessed with a Likert-type scale asking participants to rate their level of stress from 1 (not at all stressful) to 7 (very stressful) over the past month. The Maslach Burnout inventory (sensitivity 0.70, specificity 0.57) [16] is a 22 question, validated questionnaire. The emotional exhaustion subscale contains 9-items and was used to assess burnout that develops in response to chronic occupational stress.[17] Excessive sleepiness was assessed using the Epworth Sleepiness Scale (ESS) (sensitivity 0.94, specificity 1.00). [18] Performance was assessed with the questions, “In the last month, do you believe sleep deprivation or fatigue caused you to make a mistake or be unnecessarily unsafe in some way?” and “In the last month, do you believe you made a mistake or were unnecessarily unsafe in some way for reasons other than sleep deprivation or fatigue?” To assess motor vehicle safety following a shift the following questions were used: “In the last month, did you have any near miss motor vehicle accidents or crashes (narrowly avoided property damage or bodily harm) in which you were driving?”, “How likely are you to doze off...: While driving, after you worked a night shift?” and “How likely are you to doze off...: While driving, after you worked a day or evening shift?” Night shifts were defined as having worked 3 or more 8-10 hour shifts between 10 PM and 8 AM or 12 hour shifts between 7 PM and 9 AM).

Data Analyses

Chi-square analyses were used to compare police who had used versus those who had not used each sleep and wake-promoting drug on outcome variables in the past month. Outcomes considered were excessive daytime sleepiness (ESS scores exceeding 10); any near-miss crashes or dozing reported following a work shift, any errors made while at work, and levels of stress (1-7 on

Likert-type scale) and burnout (Scores of 18+ reflecting moderate-high burnout). Binary logistic regression models were used to examine the increase (or decrease) in risk associated with use of sleep- and wake-promoting medication, and in their interaction with night-shift work. Binary logistic regression models were also used to asses risky use of the social drugs (caffeine, alcohol, smoking) as predicted by use of sleep- and wake-promoting medication and night shift work. For alcohol consumption risky use was defined as exceeding 196g in the past week in males (equivalent to 14 standard drinks), and 98g per week in females (equivalent to 7 standard drinks), with a standard drink containing 14g of alcohol. Caffeine consumption was classified as 'High' (> 400mg of caffeine per day, equivalent to ~5 servings/day) or 'Low' (≤400mg per day, ~up to 4 servings) to reflect caffeine consumption in the U.S population. [19] Smoking status was assessed in two ways. Smokers were compared with non-smokers, with this former group being divided into smokers who reported engaging in this behaviour to stay awake, compared with smokers who did not report smoking to stay awake. Statistical analyses were conducted using SPSS (version 21, IBM Corporation).

Role of the funding source

Funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to the study data and had final responsibility for the decision to submit for publication.

Results

Sample Characteristics

A total of 4957 police officers (82% male), with a mean age of 38.5 years (SD = 8.3) completed the survey.

Drug Use

Table 1 shows sleep and wake-promoting drug use by police.

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 1 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Sleep-promoting drug use was reported by approximately 20% of police officers in the past month. Regarding the use of wake-promoting drugs, caffeine use was almost ubiquitous (approximately 90% used caffeine in the past month). Furthermore, over one quarter of police reported using either a wake-promoting drug, high levels of caffeine or smoked to stay awake. While only 8.9% of the sample had received a formal diagnosis of shift-work disorder by self-report, these officers were more likely to report using: sleep-promoting drugs, wake-promoting drugs, medication with sleepiness as a side effect, or to report smoking to stay awake (all $p<.05$) in the past month.

Adverse outcomes associated with drug use

Figures 1 and 2 display adverse outcomes associated with use of sleep- and wake-promoting drugs.

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT FIGURES 1 & 2 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Sleep- and wake-promoting drug use was associated with poorer outcomes on self-reported sleepiness, fatigue-related errors, drive performance following a shift, and increased levels of stress and burnout. In addition, those who smoked cigarettes to stay awake and high caffeine consumers reported poorer outcomes.

To better understand the risk of adverse outcomes associated with use of sleep- and wake-promoting drugs and night shifts, binary logistic regression modelling was performed using the following outcome variables: excessive sleepiness, near-crashes, fatigue-related errors, stress and burnout (see Table 2). We also conducted analysis controlling for previously diagnosed insomnia, OSA, and SWD, with findings indicating that use of sleep and wake-promoting drugs and night shift work were still associated with increased risk of poorer outcomes (see Supplementary Table 1).

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 2 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Police using a sleep-promoting medication or a drug that listed sleepiness as a side-effect in the past month were more likely to report a near-crash while driving (*sleep promoting:* OR= 1.61, CI: 1.21-2.13, *side effect:* OR= 1.38, CI: 1.04-1.82), more likely to report a fatigue-related error at work (*sleep promoting:* OR= 1.75, CI: 1.32-2.30, *side effect:* OR= 1.57, CI: 1.19-2.07), and higher levels of stress (*sleep promoting:* OR= 1.41, CI: 1.10-1.82, *side effect:* OR= 1.39, CI: 1.08-1.78) or burnout (*sleep promoting:* OR= 1.83, CI: 1.40-2.38, *side effect:* OR= 1.82, CI: 1.40-2.37) compared with non-users. Wake-promoting medication use was associated with increased odds of a fatigue-related error (OR= 1.68, CI: 1.01-2.79), and stress (OR= 1.74, CI: 1.06-2.89). Night-shift work was also associated with independent increases in risk for excessive sleepiness (OR= 1.48, CI: 1.22-1.80), near-crash events (OR= 1.48, CI: 1.20-1.81) and fatigue-related errors (OR= 2.40, CI: 1.97-2.92). Interactions between night-shift work and wake-promoting drug use were also found for excessive daytime sleepiness (OR= 2.56, CI: 1.19-5.54).

Binary logistic regression models were also used to assess risky use of alcohol, caffeine and those who smoked to stay awake, using sleep- and wake-medication use and night-shift work as predictors (see Table 3).

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 3 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Use of sleep-promoting medication (OR=1.49, CI: 1.12-1.98), and night-shift work (OR=1.42, CI: 1.16-1.74) each independently was associated with increased excessive caffeine use and smoking in order to stay awake (*sleep promoting:* OR= 1.97, CI: 1.06-3.64, *night-shift work:* OR= 2.12, CI: 1.34-3.36).

Discussion

The present study identified night-shifts as an independent risk factor for excessive daytime sleepiness, near-crashes and fatigue-related errors at work, supporting previous studies. [2,3] Similarly, a significant proportion of shift workers reported high levels of stress and burnout. [2,6,8] Importantly, the present study extends this work by showing that use of sleep- and-wake promoting drugs was independently associated with poorer health (e.g., stress, burnout) and performance (e.g., fatigue attributable errors, near-crashes) outcomes. Furthermore, use of sleep- and wake-promoting drugs was associated with increased excessive sleepiness in night shift

workers. Relationships between drug use and poor outcomes remained significant even after controlling for common sleep disorders. [19,20]

While we did not ask police officers about their use of specific classes of sleep-promoting medication, the use of benzodiapines is common in the United States, with a retrospective study reporting that one-in-twenty adults had been prescribed a drug from this class during 2008. [20] While short-term use is recommended within clinical guidelines to ameliorate insomnia, benzodiazepine use has been associated with impairment of driving performance, [21] with a single dose of lorazepam causing greater lane deviations compared with alcohol intoxication of .05% BAC. [22] In addition, triazolam causes residual next day decrements in driving performance,[23] and benzodiazepines with a long half-life, commonly prescribed as anxiolytics have also been associated with increased risk of a motor crash.[21] This is important given the increased rates of stress and burnout reported by police who used sleep-promoting medication in the present study, and previously reported decreases in quality of life and depression symptoms in nurses reported to have used hypnotic drugs. [24] Police using sleep-promoting medication were also more likely to report an error at work attributable to fatigue. Procedural errors and injuries at work associated with use of hypnotic drugs have also been reported in nurses [24]. Such effects may result from a desire to overcome sleepiness or anxiety (given the ESS and high stress reported by police in this sample), or reflect rebound or next day-effects.

More than 20% of police used a high level of caffeine (>400mg/day), and more than 5% used a medication or over-the-counter drug to promote wakefulness (excluding caffeine) in the past month. Of those who smoked, a third reported doing so to remain awake. Wake-promoting agents may be used by shift-workers in order to maintain vigilance and alertness on-shift; however, evidence on their efficacy is mixed. [15] Previous studies have suggested that modafinil may have cognitive enhancing effects following sleep deprivation, including in those engaged in simulated night-shift work. [25] Other reports have suggested increases in some measures of simulated driving performance specifically lane deviation, but not speed deviation or off-road incidents following modafinil suggesting caution with its use as a countermeasure for sleepiness.[26] Our study suggests use of these drugs is associated with decrements in performance, and increased levels of stress/burnout that may be related to changes in shift schedule, particularly given the interaction between use of wake-promoting medication and night-shift work significantly increasing the odds of excessive levels of daytime sleepiness.

Use of common and licit stimulants was common amongst police in our sample, and moderate caffeine consumption (e.g., up to 250mg) has been proposed as a countermeasure to increase performance during night-shift work by the National Sleep Foundation. [27] Dependence on caffeine has been associated with negative consequences, however, including poorer sleep quality and increased daytime dysfunction. [14] In our study, high caffeine users (>400mg) [19] were more likely to report a fatigue-related error or near-miss crash in the present study. These findings are consistent with a previous report that caffeine is the most prevalent stimulant in fatal-to-the-driver heavy truck crashes.[28] While use of caffeine in moderate levels may protect against sleepiness-related errors at work, exceeding these levels is associated with detrimental health and performance impacts. Our results suggest that high caffeine use may be an important marker of vulnerability to excessive sleepiness and performance impairment.

Although the majority of police in our sample were non-smokers, of those who smoked, almost one-in-three reported smoking in order to stay awake. Smoking rates are reportedly higher in night-shift workers, with rates of uptake that are significantly greater in shift workers compared to

traditional day workers. [29] Indeed, lung cancer rates of rotating shift workers are significantly greater in current smokers. [30] In addition, dependence upon nicotine has been associated with numerous adverse health effects, including poorer sleep. [14] Police in our sample who reported smoking in order to remain awake reported greater levels of daytime sleepiness, increased propensity to make fatigue-related errors and higher levels of stress and burnout, even compared with smokers who did not engage in this behaviour. As was the case with those officers reporting high caffeine consumption, it may be that these users are vulnerable to the effects of shift work, and are using high levels of these stimulants as a countermeasure against this vulnerability. This may at least in part explain the previous finding that smoking rates are higher in night-shift workers compared to day workers [29].

