Title: Acute and long-term sleep measurements produce opposing results on sleep quality in 8hr and 12hr shift patterns in law enforcement officers

Running head: Shift work, sleep quality and fitness in officers

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Total number of words: 4994

Number of references: 44

Conflicts of interests: The authors declare no conflict of interest.

Author contributorship: All authors contributed to the study design and reviewed the literature. Leona Sharma and Sharlenee conducted the literature search, data collection and data processing. Leona Sharma, Paul Burgess and Flaminia Ronca conducted the statistical analysis. Leona Sharma drafted the manuscript. All authors contributed to the interpretation of results, reviewed and critically revised the article, and approved the final version for submission.

Abstract

Occupational demands of law enforcement increase the risk of poor-quality sleep, putting officers at risk of adverse physical and mental health. This cross-sectional study aimed to characterise sleep quality in day workers, 8hr and 12hr rotating shift pattern workers. 186 officers volunteered for the study (37 female, age: 41 ± 7). Sleep quality was assessed using the Pittsburgh Sleep Quality Index, Actigraphy and the Leeds Sleep Evaluation Questionnaire. Maximal aerobic capacity (VO_2max) was measured on a treadmill via breath-by-breath analysis. There was a 70% overall prevalence of poor sleepers based on Pittsburgh Sleep Quality Index scores, where 8hr shifts exhibited the worst prevalence (92%, p = .029), however there was no difference between age, gender or role. In contrast, 12hr shifts exhibited the poorest short-term measures, including awakening from sleep (p = .039) and behaviour following wakefulness (p = .033) from subjective measures, and poorer total sleep time (p = .024) and sleep efficiency (p = .024) from the actigraphy. High VO_2max predicted poorer wake after sleep onset (Rsq = .07, p = .05) and poorer sleep latency (p = .028). There was no relationship between the Pittsburgh Sleep Quality Index scores and any of the short-term measures. The prevalence of poor sleepers in this cohort was substantially higher than in the general population, regardless of shift pattern. The results obtained from the long and short-term measures of sleep quality yielded opposing results, where long-term perceptions favoured the 12hr pattern, but short-term subjective and objective measures both favoured the 8hr pattern.

Keywords: roster, PSQI, LSEQ, actigraphy, police, VO_2max

Introduction

Sleep mediates a number of physiological parameters in humans and is an essential part of health and mental wellbeing (Garbarino et al., 2019; Yong et al., 2016; Charles et al., 2007). Sleep quality varies significantly depending on profession (Thomas et al., 1994; Garbarino & Magnavita, 2015; Peacock et al., 1983), and is particularly affected by factors such as stress, rotational shift work and night shifts (Garbarino et al., 2019; Charles et al., 2007). Poor sleep quality in occupations such as law-enforcement has been associated with an increased risk of work-related injuries, higher job stress and poorer mental health (Costa, 2015; Rajaratnam et al., 2011). The deleterious effects of poor sleep quality have far reaching implications for the long-term health prospects of police officers, a population already at an increased risk of stress-related physical illnesses such as cardiovascular diseases (Garbarino et al., 2019) and metabolic stress syndrome (Yong et al., 2016). Poor sleep quality is also a risk factor for metabolic syndrome and obesity and impacts lifestyle behaviours which influence cardiovascular health (Garbarino & Magnavita, 2015; Mota & Vale, 2009). The cyclical relationship between poor sleep quality and job stress has been observed to severely impact on health variables (Gerber et al., 2010; Lin et al., 2012). A possible mediating factor in this relationship could be exercise, since cardiorespiratory fitness and sleep have been shown to positively influence each other in healthy individuals (Strand et al., 2013), but not in elite athletes (Nedelec et al., 2018). Few data sets exist on sleep quality in law enforcement, none of which have investigated its relationship with fitness.

Law-enforcement officers (LEOs) play a pivotal role in society, often facing high pressure scenarios where they must make rapid decisions during all hours of the day. The need to cover this 24hr period has led to the development of rotating shift schedules, which require officers to work at times misaligned with their internal circadian rhythms (Ma et al., 2019; Fekedulegn et al., 2016).

Given the unavoidable nature of their working hours, it is important to work within the constraints of their occupational requirements to optimise sleep quality in police officers. There is a large body of research concerned with how shift patterns can be manipulated to provide better outcomes for workers. For example, traditionally shift patterns rotated counter-clockwise (morning – night – afternoon~~, known as the Southern Swing~~) whereas now that research shows delaying sleep is easier than advancing it, many studies recommend clockwise rotation schedules (morning-afternoon-night) (Burgess, 2007). There have also been debates on the merits and disadvantages of different shift lengths. Twelve-hour shift schedules mean that workers can have a compressed work week with greater time to rest. However, longer shift lengths may lead to lapses in concentration and may therefore be dangerous for officers. Therefore, the aims of this study were: 1. to examine the effects of different shift patterns on sleep quality, specifically comparing day only, 8hr and 12hr night shift patterns; and 2. To examine the relationship between sleep and maximal aerobic capacity (VO_2max) among LEOs.

Methods

Participants

City based LEOs across two different locations in the United Kingdom were recruited through an email internal to their organisation. 252 officers volunteered to be a part of the study, of which 186 participants (age: 41 ± 8, 137 male) completed the PSQI, while 64 of these (age: 40 ± 8, 44 male) completed the Leeds Sleep Evaluation Questionnaire (LSEQ) every morning for at least 3 shift days and 54 (age: 42 ± 8, 37 male) completed the continuous assessment with actigraphy. The number of participants who completed each measure varied (Table 1). Participants were included in the study if they were working in law enforcement in the United Kingdom, did not present any cardiovascular or neurological conditions and were above 18 years of age. No formal assessment of sleep disorders was made, however, participants were asked for details of use of sleeping pills and pre-existing medical conditions. Four participants recorded using over the counter 'Nytol' and one reported melatonin tablets 'occasionally' or 'once weekly'. Ethical approval was granted by UCL Ethics Committee (13985/004) in line with the declaration of Helsinki. All participants provided informed consent prior to taking part. This study was registered on clinicaltrials.org (13985/004) and given the ClinicalTrials.gov Identifier: NCT04204486.

Table 1. Description of number of participants who were included in analysis for each sleep variable divided by shift pattern. (n = 186)

Sleep variable completed			**Shift pattern**				**Total**
PSQI	*LSEQ*	*Actigraphy*	*12hr roster*	*8hr roster*	*Days only*	*Variable*	
✓			66	26	88	6	186
✓	✓		17	15	32	0	64
✓	✓	✓	15	10	23	0	48
✓		✓	15	13	26	0	54

PSQI (Pittsburgh Sleep Quality Index), LSEQ (Leeds Sleep Evaluation Questionnaire)

Study design

This study was originally designed as a randomised control trial to investigate sleep quality and changes in sleep quality following an exercise intervention programme. Due to interruption of the study due to the COVID-19 pandemic at the time of post-testing, we provide a cross-sectional analysis of the factors affecting sleep quality from the participants' baseline data, and any associations between sleep quality and physical fitness. These data were collected as follows: Participants were emailed the Pittsburgh Sleep Quality Index (PSQI) upon recruitment to record their long-term subjective perception of sleep quality. They then attended the Institute of Sport, Exercise and Health (ISEH) to collect anthropometric and fitness data. To record acute objective measurements of sleep quality, accelerometers were then provided at the participants' workplace and activated in person by researchers. Participants were asked to wear the accelerometer for 8 consecutive days to cover a full cycle of shift days and rest days, and to provide details of their sleeping hours and shift times each morning to aid with actigraphy analysis. During this period, participants were asked to also complete the Leeds Sleep Evaluation Questionnaire (LSEQ) daily to provide a subjective acute measure of sleep quality. All acute measurement items were recorded per day; an average of the entire wear period was then calculated for reporting, such that each score contains an average of sleep quality scores after day shifts, night shifts and rest days for each participant. All questionnaires were created using the Gorilla Experiment Builder (https://gorilla.sc/). Shift pattern information was provided by the participants who were then grouped into: 8 or 12-hour rotating shifts or Days Only (Table 2). Participants on variable shifts were excluded from the acute monitoring phase.

Table *2*. Descriptions of different shift patterns included in the study

Shift Pattern Name		**Pattern**
Rotating	12hr	2 days + 2 nights of 12-hour shifts + 4 rest days
	8hr	2 days, 2 evenings, 2 nights of 8-hour shifts + 2 rest days
Days Only		Day only - including approximate office hours, earlies/days + evenings, but no nights
Variable		Mixed earlies/days and nights

Participant characteristics

Baseline characteristics (height, weight) were measured before the study began and used to calculate body mass index (BMI). Physical fitness was teste through a VO_2max test on a treadmill, using the Bruce Protocol (Bruce, 1971) which consisted of 3-minute incremental stages on a treadmill (h/p/cosmos, Nussdorf, Germany), at each stage the inclination and speed of the treadmill increased. The participant progressed between stages and was verbally encouraged to reach volitional exhaustion. Maximal oxygen uptake (VO_2max) was measured via breath-by-breath analysis trough the Vyntus CPX Metabolic Cart (Vyaire Medical, Chicago, USA). Participants were then categorised into percentiles with a fitness grading based on their age and gender following the American College of Sports Medicine Guidelines (Ferguson, 2014). VO_2max was chosen as the gold standard for cardiopulmonary fitness (Strand et al., 2013).

Sleep measurements

Subjective long-term assessment - PSQI

The PSQI is a widely used tool for the self-assessment of sleep quality over the previous month (Buysse et al., 1989). It provides a global sleep score between 0-21, calculated from adding seven component scores together, with higher scores indicating a worse subjective sleep quality. Global scores equal to or above 5 are considered a sensitive and specific measure indicative of poor sleep quality in adult populations (Buysse et al., 1989).

Subjective acute assessment - LSEQ

The LSEQ (Shahid et al., 2011) was used to assess subjective quality of sleep alongside the actigraphy data. Participants were asked to complete the LSEQ after each long period of sleep (greater than 3 hours) and provide information on their shift type and sleep hours from the previous 24 hours. The LSEQ consisted of 10 questions. This included sleeping state variables: ease of getting to sleep (GTS) and perceived quality of sleep (QOS), which accounted for half of the questions. The other half consisted of the waking state variables: ease of awakening from sleep (AFS) and integrity of behaviour following wakefulness (BFW). Each variable was averaged to give a score out of 100 on a visual analogue scale (VAS), with the total LSEQ score being scored out of 400 as each variable was added cumulatively (Pedlar et al., 2005). A higher score indicated a better result.

Objective acute assessment - Actigraphy

Sleep quality was objectively assessed for a continuous period using a triaxial accelerometer (Actigraph GT3X+, Pensacola, Florida, USA). The devices were initialised using Actilife desktop analysis software version 6.13.2 (Actigraph GT3X+, Pensacola, Florida, USA). Participants were instructed to wear the accelerometer on their non-dominant wrist with a Velcro strap for eight consecutive days. Accelerometers were removed for water-based activities such as showering or swimming.

Raw data were downloaded in 60-s epoch length from the accelerometer using the Actilife software. Sleep diary times were manually inputted into the Actilife sleep analysis software. In cases of the misalignment of the questionnaire with objective recordings, the data were visually inspected by activity level and verified against a sleep diary to adjust the sleep time. The sleep measures were analysed using validated software algorithm based on the Cole-Kripke scoring method (Cole et al., 1992), which provided: Total sleep time (TST), Wake after sleep onset (WASO), Sleep fragmentation index (SFI) and Sleep efficiency (SE), which were then averaged to give participants a total score on each variable. Shrivastava et al. define these variables as (Shrivastava et al., 2014): TST - the number of minutes recorded as sleep between lights off and lights on, WASO – number of minutes recorded as wake after sleep onset, SFI - sum of movement index (MI) and fragmentation index (FI), SE – 100 times the ratio between TST and total time spent in bed.

Statistical analysis

A Kolmogorov-Smirnov test confirmed that all data was not normally distributed, therefore non-parametric tests were implemented. Chi-squared tests were used to analyse the prevalence of poor sleepers based on PSQI global and component scores by demographic group. Bonferroni corrections were applied for post-hoc analyses. Kruskal-Wallis tests were used to analyse the differences between groups in acute sleep quality by shift pattern. Multiple linear regressions by backward elimination were applied to investigate the association between fitness and sleep quality. Spearman's rank was used to analyse the correlations between objective and subjective sleep variables. In order to compare scores between all three methods where data sets were complete, normalised scores were created for each: z-scores of the total LSEQ were calculated; z-scores of the PSQI were calculated and inverted so a higher score signified better sleep; and a normalised total Actigraphy score was calculated as the z-scores of (TST – WASO – SFI + SE)/4. Analyses were carried were carried out using RStudio (R Core Team, 2022). An alpha level of .05 was set to detect significance.

Results

Complete responses on at least one variable were included from a total of 186 LEOs. This included 186 PSQI responses, 64 LSEQ responses and 54 objective accelerometer recordings. Participant characteristics are provided in Table 3.