Recent work has called for further research to understand the inter-individual variability in sleep-wake responses to shift work in order to identify those vulnerable or resilient to assist them in managing shifts. [6] The present study suggests that excessive use of sleep- or wake-promoting medication may be one such trait, given higher rates of use in those formally diagnosed with shift-work disorder. Our models found that both night-shift work and use of sleep-promoting medication were associated with increased odds of both high caffeine use and smoking to stay awake, with high use of each of these drugs associated with adverse health and safety outcomes. In addition to organisational efforts to promote shift-work schedules associated with better health and safety outcomes, [2] individual differences in the vulnerability to sleepiness caused by shift work should also be considered, recognising that excessive use of pharmacological countermeasures should not be considered the first-line management approach in such cases. A possible approach to assess the extent of sleepiness in shift work, and the role that artificial stimulants play in enabling shift-work or extended duration work shifts, is to raise the question: What would happen to workplace sleepiness, safety and productivity if caffeine use was not permitted?

Limitations and Future Research

The present study used self-assessment of the primary health and performance outcomes, and may be subject to a bias not to report, given the consequences of work-related errors associated with police work. Previous studies using both cross-sectional and prospective designs have reported similar levels of outcomes as reported here, however, including in occupational groups such as police where errors can have large negative impacts.[4] The retrospective nature of the drug use questionnaires may have been affected by recall bias, or a social desirability bias given the lower response rates to some of the drug use questions. Despite this, we still found significant associations between the use of sleep- and wake-promoting drugs and health and performance outcomes. Future studies should incorporate amount and frequency estimates of drug and medication use, as well as eliciting more information about specific drug classes used to better understand these associations.

Conclusion

Shift work is pervasive in society, enabling essential services to be provided around the clock, but also due to the rapid growth in flexible working arrangements. We found that over and above the effects of working night-shifts, use of sleep- and wake-promoting drugs was associated with detrimental health, performance and safety outcomes. In the past month, one-in-five police officers reported using a sleep-promoting drug, or drug that listed sleepiness as a side-effect, and almost one-in-three used a wake promoting drug, high caffeine levels, or smoking cigarettes to stay awake. Examining patterns of drug use among shift-workers may provide useful markers of vulnerability to shift work to form the basis for personalised intervention strategies.

Footnotes:

Contributors: RO, LB, SL, CO, JS, CC and SR conceived the research question and study design. LB, SL, CC and SR obtained funding for data collection. LB, SL, CO, JS, SQ, CC and SR acquired the data. RO, LB, SL, JS, DL, CC and SR analysed and/or interpreted data from the study. RO drafted the initial manuscript, with critical revision and important intellectual content provided by RO, LB, SL, CO, JS, SQ, DL, CC and SR. Administrative, technical or material support was provided by CO, JS, and SQ. Study supervision was provided by LB, CO, JS, CC and SR.

Funding: This study was supported by grant 2004-FS-BX-0001 and grant 2010C-10002 from the National Institute of Justice, Office of Justice Programs, US Department of Justice; grants R01 OH008496 and R01 OH009403 from the Centers for Disease Control and Prevention. RPO was supported by a Harvard Club of Australia Fellowship, and is the recipient on an NHMRC Peter Doherty award. LKB was supported in part by grant R01 OH 010300 from the National Institute of Occupational Safety and Health.

Competing interests: None declared. Funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Ethical approval: The protocol was approved by the Partners and Monash Human Research Ethics Committees. Participants provided written or electronic informed consent and were not informed about study hypotheses.

Data sharing statement: The data that support the findings of this study are available from the authors upon reasonable request.

References

1. Institute of Medicine (US) Committee on Sleep Medicine and Research. Functional and economic impact of sleep loss and sleep-related disorders. In: Colten HR, Altevogt BM, Eds. Sleep disorders and sleep deprivation: an unmet public health problem. National Academies Press (US), Washington DC; 2006.
2. Drake CL, Roehrs T, Richardson G, Walsh JK, Roth T. Shift work sleep disorder: prevalence and consequences beyond that of symptomatic day workers. *Sleep 2004*; **27**: 1453—62.
3. Barger LK, Ogeil RP, Drake CL, O'Brien CS, Ng KT, Rajaratnam SM. Validation of a questionnaire to screen for shift work disorder. *Sleep 2012*; **35**: 1693—1703.
4. Rajaratnam SMW, Barger LK, Lockley SW, Shea SA, Wang W, Landrigan CP, et al. Sleep disorders, health, and safety in police officers. *JAMA 2011*; **306**: 2567—78.
5. Czeisler CA, Johnson MP, Duffy JF, Brown EN, Ronda JM, Kronauer RE. Exposure to bright light and darkness to treat physiologic maladaptation to night work. *N Engl J Med 1990*; **322**: 1253—9.
6. Van Dongen HPA. Shift work and inter—individual differences in sleep and sleepiness. *Chronobiol Int 2006*; **23**: 1139—47.
7. Åkerstedt T, Wright KP. Sleep loss and fatigue in shift work and shift work disorder. *Sleep Med Clin 2009*; **4**: 257—71.
8. Kalmbach DA, Pillai V, Cheng P, Arnedt JT, Drake CL. Shift work disorder, depression, and anxiety in the transition to rotating shifts: the role of sleep reactivity. *Sleep Med 2015*; **16**: 1532—8.
9. Dorrian J, Heath G, Sargent C, Banks S, Coates A. Alcohol use in shiftworkers. *Accid Anal Prev 2017*; **99**:395—400.
10. Dorrian J, Lamond N, van den Heuvel C, Pincombe J, Rogers AE, Dawson D. A pilot study of the safety implications of Australian nurses' sleep and work hours. *Chronobiol Int 2006*; **23**: 1149—63.
11. Schuckit MA. Alcohol-use disorders. *Lancet 2009*; **373**: 492—501.
12. Room R, Babor T, Rehm J. Alcohol and public health. *Lancet 2005*; **365**: 519—30.
13. Roche AM, Pidd K, Berry JG, Harrison JE. Workers' drinking patterns: the impact on absenteeism in the Australian workplace. *Addiction 2008*; **103**: 738—48.
14. Ogeil RP, Phillips JG. Commonly used stimulants: Sleep problems, dependence and psychological distress. *Drug Alcohol Depend 2015*; **153**: 145—51.
15. Liira J, Verbeek Jos H, Costa G, Driscoll Tim R, Sallinen M, Isotalo Leena K, et al. Pharmacological interventions for sleepiness and sleep disturbances caused by shift work. *Cochrane Database Syst Rev 2014;* Issue 8 DOI: 10.1002/14651858.CD009776.pub2
16. Schaufeli WB, Bakker AB, Hoogduin K, Schaap C, Kladler A. On the clinical validity of the Maslach burnout inventory and the burnout measure. *Psychol Health 2001*; **16**: 565—82.
17. Maslach C, Jackson SE, Leiter MP. Maslach burnout inventory manual. 3rd ed. Palo Alto CA: Consulting Psychologists Press; 1996.
18. Johns MW. Sensitivity and specificity of the multiple sleep latency test (MSLT), the maintenance of wakefulness test and the Epworth sleepiness scale: Failure of the MSLT as a gold standard. *J Sleep Res 2000*; **9**: 5—11.
19. Mitchell DC, Knight CA, Hockenberry J, Teplansky R, Hartman TJ. Beverage caffeine intakes in the U.S. *Food Chem Toxicol 2014*; **63**: 136—42.
20. Olfson M, King M, Schoenbaum M. Benzodiazepine use in the United States. *JAMA Psychiatry 2015;* **72**: 136—42
21. Barbone F, McMahon AD, Davey PG, Morris AD, Reid IC, McDevitt DG, et al. Association of road-traffic accidents with benzodiazepine use. *Lancet 1998*; **352**: 1331—6.

22. Daurat A, Sagaspe P, Moták L, Taillard J, Bayssac L, Huet N, et al. Lorazepam impairs highway driving performance more than heavy alcohol consumption. *Accid Anal Prev 2013*; **60**: 31—4.
23. Kay GG, Schwartz HI, Wingertzahn MA, Jayawardena S, Rosenberg RP. Next-day residual effects of gabapentin, diphenhydramine, and triazolam on simulated driving performance in healthy volunteers: a phase 3, randomized, double-blind, placebo-controlled, crossover trial. *Hum Psychopharmacol 2016*; **31**: 217—26.
24. Futenma K, Asaoka S, Takaesu Y, Komada Y, Ishikawa J, Murakoshi A, et al. Impact of hypnotics use on daytime function and factors associated with usage by female shift work nurses. *Sleep Med 2015*; **16**: 604—11.
25. Walsh JK, Randazzo AC, Stone KL, Schweitzer PK. Modafinil improves alertness, vigilance, and executive function during simulated night shifts. *Sleep 2004*; **27**: 434—9.
26. Gurtman CG, Broadbear JH, Redman JR. Effects of modafinil on simulator driving and self-assessment of driving following sleep deprivation. *Hum Psychopharmacol 2008*; **23**: 681—92.
27. Schwartz JRL, Roth T. Shift Work Sleep Disorder. *Drugs 2012*; **66**: 2357—70.
28. National Transportation Safety Board (NTSB). Safety study: fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes (volume 1). NTSB. Washington DC; 1990.
29. van Amelsvoort LGPM, Jansen NWH, Kant I. Smoking among shift workers: more than a confounding factor. *Chronobiol Int 2006*; **23**: 1105—13.
30. Schernhammer ES, Feskanich D, Liang G, Han J. Rotating night-shift work and lung cancer risk among female nurses in the United States. *Am J Epidemiol 2013;* **178**: 1434—41.

Figure Captions:

Figure 1. Proportion of police officers reporting stress (A), burnout (B), fatigue-related errors (C) or non-fatigue errors (D) by use of drug. *p<.05, **p<.01

Figure 2. Proportion of police officers reporting excessive daytime sleepiness (A), near-misses (B), dozing during a drive following a night-shift (C) or day-shift (D) by use of drug. *p<.05, **p<.01.