Table 3. Prevalence of poor sleepers by demographic (n = 186), defined as scoring ≥ 5 on the PSQI global score.

Characteristics	n	Percentage of poor sleepers
ALL	186	70
Birth Sex		
Female	37	78
Male	149	68
Age (years)		
Less than 30	14	93
30 to 34	14	71
35 to 49	58	67
40 to 44	43	63
45 to 49	31	71
More than 50	23	78
Shift pattern		
Day only	88	67
12hr roster	66	66
8hr roster	26	92*
Variable	6	66
Role		
Firearms	98	71
Emergency Response	19	79
Neighbourhood	18	83
Office	50	60
Fitness grading		
Very poor	35	77
Poor	24	54
Fair	17	85
Good	29	66
Excellent	16	56
Superior	3	100

* Significant at $p < .05$

Subjective long-term perception

Of the participants who completed the PSQI, 130 (70%) were categorised as poor sleepers (Table 3). The 8hr shift pattern group contained significantly more poor sleepers than the other groups ($p = .029$) as determined by the PSQI global score, and reported a higher mean global score than the 12hr shift group ($p = .021$) indicating a general perception of worse sleep quality in the past 30 days (Figure 1). On the PSQI components in particular, the 8hr group had a higher prevalence of severe difficulty (score: 3/3) with Sleep efficiency ($p = .011$) and difficulty (score: 2/3) with Daytime dysfunction ($p = .004$), while the 12hr group had a higher prevalence of no difficulty (score: 0/3) on Daytime dysfunction ($p = .029$). While the PSQI global score showed no significant difference by age group, the components' analysis showed that >50's had a higher proportion of severe difficulty with Sleep latency ($p < .001$), and 30-34 year old's had a higher proportion of no difficulty with Sleep duration ($p = .042$). There were no gender or role differences in the PSQI component scores.

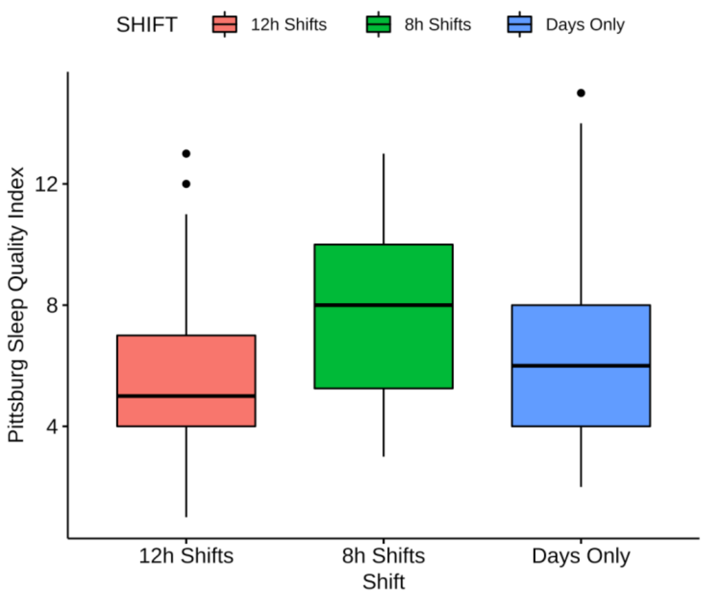

Figure 1. Comparison of PSQI scores between shift patterns. *8hr scored worse than 12hr ($p < .05$). (n=180)

Subjective acute measures

GTS was significantly higher in the 12hr group compared to both other shift patterns ($p < .014$) (Figure 2). AFS was significantly lower in the 12hr group compared to the 8hr group only ($p = .039$). BFW was lower in the 12hr group compared to both other shift patterns ($p < .033$). There was no difference in perceived QOS between groups. These results indicate that compared to the 8hr and day only shifts, officers on the 12hr shift perceived that they were falling asleep faster, but found it harder to awaken and felt less alert upon awakening.

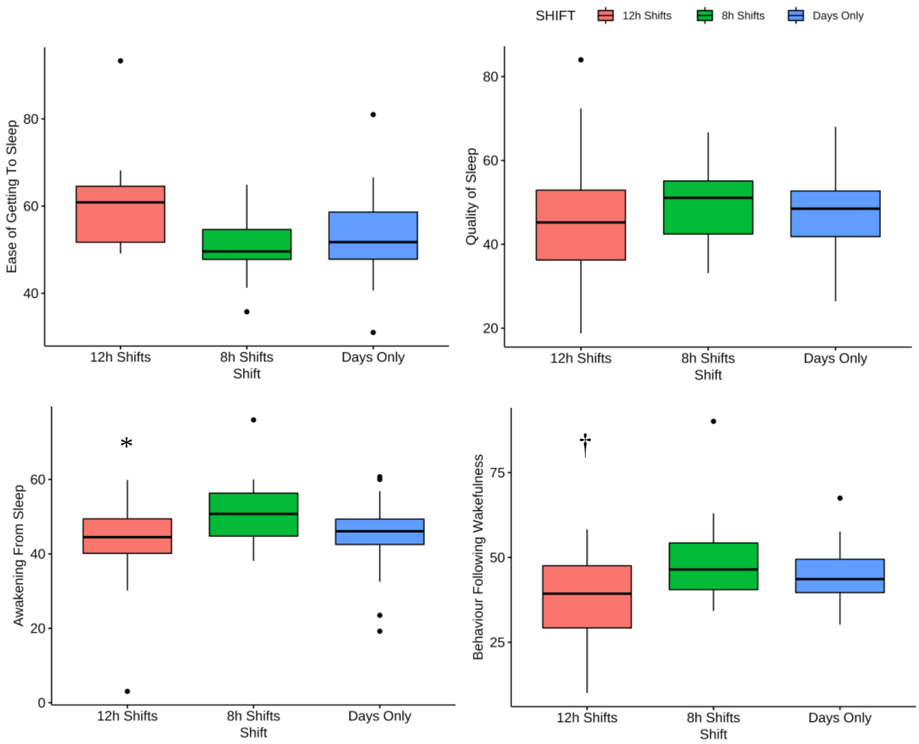

Figure 2. Comparison of Leeds Sleep Evaluation Questionnaire (LSEQ) outcomes between shift patterns (n = 64), a high score indicates better sleep quality.
* Awakening From Sleep (AFS) was significantly different between the 12hr and 8hr groups ($p < .05$)
† Ease of Getting To Sleep (GTS) and Behaviour Following Wakefulness (BFW) were significantly different in the 12hr group compared to both 8hr and Days Only ($p < .05$)

Objective acute measures

TST was lowest for the 12hr group, this reached significance in comparison to Days Only ($p = .024$) but not the 8hr group ($p = .070$) (Figure 3). SE was lower in the 12hr group compared to both 8hr and Days Only ($p < .024$). There was no difference in WASO or SFI between shift patterns. Therefore, the actigraphy measures indicate that sleep time and sleep efficiency were worse in the 12hr shift group.