Table 1. Use of sleep- and wake-promoting drugs (bold) and social drugs (italic) by police officers

Drug / Class	Categorisation for analysis (n, %)
Wake-promoting drugs (excl. caffeine and nicotine)	*Used in the past month* Yes (180, 5.4%) No (3160, 94.6%)
Sleep-promoting drugs	*Used in the past month* Yes (738, 21.6%) No (2674, 78.4%)
Drugs with sleepiness as a side-effect	*Used in the past month* Yes (648, 19.5%) No (2678, 80.5%)
Alcohol	*Risky alcohol use*[1] Yes (180, 6.3%) No (2709, 93.7%)
Caffeine	*Average consumption per day*[2] None (366, 10.7%) Low (2250, 66.0%) High (793, 23.3%)
Nicotine (Cigarettes)	*Smoking Status* Smoked to stay awake (149, 4.2% of responses and 27.2% of smokers) Smoked, but not to stay awake (398, 11.1% of responses and 72.8% of smokers) Non-smoker (3028, 84.7% of responses)

[1] USA limit for consumption: 196g/ week males (14 std drinks) & 98g/ week females (7 std drinks). A std drink contains 14g of alcohol

[2] High > 400mg of caffeine per day (5+ servings/day); Low ≤400mg per day (up to 4 servings). [19]

Table 2. Logistic regression models predicting study outcomes on sleepiness, near crashes, fatigue-related errors, stress and burnout

Dependent Variable	Model Chi-square (*7df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
ESS score >10	49.953, p<.001	.019-.026	Medication with sleepiness as a side effect	1.58 (1.19, 2.10)
			Night shift work	1.48 (1.22, 1.80)
			Wake promoting meds x night shift work	2.56 (1.19, 5.54)
Near crash	73.987, p<.001	.026-.038	Sleep promoting medication	1.61 (1.21, 2.13)
			Medication with sleepiness as a side effect	1.38 (1.04, 1.82)
			Night-shift work	1.48 (1.20, 1.81)
Fatigue errors	197.398, p<.001	.065-.091	Wake promoting medication	1.68 (1.01, 2.79)
			Sleep promoting medication	1.75 (1.32, 2.30)
			Medication with sleepiness as a side effect	1.57 (1.19, 2.07)
			Night shift work	2.40 (1.97, 2.92)
Stress[c]	58.297, p<.001	.025-.034	Wake promoting medication	1.74 (1.06, 2.89)
			Sleep promoting medication	1.41 (1.10, 1.82)
			Medication with sleepiness as a side effect	1.39 (1.08, 1.78)
			Age	.985(.976-.994)
Burnout[d]	106.26, P<.001	.043-.058	Sleep promoting medication	1.83 (1.40, 2.38)
			Medication with sleepiness as a side effect	1.82 (1.40, 2.37)
			Age	.989 (.98-.99)
			Gender	.78 (.64-.96)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age and gender.

[c]: Scores of 5-7 on a 7-point Likert-type scale

[d]: created using Maslach's burnout scale (emotional subscale) – scores of 18+ used to reflect moderate-high burnout

Table 3. Logistic regression models predicting risky use of social drugs

Dependent Variable	Model Chi-square (*7df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
High caffeine	41.81, p<.001	.017-.026	Sleep-promoting medication	1.49 (1.12, 1.98)
			Night shift work	1.42 (1.16, 1.74)
			Gender	1.29 (1.02, 1.63)
			Age	1.02 (1.01-1.03)
Alcohol misuse [c]	Overall model not significant			
Smokers who smoke to stay awake[d]	23.759, p=.001	.008-.028	Sleep promoting medication	1.97 (1.06, 3.64)
			Night shift work	2.12 (1.34, 3.36)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age and gender

[c]: users who exceeded NIH/NIAAA limits for past week use

[d]: smokers who reported engaging in this behaviour in order to remain alert

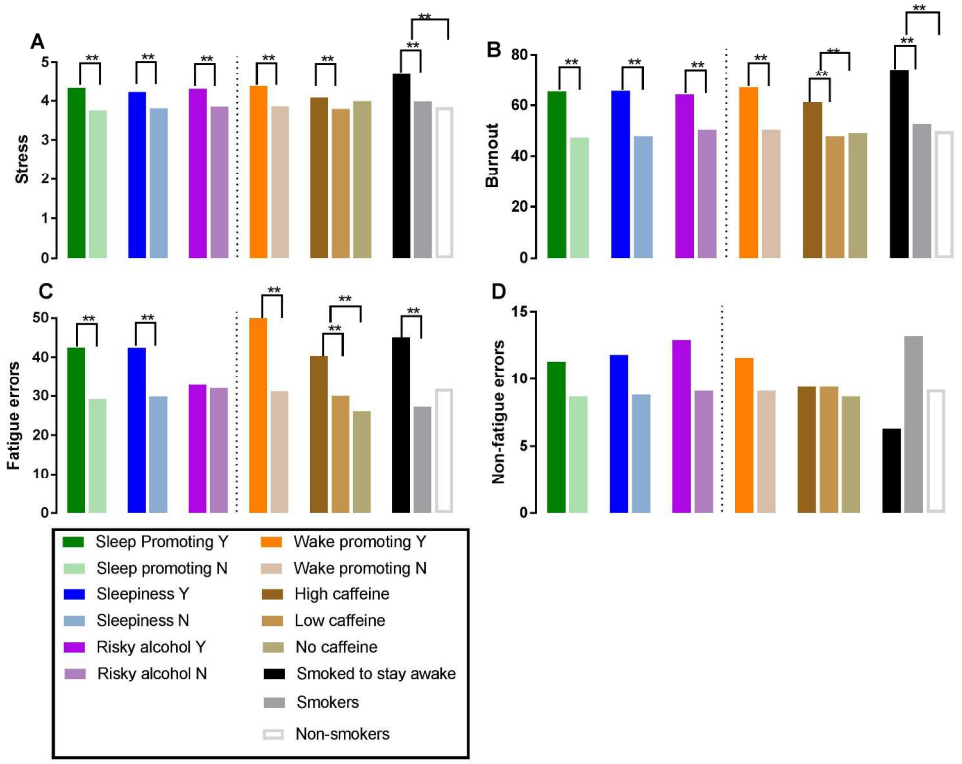

Figure 1. Proportion of police officers reporting stress (A), burnout (B), fatigue-related errors (C) or non-fatigue errors (D) by use of drug. *p<.05, **p<.01

262x212mm (300 x 300 DPI)

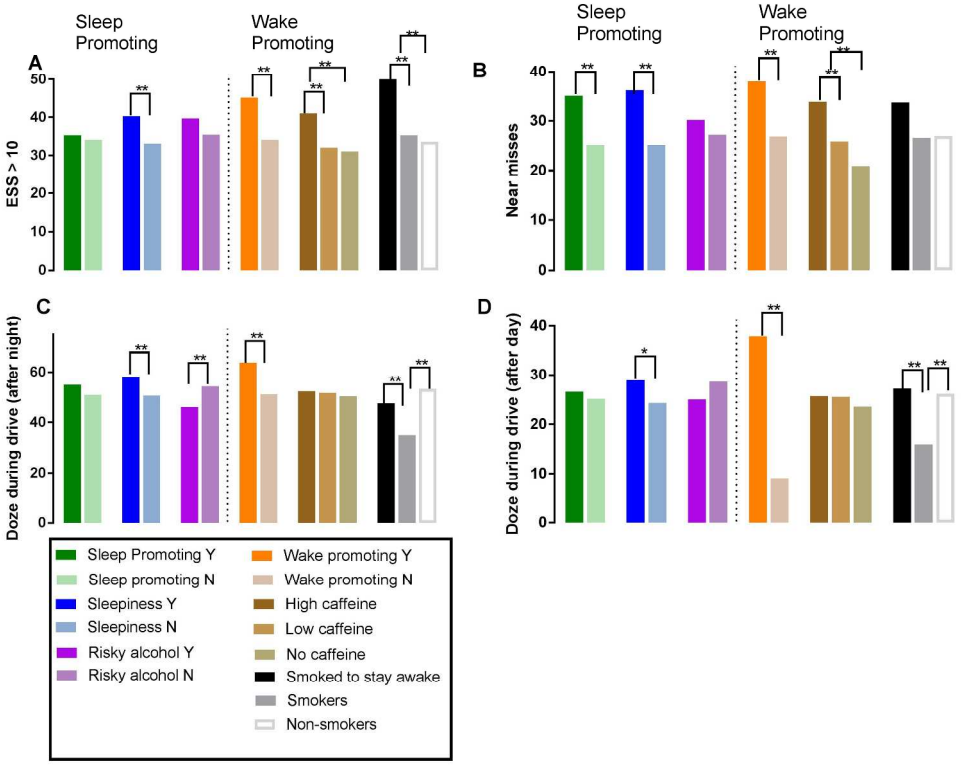

Figure 2. Proportion of police officers reporting excessive daytime sleepiness (A), near-misses (B), dozing during a drive following a night-shift (C) or day-shift (D) by use of drug. *p<.05, **p<.01.

269x218mm (300 x 300 DPI)

Supplementary Table 1. Logistic regression models predicting study outcomes controlling for OSA, insomnia and SWD diagnosis

Dependent Variable	Model Chi-square (*12df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
ESS score >10	137·91, p<·001	·050-·069	Medication with sleepiness as a side effect	1·50 (1·12, 2·00)
			Night shift work	1·32 (1·09, 1·62)
			Wake-promoting meds x night shift work	2·48 (1·19, 5·54)
			Insomnia diagnosis	1·67 (1·17, 2·40)
			OSA diagnosis	1·87 (1·57, 2·21)
			SWD diagnosis	2·42 (1·70, 3·45)
Near crash	111·47, p<·001	·036-·053	Sleep-promoting medication	1·52 (1·15, 2·02)
			Night shift work	1·38 (1·12, 1·70)
			Age	·99 (·98, 1·00)
			Insomnia diagnosis	1·57 (1·11, 2.22)
			OSA diagnosis	1·45 (1·22, 1·73)
			SWD diagnosis	1·61 (1·15, 2·25)
Fatigue errors	254·87, p<·001	·081-·113	Sleep-promoting medication	1·64 (1·24, 2·18)
			Medication with sleepiness as a side effect	1·48 (1·12, 1·96)
			Night shift work	2·18 (1·78, 2·67)
			Insomnia diagnosis	1·68 (1·18, 2·38)
			OSA diagnosis	1.54 (1·30, 1·83)
			SWD diagnosis	2·06 (1·47, 2·89)
Stress[c]	115·94, p<·001	·037-·051	Wake-promoting medication	1·70 (1·03, 2·81)
			Sleep-promoting medication	1·33 (1·03, 1·72)
			Medication with sleepiness as a side effect	1·31 (1·02, 1·69)
			Night shift work	·78 (·64, ·95)
			Age	·982(·973-·992)
			Gender	·791 (·65, ·97)
			Insomnia diagnosis	1·95 (1·38, 2·76)
			OSA diagnosis	1·46 (1·24, 1·72)
			SWD diagnosis	1.47 (1·05, 2·06)
Burnout[d]	262·33, p<·001	·087-·12	Sleep-promoting medication	1·68 (1·28, 2·21)
			Medication with sleepiness as a side effect	1·67 (1·27, 2·19)
			Age	·983 (·97-·99)
			Gender	·65 (·53-·80)
			Insomnia diagnosis	2·70 (1·78, 4·08)
			OSA diagnosis	2·21 (1·86,2·62)
			SWD diagnosis	2·33 (1·61, 3·36)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age, gender, and previous diagnosed OSA, insomnia or SWD.

[c]: Scores of 5-7 on a 7-point Likert-type scale

[d]: created using Maslach's burnout scale (emotional subscale) – scores of 18+ used to reflect moderate-high burnout

STROBE Statement – items identified by page number in bold.

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **(Pages 1 and 2)**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **(Page 2)**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **(page 3)**
Objectives	3	State specific objectives, including any prespecified hypotheses **(page 4)**
Methods		
Study design	4	Present key elements of study design early in the paper **(page 4)**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **(page 4)**
Participants	6	*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants **(page 4 + reference)**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **(pages 4 +5)**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **(page 4)**
Bias	9	Describe any efforts to address potential sources of bias **(page 5, data analysis)**
Study size	10	Explain how the study size was arrived at **(page 4)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **(page 5)**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **(page 5)**
		(*b*) Describe any methods used to examine subgroups and interactions **(page 5)**
		(*c*) Explain how missing data were addressed **(page 5)**
		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy- **(page 4 + reference)**
		(*e*) Describe any sensitivity analyses **(page 5)**

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **(page 4 + reference)**
		(b) Give reasons for non-participation at each stage **(page 4 + reference)**
		(c) Consider use of a flow diagram **n/a**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – **page 5**
		(b) Indicate number of participants with missing data for each variable of interest-**tables**
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) **n/a**
Outcome data	15*	
		Cross-sectional study—Report numbers of outcome events or summary measures **(page 5+6)**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – **pages 5,6 and tables**
		(*b*) Report category boundaries when continuous variables were categorized- **tables**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period-**n/a**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses- **page 6 and tables**
Discussion		
Key results	18	Summarise key results with reference to study objectives **(page 6+7)**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **(page 9)**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **(page 8+9)**
Generalisability	21	Discuss the generalisability (external validity) of the study results **(page 8+9)**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **(page 10)**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

A cross-sectional analysis of sleep- and wake-promoting drug use on health, fatigue-related error and near crashes in police officers

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022041.R1
Article Type:	Research
Date Submitted by the Author:	02-Jul-2018
Complete List of Authors:	Ogeil, Rowan; Monash University, Eastern Health Clinical School; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Barger, Laura; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Lockley, Steven; Monash University, Monash Institute of Cognitive and Clinical Neurosciences and School of Psychological Sciences; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine O'Brien, Conor; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Sullivan, Jason; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Qadri, Salim; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders Lubman, D; Monash University, Eastern Health Clinical School Czeisler, Charles; Brigham and Women's Hospital, Division of Sleep and Circadian Disorders; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital; Division of Sleep Medicine Rajaratnam, Shantha M. W.; Monash University, Monash Institute of Cognitive and Clinical Neurosciences and School of Psychological Sciences; Harvard Medical School, Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women\'s Hospital; Division of Sleep Medicine
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Mental health, Addiction
Keywords:	MENTAL HEALTH, shift work, drug use, health, performance, safety

A cross-sectional analysis of sleep- and wake-promoting drug use on health, fatigue-related error and near crashes in police officers

Rowan P. Ogeil, Ph.D.[1,2,3], Laura K. Barger, Ph.D.[1,2], Steven W. Lockley, Ph.D.[1,2,4], Conor S. O'Brien, B.A.[1], Jason P. Sullivan, B.S.[1], Salim Qadri, B.S.[1], Dan I. Lubman, MB ChB, Ph.D.[3], Charles A. Czeisler, Ph.D., M.D.[1,2], Shantha M.W. Rajaratnam, Ph.D.[1,2,4]

[1] Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital, Boston MA, USA.

[2] Division of Sleep Medicine, Harvard Medical School, Boston MA, USA.

[3] Eastern Health Clinical School, Monash University, Box Hill VIC, Australia and Turning Point, Eastern Health, Fitzroy VIC, Australia.

[4] Monash Institute of Cognitive and Clinical Neurosciences, School of Psychological Sciences, Monash University, Clayton VIC, Australia.

Address for Correspondence:

Rowan P. Ogeil, Ph.D.

Turning Point, 54-62 Gertrude St., Fitzroy 3065 VIC, Australia

Telephone: +613 8413 8469

Fax: +613 9416 3420

Email: Rowan.Ogeil@monash.edu

Word Count: 3600

Abstract

Objectives: To examine sleep- and wake-promoting drug use in police officers, and associations between their use and health (excessive sleepiness, stress, burnout), performance, (fatigue-related errors), and safety (near-crashes) outcomes, both alone and in combination with night-shift work.

Design: Cross-sectional survey.

Setting: Police officers from North America completed the survey either on-line or via paper/pencil at a police station.

Participants: 4957 police participated, 3693 online (91.9%, participation rate), and 1264 on-site (cooperation rate 63.1%).

Main outcome measures: Sleep and wake-promoting drug use, excessive sleepiness, near-crash motor vehicle crashes, dozing while driving, fatigue errors, stress, and burnout.

Results: Over the past month, 20% of police officers reported using sleep-promoting drugs and drugs causing sleepiness, while wake-promoting agents were used by 28% of police (5% used wake-promoting drugs, 23% used high levels of caffeine, and 4% smoked to stay awake). Use of sleep-promoting drugs was associated with increased near-crashes (OR=1.61; 95% confidence interval [CI]: 1.21 to 2.13), fatigue-related errors (OR=1.75; 95% CI: 1.32 to 2.79), higher stress (OR=1.41; 95% CI: 1.10 to 1.82), and higher burnout (OR=1.83; 95% CI: 1.40 to 2.38). Wake-promoting drug use, high caffeine and smoking to stay awake were associated with increased odds of a fatigue-related error, stress and burnout (ORs ranging from 1.68 to 2.56). Caffeine consumption was common, and while smoking was not, of those participants who did smoke, one-in-three did so to remain awake. Night-shift work was associated with independent increases in excessive sleepiness, near-crashes, and fatigue-related errors. Interactions between night-shift work and wake-promoting drug use were also found for excessive sleepiness.

Conclusions: Police who use sleep- and wake-promoting drugs, especially when working night shifts, are most vulnerable to adverse health, performance and safety outcomes. Future research should examine temporal relationships between shift-work, drug use and adverse outcomes, in order to develop optimal alertness management strategies.

Keywords: Mental health; shift work; drug use, health, performance, safety.

Strengths and limitations of this study:

- Examines the contribution of both use of sleep- and wake-promoting drugs and shift schedules on health, performance, and safety outcomes.
- Data were obtained from a large sample of North American police officers.
- Self-assessment of outcome measures was used, which may be subject to a bias not to report.
- The retrospective nature of the survey may have been affected by recall or social desirability bias.

Introduction

Sleep problems adversely impact the physical and mental health of individuals, and place a high economic and health care burden on the community. [1] Poorer health outcomes among those who work non-standard shifts include an increased prevalence of chronic sleep disorders including excessive daytime sleepiness, mental health disturbance (stress and burnout), cardiovascular disease, and diabetes. [2]

Shift-work disorder is characterised by insomnia and/or excessive daytime sleepiness associated with work schedules.[3] Between 8 and 14% of shift workers meet the clinical criteria for a diagnosis of shift-work disorder, with rates as high as 26% reported in those working rotating shifts. [2] The incidence of shift-work disorder is likely underestimated, however, given that the symptoms which define the disorder are common to many sleep disorders, and most shift workers will experience some adverse consequences as a result of opposing circadian physiology to sleep at night, and to be awake during the day. [2] As an occupational group, police provide services 24-hours a day, with officers required to work overnight shifts. Shift-work disorder in both police and other professionals is associated with adverse consequences including an increased propensity for work related errors, decrements in performance and increase incidence of motor vehicle crashes or near-crashes which collectively negatively impact both individual officers and the community. [3, 4]

The majority of shift workers do not adapt to the shifted sleep-wake schedule required for their work,[5] and our understanding of those workers who may be more vulnerable or resistant to shift-work disorder is limited.[6] Circadian misalignment between internally driven physiological processes and the light-dark cycle has been proposed as the mechanism which underlies poorer physical and mental health observed in shift workers.[7] Kalmbach et al. [8] reported that those who develop shift-work disorder report greater levels of anxiety and depression compared to shift workers who do not. These negative effects were further compounded in shift workers with circadian systems that were slower to adapt to changes associated with work-shifts, suggesting that while the biological clock has difficulty adapting to the demands imposed by shift-work, that there are likely trait and state characteristics of individuals that are associated with greater impairment or resilience to health and performance effects following night-shift work.

Hitherto, research examining shift schedules and effects on health and performance outcomes has generally not considered the use of sleep- and wake-promoting drugs. While 1 in 10 adults in the general population have used alcohol as a sleep aid, recent data suggest higher rates of consumption in shift workers with one in six consuming alcohol to help initiate sleep between shifts.[9] Indeed, following prescription sleep medications (e.g., benzodiazepines), alcohol is also commonly used as sleeping aid by shift workers. [10] High alcohol or continued use of prescription sleeping aids is of concern given that their long-term use is associated with poor health and public health outcomes. [11, 12] For example, Roche et al. [13] reported that high-risk drinkers are 22 times more likely than low-risk drinkers to be absent from work due to alcohol use, placing a large burden on the economy due to lost productivity.

Common wake-promoting medications used by shift workers include freely available stimulants (e.g., caffeine and nicotine), [14] in addition to medication obtained via prescription, over-the-counter or as a supplement. A Cochrane review that examined pharmacological product efficacy for shift work disorder found mixed to limited efficacy of wake-promoting agents including modafinil and caffeine. [15] As with sleep-promoting medication, there may be negative consequences that accompany continued use of stimulants. For example, reliance on caffeine has been associated with poorer sleep quality, increased levels of daytime dysfunction, and increased

levels of night time disturbance. In contrast, nicotine dependence has been associated with poorer sleep quality and increased use of sleep medication and sleep disturbances. [14]

This study investigated the use of the sleep- and wake-promoting drugs and their associations with night shift work and health indices (excessive sleepiness, stress, burnout), performance (fatigue-related errors), and safety (near-crashes) outcomes. These outcomes were chosen given that they have previously been demonstrated to be negatively impacted by night shifts [2,4] , and increases in these outcomes is likely to play a role in unintentional injuries and increased mortality in police officers. [16]

Methods

Participants

Police officers in North America (United States 97%, Canada 3%) were recruited to participate in a cross-sectional study either online (*n*=3693) or on-site (*n*=1264). A total of 4957 officers completed the survey between July 2005 and December 2007 with a cooperation rate of 63.1% in the on-site cohort and a 91.9%, participation rate in the online sample.[4] Further details of the sample have been described previously[4], and when completing the survey all participants reported being 18 years or older, and were sworn police officers.