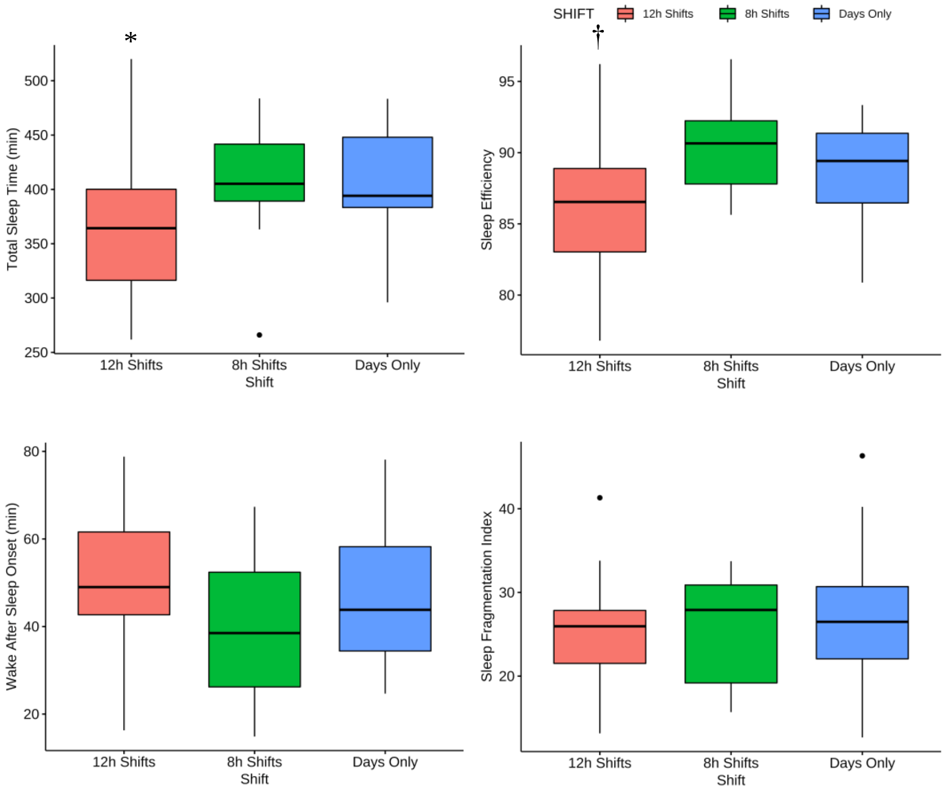

Figure 3. Comparison of Actigraphy sleep outcomes between shift patterns. (n = 54)
* Total Sleep Time (TST) was lower in the 12hr group compared to Days Only (p < .05)
† Sleep Efficiency (SE) was worse in the 12hr group compared to both 8hr and Days Only (p < .05)

Relationship between subjective and objective sleep measures

Of all LSEQ and actigraphy outcomes, only TST was significantly correlated with BFW (Rho = .35, p = .013) (Table 4). The PSQI global score was not associated with any of the subjective or objective acute sleep measures. Normalised total scores of the three methods (Figure 4) showed that 12hr scored more poorly than the 8hr group on the LSEQ (p = .024) and Actigraphy (p = .019) but scored better on the PSQI with marginal significance (p = .048).

Table 4. Spearman's correlations between the two acute sleep measures (LSEQ, Actigraphy) and the long-term subjective perceptions (PSQI) for all participants in the study (LSEQ vs Actigraphy, n = 48; LSEQ vs PSQI, n = 64, Actigraphy vs PSQI, n = 54)

	Variable	*M*	*SD*	1	2	3	4	5	6	7	8
LSEQ:	1. GTS	54.46	9.78								
	2. QOS	48.00	11.52	.40**							
	3. AFS	46.14	10.67	.26*	.40***						
	4. BFW	44.15	11.44	.18	.51***	.42***					
Actigraphy:	5. TST	395.10	59.89	.09	.04	.16	.35*				
	6. SE	88.33	4.15	.01	.21	.04	.21	.41*			
	7. WASO	45.94	16.40	-.06	-.18	-.01	-.05	-.03	-.80***		
	8. SFI	26.20	6.91	-.06	-.12	-.06	.10	-.19	-.58***	.45***	
Long-term perception:	9. PSQI	6.38	2.87	-.10	-.15	-.14	-.21	-.10	.22	-.15	-.04

* indicates p < .05, ** p < .01 ***, p < .001

LSEQ (Leeds Sleep Evaluation Questionnaire), GTS (Ease Of Getting To Sleep), QOS (Quality Of Sleep), AFS (Ease Of Awaking Following Sleep), BFW (Behaviour Following Wakefulness), TST (Total Sleep Time), SE (Sleep Efficiency), WASO (Wake After Sleep Onset), SFI (Sleep Fragmentation Index), PSQI (Pittsburgh Sleep Quality Index)

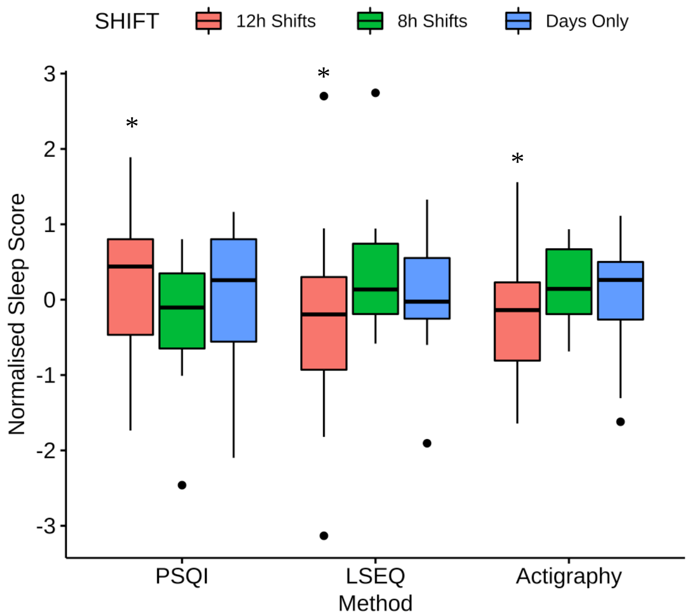

Figure 4. Comparison of normalised total sleep scores only for participants with complete data sets for all three methods (n = 48). * Significant difference between 12hr and 8hr shift groups ($p < .05$)

Relationship between cardiorespiratory fitness and sleep quality

Multiple linear regressions by backward elimination were created for all acute subjective and objective sleep measures as dependent variables, where the full model contained: age, sex, shift pattern, years on shift, role, body fat and VO_2max. The only measure that yielded a significant model was WASO, where VO_2max predicted 7% of the variance in minutes of WASO (Rsq = .07, p = .05), suggesting that officers with higher cardiovascular fitness were more likely to wake up for longer during the night (Figure 5). Fitness was not significantly related to the PSQI global scores, but Excellent and Superior fitness showed a higher prevalence of difficulty with Sleep latency (p = .028). These results indicate that officers with higher fitness levels perceived that it was harder to fall asleep, and exhibited more minutes of wakefulness after sleep onset based on actigraphy measurements.