The protocol was approved by the Partners and Monash Human Research Ethics Committees, with the secondary analysis of data for the present analysis approved in April 2015. Participants provided written or electronic informed consent and were not informed about study hypotheses.

Materials and Survey Instruments

In the survey, participants completed sections on their demographics (age, gender, primary role within the police force, length of service, ethnicity). Participants then answered questions about their sleep-promoting drug use (alcohol, prescription sleep medication, over the counter (OTC) or herbal medication, medication that listed sleepiness as a side-effect), and wake-promoting drug use (caffeine, cigarettes, prescribed medication, OTC/herbal medication). Each of these drug use questions asked participants about their use of these types of drugs over the past month, with responses subsequently coded as “used” or “not used” in the past month.

The survey also contained questions about health, performance and safety outcomes over the past month. Stress was assessed with a Likert-type scale asking participants to rate their level of stress from 1 (not at all stressful) to 7 (very stressful) over the past month. The Maslach Burnout inventory (sensitivity 0.70, specificity 0.57) [17] is a 22 question, validated questionnaire. The emotional exhaustion subscale contains 9-items and was used to assess burnout that develops in response to chronic occupational stress.[18] Excessive sleepiness was assessed using the Epworth Sleepiness Scale (ESS) (sensitivity 0.94, specificity 1.00). [19] Performance was assessed with the questions, “In the last month, do you believe sleep deprivation or fatigue caused you to make a mistake or be unnecessarily unsafe in some way?” and “In the last month, do you believe you made a mistake or were unnecessarily unsafe in some way for reasons other than sleep deprivation or fatigue?” To assess motor vehicle safety following a shift the following questions were used: “In the last month, did you have any near miss motor vehicle accidents or crashes (narrowly avoided property damage or bodily harm) in which you were driving?”, “How likely are you to doze off...: While driving, after you worked a night shift?” and “How likely are you to doze off...: While driving, after you worked a day or evening shift?” Night shifts were defined as having

worked 3 or more 8-10 hour shifts between 10 PM and 8 AM or 12 hour shifts between 7 PM and 9 AM)in the last month .

Data Analyses

Chi-square analyses were used to compare police who had used versus those who had not used each sleep and wake-promoting drug on outcome variables in the past month. Outcomes considered were excessive daytime sleepiness (ESS scores exceeding 10); any near-miss crashes or dozing reported following a work shift, any errors made while at work, and levels of stress (1-7 on Likert-type scale) and burnout (Scores of 18+ reflecting moderate-high burnout). Binary logistic regression models were used to examine the increase (or decrease) in risk associated with use of sleep- and wake-promoting medication, and in their interaction with night-shift work. Binary logistic regression models were also used to asses risky use of the social drugs (caffeine, alcohol, smoking) as predicted by use of sleep- and wake-promoting medication and night shift work. For alcohol consumption risky use was defined as exceeding 196g in the past week in males (equivalent to 14 standard drinks), and 98g per week in females (equivalent to 7 standard drinks), with a standard drink containing 14g of alcohol. Caffeine consumption was classified as 'High' (> 400mg of caffeine per day, equivalent to ~5 servings/day) or 'Low' (≤400mg per day, ~up to 4 servings) to reflect caffeine consumption in the U.S population. [20] Smoking status was assessed in two ways. Smokers were compared with non-smokers, with this former group being divided into smokers who reported engaging in this behaviour to stay awake, compared with smokers who did not report smoking to stay awake. Statistical analyses were conducted using SPSS (version 21, IBM Corporation).

Patient and public involvement

This study utilised secondary data of an existing data source, hence patients and the general public were not involved in the development or design of the research.

Results

Sample Characteristics

A total of 4957 police officers (82% male), with a mean age of 38.5 years (SD = 8.3) completed the survey.

Drug Use

Table 1 shows sleep and wake-promoting drug use by police.

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 1 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Sleep-promoting drug use was reported by approximately 20% of police officers in the past month. Regarding the use of wake-promoting drugs, caffeine use was almost ubiquitous (approximately 90% used caffeine in the past month). Furthermore, over one quarter of police reported using either a wake-promoting drug, high levels of caffeine or smoked to stay awake. While only 8.9% of the sample had received a formal diagnosis of shift-work disorder by self-report, these officers were more likely to report using: sleep-promoting drugs, wake-promoting drugs, medication with sleepiness as a side effect, or to report smoking to stay awake (all $p<.05$) in the past month.

Adverse outcomes associated with drug use

Figures 1 and 2 display adverse outcomes associated with use of sleep- and wake-promoting drugs.

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT FIGURES 1 & 2 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Sleep- and wake-promoting drug use was associated with poorer outcomes on self-reported sleepiness, fatigue-related errors, drive performance following a shift, and increased levels of stress and burnout. In addition, those who smoked cigarettes to stay awake and high caffeine consumers reported poorer outcomes.

To better understand the risk of adverse outcomes associated with use of sleep- and wake-promoting drugs and night shifts, binary logistic regression modelling was performed using the following outcome variables: excessive sleepiness, near-crashes, fatigue-related errors, stress and burnout (see Table 2). We also conducted analysis controlling for previously diagnosed insomnia, OSA, and SWD, with findings indicating that use of sleep and wake-promoting drugs and night shift work were still associated with increased risk of poorer outcomes (see Supplementary Table 1).

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 2 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Police using a sleep-promoting medication or a drug that listed sleepiness as a side-effect in the past month were more likely to report a near-crash while driving (*sleep promoting:* OR= 1.61, CI: 1.21-2.13, *side effect:* OR= 1.38, CI: 1.04-1.82), more likely to report a fatigue-related error (*sleep promoting:* OR= 1.75, CI: 1.32-2.30, *side effect:* OR= 1.57, CI: 1.19-2.07), and higher levels of stress (*sleep promoting:* OR= 1.41, CI: 1.10-1.82, *side effect:* OR= 1.39, CI: 1.08-1.78) or burnout (*sleep promoting:* OR= 1.83, CI: 1.40-2.38, *side effect:* OR= 1.82, CI: 1.40-2.37) compared with non-users. Wake-promoting medication use was associated with increased odds of a fatigue-related error (OR= 1.68, CI: 1.01-2.79), and stress (OR= 1.74, CI: 1.06-2.89). Night-shift work was also associated with independent increases in risk for excessive sleepiness (OR= 1.48, CI: 1.22-1.80), near-crash events (OR= 1.48, CI: 1.20-1.81) and fatigue-related errors (OR= 2.40, CI: 1.97-2.92). Interactions between night-shift work and wake-promoting drug use were also found for excessive daytime sleepiness (OR= 2.56, CI: 1.19-5.54).

Binary logistic regression models were also used to assess risky use of alcohol, caffeine and those who smoked to stay awake, using sleep- and wake-medication use and night-shift work as predictors (see Table 3).

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

INSERT TABLE 3 ABOUT HERE

--*-*-*-**-*-*-*-*-**-*-*-*-*-**-*-*-*-*

Use of sleep-promoting medication (OR=1.49, CI: 1.12-1.98), and night-shift work (OR=1.42, CI: 1.16-1.74) each independently was associated with increased excessive caffeine use and smoking in order to stay awake (*sleep promoting:* OR= 1.97, CI: 1.06-3.64, *night-shift work:* OR= 2.12, CI: 1.34-3.36).

Discussion

The present study identified night-shifts as an independent risk factor for excessive daytime sleepiness, near-crashes and fatigue-related errors, supporting previous studies. [2,3] Similarly, a significant proportion of shift workers reported high levels of stress and burnout. [2,6,8] Importantly, the present study extends this work by showing that use of sleep- and-wake promoting drugs was independently associated with poorer health (e.g., stress, burnout) and performance (e.g., fatigue attributable errors, near-crashes) outcomes. Use of sleep- and wake-promoting drugs was also associated with increased excessive sleepiness in night shift workers. Relationships between drug use and poor outcomes remained significant even after controlling for common sleep disorders.

One-in-five police officers reported using a sleep-promoting drug, or drug that listed sleepiness as a side-effect. While we did not ask police officers about their use of specific classes of sleep-promoting medication, the use of benzodiapines is common in the United States, with a retrospective study reporting that one-in-twenty adults had been prescribed a drug from this class during 2008 [21], suggesting higher rates of use of sleep-promoting drugs in this group. While short-term use of medications including benzodiazepines is recommended to ameliorate insomnia, benzodiazepine use has been associated with impairment of driving performance, [22] with a single dose of lorazepam causing greater lane deviations compared with alcohol intoxication of .05% BAC. [23] In addition, triazolam causes residual next day decrements in driving performance,[24] and benzodiazepines with a long half-life, commonly prescribed as anxiolytics have also been associated with increased risk of a motor crash.[22] This is important given the increased rates of stress and burnout reported by police who used sleep-promoting medication in the present study, and previously reported decreases in quality of life and depression symptoms in nurses reported to have used hypnotic drugs. [25] Police using sleep-promoting medication were also more likely to report an error at work attributable to fatigue. Procedural errors and injuries at work associated with use of hypnotic drugs have also been reported in nurses [25]. Such effects may result from a desire to overcome sleepiness or anxiety (given the ESS and high stress reported by police in this sample), or reflect rebound or next day-effects.

Caffeine is widely consumed across the population, with 89% of adults in the US consuming caffeinated beverages [26] , similar to the distribution of use reported in our study. However, while mean average consumption is estimated at 186mg across the population [26], we found that more than 20% of police used a high level of caffeine (>400mg/day), and more than 5% used a medication or over-the-counter drug to promote wakefulness (excluding caffeine) in the past month. Lifetime prevalence of wake-promoting drugs differs across the population, but student samples have estimated a lifetime prevalence of 2-8% depending on drug class, broadly similar to use in the present study [27]. Of those who smoked, a third reported doing so to remain awake. Wake-promoting agents may be used by shift-workers in order to maintain vigilance and alertness on-shift; however, evidence on their efficacy is mixed. [15] Previous studies have suggested that modafinil may have cognitive enhancing effects following sleep deprivation, including in those engaged in simulated night-shift work. [28] Other reports have suggested increases in some measures of simulated driving performance, specifically lane deviation but not speed deviation or off-road incidents, following modafinil suggesting caution with its use as a countermeasure for sleepiness.[29] Our logistic regression analysis did not find wake-promoting drug use a significant predictor of near-crashes. This may reflect that these drugs are being used to alleviate tiredness prior to driving a vehicle, or alternatively, if there is a negative impact on driving performance as found in the studies above, that a much smaller proportion of police officers were using wake-promoting (~5.4%) compared with sleep-promoting drugs (~20%). Our study did find that use of wake-promoting drugs was associated with reported decrements in performance, and also

increased levels of stress/burnout that may be related to changes in shift schedule, particularly given the interaction between use of wake-promoting medication and night-shift work that significantly increases the odds of excessive levels of daytime sleepiness. Given this pattern of findings, future research should investigate both the time of day and intention for use of wake-promoting drugs to determine whether they are being used to aid work-related tasks specifically at work and/or driving, and whether there are pharmacokinetic consequences to this timing which may impact subsequent behaviours.

Widespread use of licit stimulants was common amongst police in our sample, and moderate caffeine consumption (e.g., up to 250mg) has been proposed as a countermeasure to increase performance during night-shift work by the National Sleep Foundation. [30] Dependence on caffeine has been associated with negative consequences, however, including poorer sleep quality and increased daytime dysfunction. [14] In our study, high caffeine users (>400mg) [20] were more likely to report a fatigue-related error or near-miss crash in the present study. These findings are consistent with a previous report that caffeine is the most prevalent stimulant in fatal-to-the-driver heavy truck crashes.[31] While use of caffeine in moderate levels may protect against sleepiness-related errors at work, exceeding these levels is associated with detrimental health and performance impacts. Our results suggest that high caffeine use may be an important marker of vulnerability to excessive sleepiness and performance impairment.

Although the majority of police in our sample were non-smokers, of those who smoked, almost one-in-three reported smoking in order to stay awake. Smoking rates are reportedly higher in night-shift workers, with rates of uptake that are significantly greater in shift workers compared to traditional day workers. [32] Indeed, lung cancer rates of rotating shift workers are significantly greater in current smokers. [33] In addition, dependence upon nicotine has been associated with numerous adverse health effects, including poorer sleep. [14] Police in our sample who reported smoking in order to remain awake reported greater levels of daytime sleepiness, increased propensity to make fatigue-related errors and higher levels of stress and burnout, even compared with smokers who did not engage in this behaviour. As was the case with those officers reporting high caffeine consumption, it may be that these users are vulnerable to the effects of shift work, and are using high levels of these stimulants as a countermeasure against this vulnerability. This may at least in part explain the previous finding that smoking rates are higher in night-shift workers compared to day workers [32].

Recent work has called for further research to understand the inter-individual variability in sleep-wake responses to shift work in order to identify those vulnerable or resilient to assist them in managing shifts. [6] The present study suggests that excessive use of sleep- or wake-promoting medication may be one such trait, given higher rates of use in those formally diagnosed with shift-work disorder. Our models found that both night-shift work and use of sleep-promoting medication were associated with increased odds of both high caffeine use and smoking to stay awake, with high use of each of these drugs associated with adverse health and safety outcomes. In addition to organisational efforts to promote shift-work schedules associated with better health and safety outcomes, [2] individual differences in the vulnerability to sleepiness caused by shift work should also be considered, recognising that excessive use of pharmacological countermeasures should not be considered the first-line management approach in such cases. A possible approach to assess the extent of sleepiness in shift work, and the role that stimulants including licit and available ones play in enabling shift-work or extended duration work shifts, is to raise the hypothetical question: What would happen to workplace sleepiness, safety, and productivity if caffeine use was not permitted?

Limitations and Future Research

The present study used self-assessment of the primary health and performance outcomes, and may be subject to a bias not to report, given the consequences of errors associated with police work and the non-complete cooperation and response rates. Previous studies using both cross-sectional and prospective designs have reported similar levels of outcomes as reported here, however, including in occupational groups such as police where errors can have large negative impacts.[4] The retrospective nature of the drug use questionnaires may have been affected by recall bias, or a social desirability bias given the lower response rates to some of the drug use questions. In addition, we did not ask participants to nominate whether specific drug classes under the rubric of sleep-promoting or wake-promoting had been used, and future studies may utilise other methods to gauge drug use and/or behavioural outcomes using timeline follow back methods [34] over longer periods to further examine the relationship between drug use, health, productivity and safety variables. Despite this, we still found significant associations between the use of sleep- and wake-promoting drugs and health and performance outcomes. Future studies should incorporate amount and frequency estimates of drug and medication use, as well as eliciting more information about the time at which these drugs are used, and specific drug classes used to better understand these associations. Collection of these additional data may also allow for further examination of the small sub-group of officers who reported use of both a sleep-promoting and a wake-promoting drug in the past month.

Conclusion

The present study found that over and above the effects of working night-shifts, use of sleep- and wake-promoting drugs was associated with detrimental health (stress, burnout, excessive daytime sleepiness), performance (errors) and safety (near-crashes) outcomes. In the past month, one-in-five police officers reported using a sleep-promoting drug, or drug that listed sleepiness as a side-effect, and almost one-in-three used a wake promoting drug, high caffeine levels, or smoking cigarettes to stay awake. Examining patterns of drug use among shift-workers may provide useful markers of vulnerability to shift work to form the basis for personalised intervention strategies.

Footnotes:

Contributors: RO, LB, SL, CO, JS, CC and SR conceived the research question and study design. LB, SL, CC and SR obtained funding for data collection. LB, SL, CO, JS, SQ, CC and SR acquired the data. RO, LB, SL, JS, DL, CC and SR analysed and/or interpreted data from the study. RO drafted the initial manuscript, with critical revision and important intellectual content provided by RO, LB, SL, CO, JS, SQ, DL, CC and SR. Administrative, technical or material support was provided by CO, JS, and SQ. Study supervision was provided by LB, CO, JS, CC and SR.

Funding: This study was supported by grant 2004-FS-BX-0001 and grant 2010C-10002 from the National Institute of Justice, Office of Justice Programs, US Department of Justice; grants R01 OH008496 and R01 OH009403 from the Centers for Disease Control and Prevention. RO was supported by a Harvard Club of Australia Fellowship, and is the recipient on an NHMRC Peter Doherty award. LB was supported in part by grant R01 OH 010300 from the National Institute of Occupational Safety and Health.

Competing interests: LB has consulted for Sygma, NASA Ames Research Center, Insight and CurAegis. She is on the scientific advisory board of CurAegis.

SL declares no conflicts with the work described herein. In the past 3 years, he has received consulting fees from the Atlanta Falcons, Atlanta Hawks, Consumer Sleep Solutions, OpTerra Energy Services Inc., Pegasus Capital Advisors LP, Serrado Capital, Slingshot Insights, and Team C Racing, and has current consulting contracts with Akili Interactive, Apex 2100 Ltd, Delos Living LLC, Headwaters Inc., Hintsa Performance AG, Light Cognitive, Lighting Science Group Corporation, Mental Workout, PlanLED, , Six Senses and Wyle Integrated Science and Engineering. SL has received unrestricted equipment gifts from Biological Illuminations LLC, Bionetics Corporation, and F.Lux Software LLC; has equity in iSLEEP, Pty; advance author payment and/or royalties from Oxford University Press; honoraria plus travel, accommodation and/or meals for invited seminars, conference presentations or teaching from BHP Billiton, Lightfair, Informa Exhibitions (USGBC), Teague; travel, accommodation and/or meals only (no honoraria) for invited seminars, conference presentations or teaching from DIN, FASEB, Lightfair, SLTBR, and USGBC. SL has completed an investigator-initiated research grant from Biological Illumination LLC and has an ongoing investigator initiated grant from F. Lux Software LLC. SL holds a process patent for “Systems and methods for determining and/or controlling sleep quality,” which is assigned to the Brigham and Women’s Hospital per Hospital policy. SL has also served as a paid expert for legal proceedings related to light, sleep, and health. SL is a Program Leader for the CRC for Alertness, Safety and Productivity, Australia.

DIL has received speaking honoraria from AstraZeneca, Janssen, Servier and Lundbeck, and has provided consultancy advice to Lundbeck and Indivior.

CC has received consulting fees from or served as a paid member of scientific advisory boards for: Ganésco Inc.; Institute of Digital Media and Child Development; Klarman Family Foundation; Vanda Pharmaceuticals and Washington State Board of Pilotage Commissioners. CC has also received education/research support from Optum, Philips Respironics, Inc., San Francisco Bar Pilots, Schneider Inc., Sysco, and Vanda Pharmaceuticals. The Sleep and Health Education Program of the Harvard Medical School Division of Sleep Medicine, and the Sleep Matters Initiative (which CC directs) have received funding for educational activities from Cephalon, Inc., Jazz Pharmaceuticals, ResMed, Takeda Pharmaceuticals, Teva Pharmaceuticals Industries Ltd., Sanofi-Aventis, Inc., Sepracor, Inc., Wake Up Narcolepsy, and Mary Ann & Stanley Snider via Combined

Jewish Philanthropies. CC is the incumbent of an endowed professorship provided to Harvard University by Cephalon, Inc. and holds a number of process patents in the field of sleep/circadian rhythms (e.g., photic resetting of the human circadian pacemaker). Since 1985, CC has also served as an expert on various legal and technical cases related to sleep and/or circadian rhythms including those involving the following commercial entities: Complete General Construction Company, FedEx, Greyhound, HG Energy LLC, South Carolina Central Railroad Co., Steel Warehouse Inc., Stric-Lan Companies LLC, Texas Premier Resource LLC and United Parcel Service (UPS). CC owns or owned an equity interest in Vanda Pharmaceuticals. He received royalties from McGraw Hill and Koninklijke Philips Electronics, N.V. for the Actiwatch-2 and Actiwatch-Spectrum devices. CC's interests were reviewed and managed by Brigham and Women's Hospital and Partners HealthCare in accordance with their conflict of interest policies.

SR reports that he has served as a consultant through his institution to Vanda Pharmaceuticals, Philips Respironics, EdanSafe, The Australian Workers' Union, National Transport Commission, Transport Accident Commission, New South Wales Department of Education and Communities, and has through his institution received research grants and/or unrestricted educational grants from Vanda Pharmaceuticals, Shell, Teva Pharmaceuticals, Rio Tinto, Seeing Machines, Takeda Pharmaceuticals North America, Philips Lighting, Philips Respironics, Cephalon, and ResMed Foundation, and reimbursements for conference travel expenses from Vanda Pharmaceuticals. His institution has received equipment donations or other support from Optalert, Compumedics, and Tyco Healthcare. He has served as an expert witness and/or consultant to shift work organizations. SR also serves as a Program Leader in the Cooperative Research Centre for Alertness, Safety and Productivity.

Funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Ethical approval: The protocol was approved by the Partners and Monash Human Research Ethics Committees. Participants provided written or electronic informed consent and were not informed about study hypotheses.