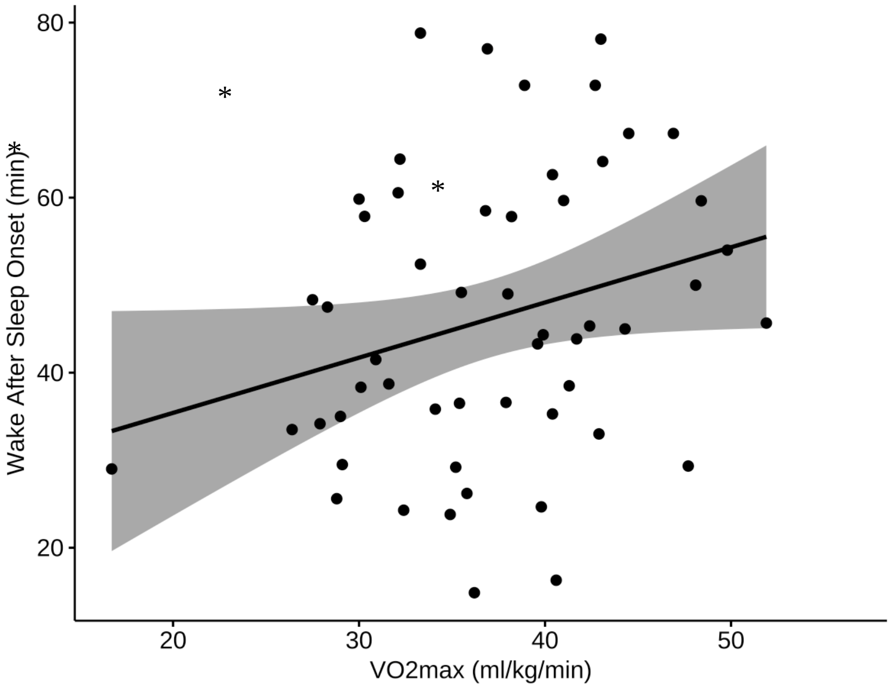

Figure 5. Relationship between cardiorespiratory fitness (VO_2max) and Wake After Sleep Onset (WASO) in the full sample of participants. (n = 54)

8hr shift groups ($p < .05$)

Discussion

Of the entire sample, a striking 70% of participants in this study exhibited poor quality of sleep regardless of shift type. The analysis set out to identify whether one shift pattern might be more appropriate than another, however there was a strong incongruence between the long-term perceptions of sleep quality and the acute measurements. LEOs operating on 8hr shift rosters perceive to have significantly poorer quality of sleep when completing a recall questionnaire of the past 30 days. However, both the acute objective and subjective measurements indicated that LEOs on 12hr shifts exhibit the poorest quality of sleep compared to 8hr and Days Only. There was no correlation between the long-term scores and any of the acute measurements. Age and gender did not significantly impact differences in sleep quality, but cardiorespiratory fitness was associated with poorer general sleep efficiency measured by both actigraphy and PSQI components.

Comparison to other populations

In a meta-analysis of 13 studies conducted by Garbarino et al. (2019) the pooled prevalence of poor sleepers in LEOs was 51.1% [95% CI 41.8–60.3]. Therefore, when compared to similar populations, this study found a higher prevalence of poor sleepers (70%). Similarly, Garbarino et al. (2019) found no significant association between gender and sleep variables in LEOs. Chang et al. (2015) conducted a cross-sectional study of 796 LEOs, and reported a poor sleep quality prevalence of 52.3%, however their study did not include females. These figures are substantially higher than in the general population. Zeitlholfer et al. (2000) reported a prevalence of 32.1% of poor sleepers in the general population in a sample of 1049 Austrians aged above 15. The vast difference in prevalence of poor sleepers between the populations could be due to higher levels of stress and work pressure present in the LEOs compared to other occupations (Garbarino et al., 2019; Ramey et al., 2012; Gerber et al., 2010), as well as the demands of rotating shift work that the majority of the LEO population engage in. The higher prevalence in the present study compared to other LEO studies could be due to the sample selection, where 52% of volunteers in this study worked night shifts. Nonetheless, LEOs on Days Only showed a 67% prevalence of poor sleepers, which is still significantly higher than the general population. The high levels of stress and work pressure present in law enforcement, in all shift patterns, is likely to be a strong contributor to poor sleep in this population, far beyond their working schedule (Garbarino et al., 2019; Ramey et al., 2012; Gerber et al., 2010).

Nonetheless, shift work is notoriously detrimental to sleep. In the present study, the 8hr and 12hr shift groups exhibited poorer sleep on differing measures. Fekedulegn et al. (2016) reported a 61% higher prevalence of poor sleepers in those working night shifts in a sample of 710 officers. A more recent study found LEOs working night shifts reported poorer sleep on the PSQI ($p < .001$) and exhibited significantly poorer cognition measured through a battery of executive function tasks (Elhami Athar et al., 2020). Therefore, while it has been established that night shifts are detrimental to sleep quality and mental wellbeing, it is less clear whether a certain shift pattern may have a lesser impact on officer health and wellbeing.

Comparison between shift patterns

The present study included two types of night shift patterns: 8hr and 12hr forward rotating shifts (Table 2). Both groups of officers on the rotating shift schedule had fast-rotating cycles of the same length (8 days). Rotating shift work can be classified as clockwise (morning - evening - night) or counterclockwise (morning – night - afternoon) in the direction shifts change (Burgess, 2007). The nature of the free-running human biological clock, has a cycle of roughly 25 hours when external environmental cues are removed (Escames et al., 2011). Thus, making phase-delay (delaying sleep) easier than phase-advance (attempting to sleep earlier) (Åkerstedt, 1998) which favours clockwise shift patterns. 12hr patterns cannot be classed as clockwise due to the rapid swing from day to night shifts rather than a gradual phase delay of morning-afternoon-night.