Data sharing statement: The data that support the findings of this study are available from the authors upon reasonable request.

References

1. Institute of Medicine (US) Committee on Sleep Medicine and Research. Functional and economic impact of sleep loss and sleep-related disorders. In: Colten HR, Altevogt BM, Eds. Sleep disorders and sleep deprivation: an unmet public health problem. National Academies Press (US), Washington DC; 2006.
2. Drake CL, Roehrs T, Richardson G, Walsh JK, Roth T. Shift work sleep disorder: prevalence and consequences beyond that of symptomatic day workers. *Sleep 2004*; **27**: 1453—62.
3. Barger LK, Ogeil RP, Drake CL, O'Brien CS, Ng KT, Rajaratnam SM. Validation of a questionnaire to screen for shift work disorder. *Sleep 2012*; **35**: 1693—1703.
4. Rajaratnam SMW, Barger LK, Lockley SW, Shea SA, Wang W, Landrigan CP, et al. Sleep disorders, health, and safety in police officers. *JAMA 2011*; **306**: 2567—78.
5. Czeisler CA, Johnson MP, Duffy JF, Brown EN, Ronda JM, Kronauer RE. Exposure to bright light and darkness to treat physiologic maladaptation to night work. *N Engl J Med 1990*; **322**: 1253—9.
6. Van Dongen HPA. Shift work and inter—individual differences in sleep and sleepiness. *Chronobiol Int 2006*; **23**: 1139—47.
7. Åkerstedt T, Wright KP. Sleep loss and fatigue in shift work and shift work disorder. *Sleep Med Clin 2009*; **4**: 257—71.
8. Kalmbach DA, Pillai V, Cheng P, Arnedt JT, Drake CL. Shift work disorder, depression, and anxiety in the transition to rotating shifts: the role of sleep reactivity. *Sleep Med 2015*; **16**: 1532—8.
9. Dorrian J, Heath G, Sargent C, Banks S, Coates A. Alcohol use in shiftworkers. *Accid Anal Prev 2017*; **99**:395—400.
10. Dorrian J, Lamond N, van den Heuvel C, Pincombe J, Rogers AE, Dawson D. A pilot study of the safety implications of Australian nurses' sleep and work hours. *Chronobiol Int 2006*; **23**: 1149—63.
11. Schuckit MA. Alcohol-use disorders. *Lancet 2009*; **373**: 492—501.
12. Room R, Babor T, Rehm J. Alcohol and public health. *Lancet 2005*; **365**: 519—30.
13. Roche AM, Pidd K, Berry JG, Harrison JE. Workers' drinking patterns: the impact on absenteeism in the Australian workplace. *Addiction 2008*; **103**: 738—48.
14. Ogeil RP, Phillips JG. Commonly used stimulants: Sleep problems, dependence and psychological distress. *Drug Alcohol Depend 2015*; **153**: 145—51.
15. Liira J, Verbeek Jos H, Costa G, Driscoll Tim R, Sallinen M, Isotalo Leena K, et al. Pharmacological interventions for sleepiness and sleep disturbances caused by shift work. *Cochrane Database Syst Rev 2014;* Issue 8 DOI: 10.1002/14651858.CD009776.pub2
16. Vila B. Impact of long work hours on police officers and the communities they serve. *Am J Ind Med 2006*; **49**:972-980.
17. Schaufeli WB, Bakker AB, Hoogduin K, Schaap C, Kladler A. On the clinical validity of the Maslach burnout inventory and the burnout measure. *Psychol Health 2001*; **16**: 565—82.
18. Maslach C, Jackson SE, Leiter MP. Maslach burnout inventory manual. 3rd ed. Palo Alto CA: Consulting Psychologists Press; 1996.
19. Johns MW. Sensitivity and specificity of the multiple sleep latency test (MSLT), the maintenance of wakefulness test and the Epworth sleepiness scale: Failure of the MSLT as a gold stan dard. *J Sleep Res 2000*; **9**: 5—11.
20. Mitchell DC, Knight CA, Hockenberry J, Teplansky R, Hartman TJ. Beverage caffeine intakes in the U.S. *Food Chem Toxicol 2014*; **63**: 136—42.
21. Olfson M, King M, Schoenbaum M. Benzodiazepine use in the United States. *JAMA Psychiatry 2015;* **72**: 136—42
22. Barbone F, McMahon AD, Davey PG, Morris AD, Reid IC, McDevitt DG, et al. Association of road-traffic accidents with benzodiazepine use. *Lancet 1998*; **352**: 1331—6.

23. Daurat A, Sagaspe P, Moták L, Taillard J, Bayssac L, Huet N, et al. Lorazepam impairs highway driving performance more than heavy alcohol consumption. *Accid Anal Prev 2013*; **60**: 31—4.
24. Kay GG, Schwartz HI, Wingertzahn MA, Jayawardena S, Rosenberg RP. Next-day residual effects of gabapentin, diphenhydramine, and triazolam on simulated driving performance in healthy volunteers: a phase 3, randomized, double-blind, placebo-controlled, crossover trial. *Hum Psychopharmacol 2016*; **31**: 217—26.
25. Futenma K, Asaoka S, Takaesu Y, Komada Y, Ishikawa J, Murakoshi A, et al. Impact of hypnotics use on daytime function and factors associated with usage by female shift work nurses. *Sleep Med 2015*; **16**: 604—11.
26. Fulgoni VL, Keast DR, Lieberman HR. Trends in intake and sources of caffeine in the diets of US adults: 2001–2010. *Am J Clin Nutrition 2015;* **101**: 1081-1087.
27. Singh I, Bard I, Jackson, J. Robust Resilience and Substantial Interest: A Survey of Pharmacological Cognitive Enhancement among University Students in the UK and Ireland. *PLOS One 2014;* **9**: e105969
28. Walsh JK, Randazzo AC, Stone KL, Schweitzer PK. Modafinil improves alertness, vigilance, and executive function during simulated night shifts. *Sleep 2004*; **27**: 434—9.
29. Gurtman CG, Broadbear JH, Redman JR. Effects of modafinil on simulator driving and self-assessment of driving following sleep deprivation. *Hum Psychopharmacol 2008*; **23**: 681—92.
30. Schwartz JRL, Roth T. Shift Work Sleep Disorder. *Drugs 2012*; **66**: 2357—70.
31. National Transportation Safety Board (NTSB). Safety study: fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes (volume 1). NTSB. Washington DC; 1990.
32. van Amelsvoort LGPM, Jansen NWH, Kant I. Smoking among shift workers: more than a confounding factor. *Chronobiol Int 2006*; **23**: 1105—13.
33. Schernhammer ES, Feskanich D, Liang G, Han J. Rotating night-shift work and lung cancer risk among female nurses in the United States. *Am J Epidemiol 2013;* **178**: 1434—41.
34. Pedersen ER, Grow J, Duncan S, Neighbors C, Larimer ME. Concurrent validity of an online version of the Timeline Followback assessment. *Psychol Addict Behav 2012;* **26**, 672-677.

Figure Captions:

Figure 1. Proportion of police officers reporting stress (A), burnout (B), fatigue-related errors (C) or non-fatigue errors (D) by use of drug. *p<.05, **p<.01

Figure 2. Proportion of police officers reporting excessive daytime sleepiness (A), near-misses (B), dozing during a drive following a night-shift (C) or day-shift (D) by use of drug. *p<.05, **p<.01.

Table 1. Use of sleep- and wake-promoting drugs (bold) and social drugs (italic) by police officers

Drug / Class	Categorisation for analysis (n, % valid responses)
Wake-promoting drugs (excl. caffeine and nicotine)	*Used in the past month* Yes (180, 5.4%) No (3160, 94.6%)
Sleep-promoting drugs	*Used in the past month* Yes (738, 21.6%) No (2674, 78.4%)
Drugs with sleepiness as a side-effect	*Used in the past month* Yes (648, 19.5%) No (2678, 80.5%)
Alcohol	*Risky alcohol use*[1] Yes (180, 6.3%) No (2709, 93.7%)
Caffeine	*Average consumption per day*[2] None (366, 10.7%) Low (2250, 66.0%) High (793, 23.3%)
Nicotine (Cigarettes)	*Smoking Status* Smoked to stay awake (149, 4.2% of responses and 27.2% of smokers) Smoked, but not to stay awake (398, 11.1% of responses and 72.8% of smokers) Non-smoker (3028, 84.7% of responses)

[1] USA limit for consumption: 196g/ week males (14 std drinks) & 98g/ week females (7 std drinks). A std drink contains 14g of alcohol

[2] High > 400mg of caffeine per day (5+ servings/day); Low ≤400mg per day (up to 4 servings). [19]

[3] n=98 (2.9%) of police officers reported use of a sleep-promoting/ drug with sleepiness as a side-effect and a wake-promoting drug in the past month.

Table 2. Logistic regression models predicting study outcomes on sleepiness, near crashes, fatigue-related work errors, stress and burnout

Dependent Variable	Model Chi-square (*7df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
ESS score >10	49.953, p<.001	.019-.026	Medication with sleepiness as a side effect	1.58 (1.19, 2.10)
			Night shift work	1.48 (1.22, 1.80)
			Wake promoting meds x night shift work	2.56 (1.19, 5.54)
Near crash	73.987, p<.001	.026-.038	Sleep promoting medication	1.61 (1.21, 2.13)
			Medication with sleepiness as a side effect	1.38 (1.04, 1.82)
			Night-shift work	1.48 (1.20, 1.81)
Fatigue-related errors	197.398, p<.001	.065-.091	Wake promoting medication	1.68 (1.01, 2.79)
			Sleep promoting medication	1.75 (1.32, 2.30)
			Medication with sleepiness as a side effect	1.57 (1.19, 2.07)
			Night shift work	2.40 (1.97, 2.92)
Stress[c]	58.297, p<.001	.025-.034	Wake promoting medication	1.74 (1.06, 2.89)
			Sleep promoting medication	1.41 (1.10, 1.82)
			Medication with sleepiness as a side effect	1.39 (1.08, 1.78)
			Age	.985(.976-.994)
Burnout[d]	106.26, P<.001	.043-.058	Sleep promoting medication	1.83 (1.40, 2.38)
			Medication with sleepiness as a side effect	1.82 (1.40, 2.37)
			Age	.989 (.98-.99)
			Gender	.78 (.64-.96)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age and gender.

[c]: Scores of 5-7 on a 7-point Likert-type scale

[d]: created using Maslach's burnout scale (emotional subscale) – scores of 18+ used to reflect moderate-high burnout

Table 3. Logistic regression models predicting risky use of social drugs

Dependent Variable	Model Chi-square (*7df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
High caffeine	41.81, p<.001	.017-.026	Sleep-promoting medication	1.49 (1.12, 1.98)
			Night shift work	1.42 (1.16, 1.74)
			Gender	1.29 (1.02, 1.63)
			Age	1.02 (1.01-1.03)
Alcohol misuse [c]	Overall model not significant			
Smokers who smoke to stay awake[d]	23.759, p=.001	.008-.028	Sleep promoting medication	1.97 (1.06, 3.64)
			Night shift work	2.12 (1.34, 3.36)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age and gender

[c]: users who exceeded NIH/NIAAA limits for past week use

[d]: smokers who reported engaging in this behaviour in order to remain alert

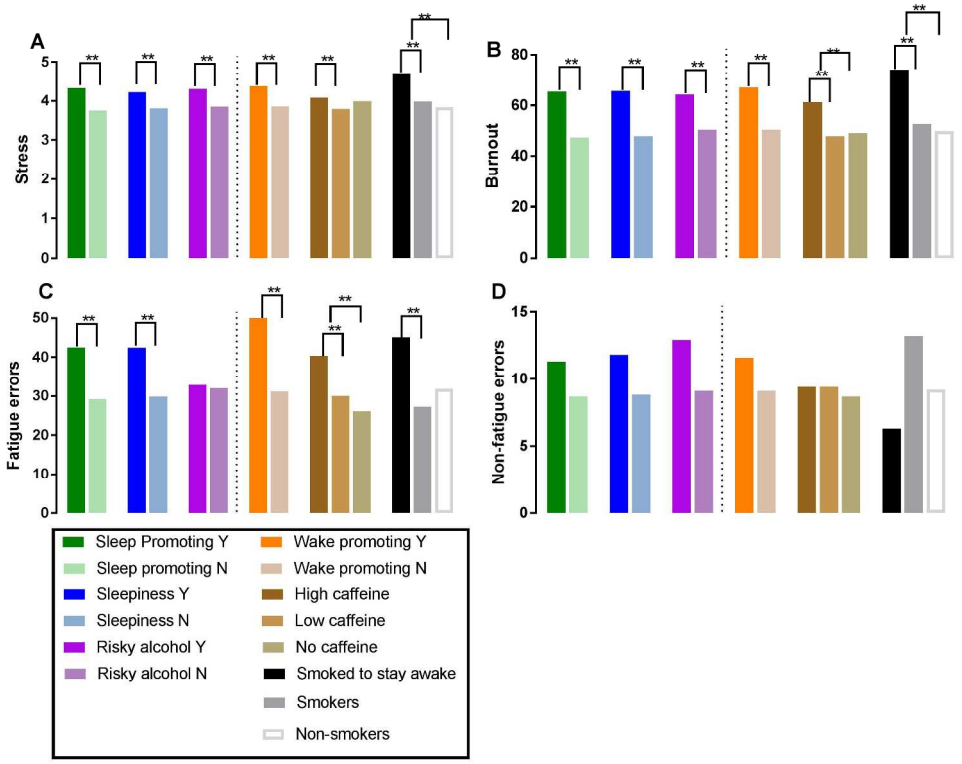

Figure 1. Proportion of police officers reporting stress (A), burnout (B), fatigue-related errors (C) or non-fatigue errors (D) by use of drug. *p<.05, **p<.01

262x212mm (300 x 300 DPI)

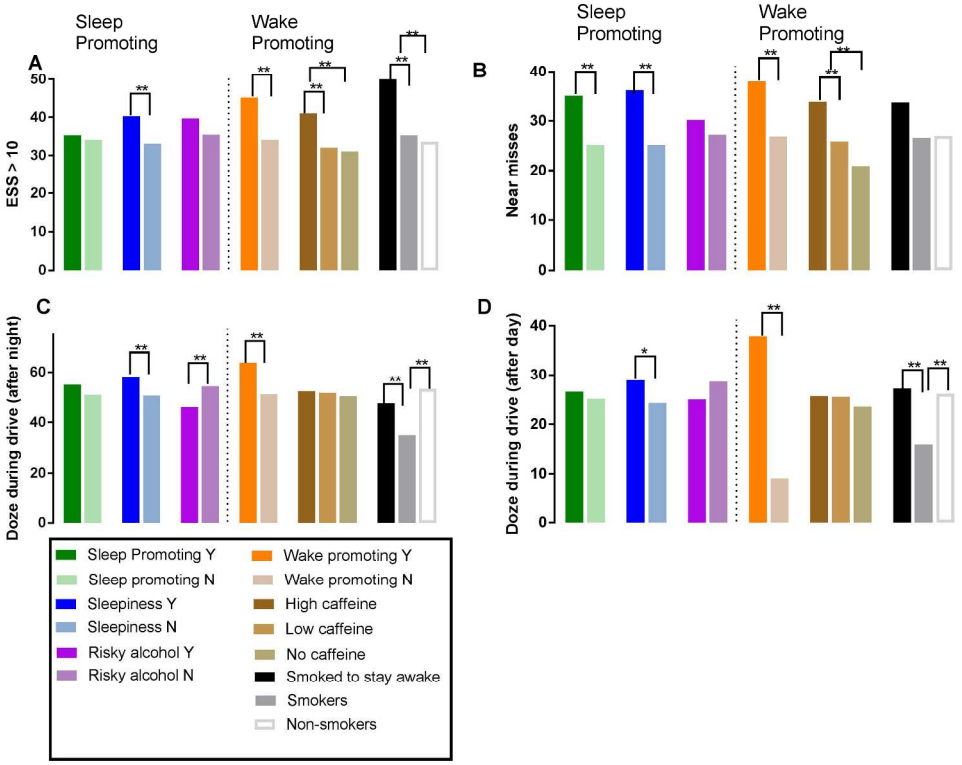

Figure 2. Proportion of police officers reporting excessive daytime sleepiness (A), near-misses (B), dozing during a drive following a night-shift (C) or day-shift (D) by use of drug. *p<.05, **p<.01.

269x218mm (300 x 300 DPI)

Supplementary Table 1. Logistic regression models predicting study outcomes controlling for OSA, insomnia and SWD diagnosis

Dependent Variable	Model Chi-square (*12df*), sig value	Variance explained [a]	Significant predictors [b]	OR (95% CI)
ESS score >10	137·91, p<·001	·050-·069	Medication with sleepiness as a side effect	1·50 (1·12, 2·00)
			Night shift work	1·32 (1·09, 1·62)
			Wake-promoting meds x night shift work	2·48 (1·19, 5·54)
			Insomnia diagnosis	1·67 (1·17, 2·40)
			OSA diagnosis	1·87 (1·57, 2·21)
			SWD diagnosis	2·42 (1·70, 3·45)
Near crash	111·47, p<·001	·036-·053	Sleep-promoting medication	1·52 (1·15, 2·02)
			Night shift work	1·38 (1·12, 1·70)
			Age	·99 (·98, 1·00)
			Insomnia diagnosis	1·57 (1·11, 2.22)
			OSA diagnosis	1·45 (1·22, 1·73)
			SWD diagnosis	1·61 (1·15, 2·25)
Fatigue errors	254·87, p<·001	·081-·113	Sleep-promoting medication	1·64 (1·24, 2·18)
			Medication with sleepiness as a side effect	1·48 (1·12, 1·96)
			Night shift work	2·18 (1·78, 2·67)
			Insomnia diagnosis	1·68 (1·18, 2·38)
			OSA diagnosis	1.54 (1·30, 1·83)
			SWD diagnosis	2·06 (1·47, 2·89)
Stress[c]	115·94, p<·001	·037-·051	Wake-promoting medication	1·70 (1·03, 2·81)
			Sleep-promoting medication	1·33 (1·03, 1·72)
			Medication with sleepiness as a side effect	1·31 (1·02, 1·69)
			Night shift work	·78 (·64, ·95)
			Age	·982(·973-·992)
			Gender	·791 (·65, ·97)
			Insomnia diagnosis	1·95 (1·38, 2·76)
			OSA diagnosis	1·46 (1·24, 1·72)
			SWD diagnosis	1.47 (1·05, 2·06)
Burnout[d]	262·33, p<·001	·087-·12	Sleep-promoting medication	1·68 (1·28, 2·21)
			Medication with sleepiness as a side effect	1·67 (1·27, 2·19)
			Age	·983 (·97-·99)
			Gender	·65 (·53-·80)
			Insomnia diagnosis	2·70 (1·78, 4·08)
			OSA diagnosis	2·21 (1·86,2·62)
			SWD diagnosis	2·33 (1·61, 3·36)

[a]: Estimates here represent Cox & Snell R-Square and Nagelkerke R-square values

[b]: Predictors and levels entered into the model: wake medications: used in the past month vs not used, sleep medications: used in the past month vs not used, medication with sleepiness as a side effect: used in the past month vs not used, night-shifts: worked vs not. Only variables significantly contributing to the model are included in the table. Model controlled for age, gender, and previous diagnosed OSA, insomnia or SWD.

[c]: Scores of 5-7 on a 7-point Likert-type scale

[d]: created using Maslach's burnout scale (emotional subscale) – scores of 18+ used to reflect moderate-high burnout

STROBE Statement – items identified by page number in bold.

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **(Pages 1 and 2)**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **(Page 2)**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **(page 3)**
Objectives	3	State specific objectives, including any prespecified hypotheses **(page 4)**
Methods		
Study design	4	Present key elements of study design early in the paper **(page 4)**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **(page 4)**
Participants	6	*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants **(page 4 + reference)**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **(pages 4 +5)**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **(page 4)**
Bias	9	Describe any efforts to address potential sources of bias **(page 5, data analysis)**
Study size	10	Explain how the study size was arrived at **(page 4)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **(page 5)**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **(page 5)**
		(*b*) Describe any methods used to examine subgroups and interactions **(page 5)**
		(*c*) Explain how missing data were addressed **(page 5)**
		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy- **(page 4 + reference)**
		(*e*) Describe any sensitivity analyses **(page 5)**

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **(page 4 + reference)**
		(b) Give reasons for non-participation at each stage **(page 4 + reference)**
		(c) Consider use of a flow diagram **n/a**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders – **page 5**
		(b) Indicate number of participants with missing data for each variable of interest-**tables**
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) **n/a**
Outcome data	15*	
		Cross-sectional study—Report numbers of outcome events or summary measures **(page 5+6)**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – **pages 5,6 and tables**
		(*b*) Report category boundaries when continuous variables were categorized- **tables**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period-**n/a**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses- **page 6 and tables**
Discussion		
Key results	18	Summarise key results with reference to study objectives **(page 6+7)**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **(page 9)**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **(page 8+9)**
Generalisability	21	Discuss the generalisability (external validity) of the study results **(page 8+9)**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **(page 10)**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.