This study presents contradictory results regarding the impact of 8hr and 12hr rotating shift work on sleep quality. The 8hr shift group scored more poorly on the PSQI, however the 12hr group score more poorly on several subjective and objective acute measures. The Days only group did not score worse on any measure. For long-term perceptions, the 8hr group had significantly poorer global PSQI scores, with significantly poorer scores on Sleep efficiency and Daytime dysfunction components compared to the other groups. This indicates that officers on the 8hr pattern perceived it was more difficult to sleep while in bed, resulting in poorer mood and more tiredness during the day. However, the continuous subjective and objective measurements throughout a full shift cycle indicate almost the opposite: objective actigraphy measurements showed that officers on the 12hr shift had poorer Sleep Efficiency and shorter Total Sleep Time and, based on the subjective measurements, they then found it harder to wake up in the morning and felt less alert when awakening. These results (Figure 2) indicate that compared to the 8hr and day only shifts, officers on the 12hr shift perceived that they were falling asleep faster, but found it harder to awaken and felt less alert upon awakening. The only continuous measurement which appeared to favour the 12hr schedule was GTS, although the faster falling asleep time was likely more due to tiredness. To confirm these incongruences, the correlation matrix (Table 4) shows no relationship between the PSQI score and any of the acute measures. While the validation of sleep measures is beyond the scope of this paper, it is important to note that this finding warrants further research on how sleep quality is measured in shift workers.

The current literature favours 12hr shift patterns, as they are suggested to allow a greater rest period within the shift cycle (1/3rd longer than 8hr shift patterns) (Costa, 2015; Åkerstedt & Wright, 2009). After more than one night shift, 3 days are necessary for recuperation in order to fully overcome the impairment in alertness caused by the shift in the sleep-wake cycle (Burgess, 2007). This might explain why the 12hr group yielded better PSQI scores, where participants are asked to provide an overview of 30 days of sleep quality rather than an immediate recall of sleep after a shift. The 12hr shift in this cohort included a four-day rest period after night shifts, which might be enough to aid recovery from sleep loss (Table 2). This extended rest period may also contribute to the officer's welfare due to their ability to socialise more, spend more time with family and engage in hobbies between rosters (Gerber et al., 2010). A major complaint of shift workers across many professions is social isolation due to job-enforced self-exclusion from social activities (Costa, 2015), therefore, by providing longer breaks between shifts, officers on the 12hr shift might feel that their wellbeing is being impacted less than those on 8hr shifts who only have two days of rest every six days of work.

The better continuous scores observed in the 8hr group in this study are therefore inconsistent with the literature, which is based on PSQI studies. Considering that night shifts have worse scores in all sleep domains to the desynchronization of the circadian rhythm, and that the 12hr shift patterns exhibit a more drastic swing between day and night, it is possible that, while the long-term perception of the impact of 12hr shifts on life satisfaction might be better, the short-term impact on alertness and sleep quality might be stronger. Therefore, 8hr shifts may have scored better in the continuous sleep measurements because the clockwise nature of the shifts (day – evening - night) grant the opportunity for gradual adaptation (Åkerstedt, 1998). Further research is needed to investigate the long-term effects of either shift pattern on general health outcomes.

Cardiorespiratory fitness

Cardiorespiratory fitness was the only variable that showed weak but consistent relationships across both long-term and acute measurements. In this study, officers with higher VO_2max ratings generally exhibited poorer sleep outcomes. They found it harder to fall asleep according to the PSQI; this was then confirmed through actigraphy, where a higher VO_2max was associated with more waking minutes during the night (WASO), regardless of age, gender and shift pattern. These results (Figure 5) indicate that officers with higher fitness levels perceived that it was harder for them to fall asleep, and exhibited more minutes of wakefulness after sleep onset based on actigraphy measurements. This was an unexpected result, but not inexplicable.

Sleep quality has largely been associated with better fitness (Strand et al., 2013; Mota & Vale, 2010; Lee & Lin, 2007). However, similar relationships to the one found in the present study, particularly in relation to WASO, have been echoed in studies on elite athletes (Nedelec et al., 2018). For example, in a systematic review, Gupta et al. (2017) found that prevalence of sleep disorders in athletes ranged from 13% to 70%. A potential explanation for this, especially for those with 'excellent' fitness could be related to the acute and chronic stresses which can manifest in the variability of sleep quality of highly trained athletes (Nedelec et al., 2018). Long and intense periods of exercise can lead to inadequate recovery sleep sessions (Driver & Taylor, 2000). The overtraining principle manifests in the sleep pattern, leading to increased fragmentation (Härmä, 1996), as reflected by increased WASO scores. Another potential explanation for this is the 'ceiling effect' (Youngstedt, 2003), where athletes and very fit individuals have exhausted the possible sleep-related adaptations that come with from improved fitness, and other factors may more strongly influence their sleep quality such as stress or nutritional factors (Nedelec et al., 2018). This latter explanation may be true for the LEOs in this study. The fitter volunteers in this study, regardless of shift pattern, were vastly specialist LEOs, who are a select group of individuals required to maintain a higher fitness standard. These officers are typically older, hold more stressful operational responsibilities and are more experienced, which may also imply having experienced greater exposure to trauma. A combination of these factors with the requirement to maintain high fitness standards could therefore be impacting the quality of sleep of these officers. Tailored fitness strategies designed around the occupational demands and stressors of law enforcements could help mitigate these effects.

Strengths and limitations

This study addressed the gap for objective measurements in sleep quality in LEOs and combined a variety of measurements (objective and subjective, short and long term) to provide insight into the effects of differing shift patterns. Another strength of the study was the inclusion of both genders, which is often lacking in the literature.

A limitation is the compliance with the LSEQ and actigraphy continuous measurement which varied among participants. Participants did not always fill the daily questionnaire leading to missing data for some participants, which made it challenging to determine sleep times in the actigraphy data in some cases. This study could have also benefited from taking into consideration the napping habits and caffeine intake of the participants. Garbarino et al. (2004) found that organisational factors allowed certain shift workers, in a police population, to take prophylactic naps to reduce sleepiness during the shift. The sample size of the 8hr group was smaller than other groups, which may have impacted the results. Finally, the incongruence between the PSQI and continuous measurements requires further research. It may be possible that the week chosen for the continuous measurements was substantially different to the officers' general working lives, although these two segments overlapped for most participants. It is perhaps more plausible to assume that the three methods may be measuring different aspects of sleep, and that subjective reporting with a longer recall time (30 days for the PSQI vs 12 hours for the LSEQ) could be measuring different aspects of perception. Further research is needed to investigate the accuracy and relatability of long- and short-term measures of sleep in order to create scales that are more relevant to shift workers.

Implications and recommendations

These results do not present an obvious answer as to which shift pattern is better for sleep quality in LEOs. However, it is clear that there is a high prevalence of poor sleep among LEOs. There are many strategies officers can employ to improve this, such as strategic napping (Åkerstedt & Torsvall, 1985; Bonnefond et al., 2001) and anchor sleep (Burgess, 2007). The present study clearly supports the consensus in current PSQI literature that officers need a minimum of 3 rest days (Burgess, 2007) to recover from significant changes in shift pattern given that the 12hr shift type were allowed 4 days of rest, whereas 8hrs had 2 days of rest between shift cycles. The study also supports the need for education on sleep hygiene practices in order to optimise sleep quality (Garbarino et al., 2019; Zee & Goldstein, 2010). Garbarino et al. (2020) reported that promoting sleep health awareness in police officers led to a significant improvement in the quantity and quality of sleep reported. In the present study no formal assessment of sleep knowledge or disorders was conducted which could give a better clinical analysis. This is pertinent considering a previous study (Garbarino et al., 2004) found shift work may exacerbate intrinsic sleep disorders.

Conclusion

This study reports a very high prevalence of poor sleepers among law enforcement workers, regardless of shift pattern. Long and short-term measurements provided opposing findings regarding shift outcomes. The long-term perception of sleep quality, measured via the PSQI, indicated that the 8hr shift pattern produced the highest prevalence of poor sleepers, where this group scored worst on general sleep quality and efficiency, resulting in poorer mood during the day. However, LSEQ and actigraphy measured throughout a full shift cycle indicated that officers on the 12hr shifts instead had poorest objective sleep efficiency and felt less alert when awakening. Finally, LEOs with high cardiorespiratory fitness were more likely to exhibit more fragmented sleep, possibly due to multiple accumulated stressors. Therefore, the method implemented for measuring sleep quality appears to have substantial implications on study outcomes; the incongruence between the long- and short-term measures reported here warrants further research into how sleep quality is measured in shift workers in order to determine appropriate shift patterns to safeguard officer wellbeing.

References

1. Åkerstedt, T. (1990). Psychological and psychophysiological effects of shift work. *Scandinavian Journal Of Work, Environment & Health*, *16*, 67-73. doi: 10.5271/sjweh.1819
2. Åkerstedt, T. (1998). Is there an optimal sleep-wake pattern in shift work? *Scandinavian Journal of Work, Environment & Health*, *24*, 18–27. http://www.jstor.org/stable/40966833
3. Åkerstedt, T., & Torsvall, L. (1985). Napping in Shift Work. *Sleep*, *8*(2), 105-109. doi: 10.1093/sleep/8.2.105
4. Bonnefond, A., Muzet, A., Winter-Dill, A., Bailloeuil, C., Bitouze, F., & Bonneau, A. (2001). Innovative working schedule: introducing one short nap during the night shift. *Ergonomics*, *44*(10), 937-945. doi: 10.1080/00140130110061138
5. Bruce R. A. (1971). Exercise testing of patients with coronary heart disease. Principles and normal standards for evaluation. *Annals of clinical research*, *3*(6), 323–332.
6. Burgess, P. (2007). Optimal Shift Duration and Sequence: Recommended Approach for Short-Term Emergency Response Activations for Public Health and Emergency Management. *American Journal Of Public Health*, *97*(Supplement_1), S88-S92. doi: 10.2105/ajph.2005.078782
7. Buysse, D., Reynolds, C., Monk, T., Berman, S., & Kupfer, D. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. doi: 10.1016/0165-1781(89)90047-4
8. Chang, J., Huang, P., Lin, Y., Lin, C., Lin, C., Shieh, Y., & Lin, Y. (2015). Association between sleep duration and sleep quality, and metabolic syndrome in Taiwanese police officers. *International Journal Of Occupational Medicine And Environmental Health*, *28*(6), 1011-1023. doi: 10.13075/ijomeh.1896.00359
9. Charles, L., Burchfiel, C., Fekedulegn, D., Vila, B., Hartley, T., & Slaven, J. et al. (2007). Shift work and sleep: the Buffalo Police health study. *Policing: An International Journal Of Police Strategies & Management*, *30*(2), 215-227. doi: 10.1108/13639510710753225
10. Cole, R., Kripke, D., Gruen, W., Mullaney, D., & Gillin, J. (1992). Automatic Sleep/Wake Identification From Wrist Activity. *Sleep*, *15*(5), 461-469. doi: 10.1093/sleep/15.5.461
11. Costa, G. (2015). Sleep deprivation due to shift work. *Handbook Of Clinical Neurology*, 437-446. doi: 10.1016/b978-0-444-62627-1.00023-8
12. Driver, H. S., & Taylor, S. R. (2000). Exercise and sleep. Sleep medicine reviews, 4(4), 387–402. https://doi.org/10.1053/smrv.2000.0110
13. Elhami Athar, M., Atef-Vahid, M., & Ashouri, A. (2020). The Influence of Shift Work on the Quality of Sleep and Executive Functions. *Journal Of Circadian Rhythms*, *18*(1). doi: 10.5334/jcr.194
14. Escames, G., Ozturk, G., Baño-Otálora, B., Pozo, M., Madrid, J., & Reiter, R. et al. (2011). Exercise and melatonin in humans: reciprocal benefits. *Journal Of Pineal Research*, *52*(1), 1-11. doi: 10.1111/j.1600-079x.2011.00924.x
15. Fekedulegn, D., Burchfiel, C., Charles, L., Hartley, T., Andrew, M., & Violanti, J. (2016). Shift Work and Sleep Quality Among Urban Police Officers. *Journal Of Occupational & Environmental Medicine*, *58*(3), e66-e71. doi: 10.1097/jom.0000000000000620
16. Ferguson B. (2014). ACSM's Guidelines for Exercise Testing and Prescription 9th Ed. 2014. *The Journal of the Canadian Chiropractic Association*, *58*(3), 328.
17. Garbarino, S., Mascialino, B., Penco, M. A., Squarcia, S., De Carli, F., Nobili, L., Beelke, M., Cuomo, G., & Ferrillo, F. (2004). Professional shift-work drivers who adopt prophylactic naps can reduce the risk of car accidents during night work. *Sleep*, 27(7), 1295–1302. https://doi.org/10.1093/sleep/27.7.1295
18. Garbarino, S., & Magnavita, N. (2015). Work Stress and Metabolic Syndrome in Police Officers. A Prospective Study. *PLOS ONE*, *10*(12), e0144318. doi: 10.1371/journal.pone.0144318
19. Garbarino, S., Guglielmi, O., Puntoni, M., Bragazzi, N., & Magnavita, N. (2019). Sleep Quality among Police Officers: Implications and Insights from a Systematic Review and Meta-Analysis of the Literature. *International Journal Of Environmental Research And Public Health*, *16*(5), 885. doi: 10.3390/ijerph16050885

20. Garbarino, S., Tripepi, G., & Magnavita, N. (2020). Sleep health promotion in the Workplace. *International Journal of Environmental Research and Public Health, 17*(21), 7952. https://doi.org/10.3390/ijerph17217952
21. Gerber, M., Hartmann, T., Brand, S., Holsboer-Trachsler, E., & Pühse, U. (2010). The relationship between shift work, perceived stress, sleep and health in Swiss police officers. *Journal Of Criminal Justice*, *38*(6), 1167-1175. doi: 10.1016/j.jcrimjus.2010.09.005
22. Greenwood, K., Rich, W., & James, J. (1995). Sleep hygiene practices and sleep duration in rotating-shift shiftworkers. *Work & Stress*, *9*(2-3), 262-271. doi: 10.1080/02678379508256562
23. Gupta, L., Morgan, K., & Gilchrist, S. (2017). Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sports medicine (Auckland, N.Z.)*, *47*(7), 1317–1333. https://doi.org/10.1007/s40279-016-0650-6
24. Härmä M. (1996). Ageing, physical fitness and shiftwork tolerance. *Applied ergonomics*, *27*(1), 25–29. https://doi.org/10.1016/0003-6870(95)00046-1
25. Knutsson, A., & Åkerstedt, T. (1992). The healthy-worker effect: Self-selection among Swedish shift workers. *Work & Stress*, *6*(2), 163-167. doi: 10.1080/02678379208260350
26. Lee, A. J., & Lin, W. H. (2007). Association between sleep quality and physical fitness in female young adults. *The Journal of sports medicine and physical fitness*, *47*(4), 462–467.
27. Lin, S., Liao, W., Chen, M., & Fan, J. (2012). The impact of shift work on nurses' job stress, sleep quality and self-perceived health status. *Journal Of Nursing Management*, *22*(5), 604-612. doi: 10.1111/jonm.12020
28. Ma, C., Hartley, T., Sarkisian, K., Fekedulegn, D., Mnatsakanova, A., & Owens, S. et al. (2019). Influence of Work Characteristics on the Association Between Police Stress and Sleep Quality. *Safety And Health At Work*, *10*(1), 30-38. doi: 10.1016/j.shaw.2018.07.004
29. Minors, D. S., & Waterhouse, J. M. (1981). Anchor sleep as a synchronizer of rhythms on abnormal routines. *International journal of chronobiology*, *7*(3), 165–188.
30. Mota, J., & Vale, S. (2009). Associations between sleep quality with cardiorespiratory fitness and BMI among adolescent girls. *American Journal Of Human Biology*, *22*(4), 473-475. doi: 10.1002/ajhb.21019
31. Nedelec M, Aloulou A, Duforez F, Meyer T, Dupont G. The Variability of Sleep Among Elite Athletes. Vol. 4, Sports Medicine - Open. Springer; 2018. p. 1–13.
32. Peacock, B., Glube, R., Miller, M., & Clune, P. (1983). Police officers' responses to 8 and 12 hour shift schedules. *Ergonomics*, *26*(5), 479-493. doi: 10.1080/00140138308963364
33. Pedlar, C., Whyte, G., Emegbo, S., Stanley, N., Hindmarch, I., & Godfrey, R. (2005). Acute sleep responses in a normobaric hypoxic tent. *Medicine and science in sports and exercise*, *37*(6), 1075–1079.
34. R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
35. Rajaratnam, S., Barger, L., Lockley, S., Shea, S., Wang, W., & Landrigan, C. et al. (2011). Sleep Disorders, Health, and Safety in Police Officers. *JAMA*, *306*(23), 2567. doi: 10.1001/jama.2011.1851
36. Ramey, S., Perkhounkova, Y., Moon, M., Budde, L., Tseng, H., & Clark, M. (2012). The Effect of Work Shift and Sleep Duration on Various Aspects of Police Officers' Health. *Workplace Health & Safety*, *60*(5), 215-222. doi: 10.3928/21650799-20120416-22
37. Shahid, A., Wilkinson, K., Marcu, S., & Shapiro, C. (2011). Leeds Sleep Evaluation Questionnaire (LSEQ). STOP, THAT And One Hundred Other Sleep Scales, 211-213. doi: 10.1007/978-1-4419-9893-4_48
38. Shrivastava, D., Jung, S., Saadat, M., Sirohi, R., & Crewson, K. (2014). How to interpret the results of a sleep study. *Journal Of Community Hospital Internal Medicine Perspectives*, *4*(5), 24983. doi: 10.3402/jchimp.v4.24983
39. Strand, L., Laugsand, L., Wisløff, U., Nes, B., Vatten, L., & Janszky, I. (2013). Insomnia Symptoms and Cardiorespiratory Fitness in Healthy Individuals: The Nord-Trøndelag Health Study (HUNT). *Sleep*, *36*(1), 99-108. doi: 10.5665/sleep.2310
40. Thomas, H., Schwartz, E., & Whitehead, D. (1994). Eight-versus 12-hour shifts: Implications for emergency physicians. *Annals Of Emergency Medicine*, *23*(5), 1096-1100. doi: 10.1016/s0196-0644(94)70109-1

41. Yong, L., Li, J., & Calvert, G. (2016). Sleep-related problems in the US working population: prevalence and association with shiftwork status. *Occupational And Environmental Medicine*, *74*(2), 93-104. doi: 10.1136/oemed-2016-103638
42. Youngstedt S. D. (2003). Ceiling and floor effects in sleep research. Sleep medicine reviews, 7(4), 351–365. doi.org:10.1053/smrv.2001.0239
43. Zee, P., & Goldstein, C. (2010). Treatment of Shift Work Disorder and Jet Lag. *Current Treatment Options In Neurology*, *12*(5), 396-411. doi: 10.1007/s11940-010-0090-9
44. Zeitlhofer, J., Schmeiser-Rieder, A., Tribl, G., Rosenberger, A., Bolitschek, J., & Kapfhammer, G. et al. (2000). Sleep and quality of life in the Austrian population. *Acta Neurologica Scandinavica*, *102*(4), 249-257. doi: 10.1034/j.1600-0404.2000.102004249.x