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Fatigue-related risk perception among emergency physicians working extended shifts

Pierre Berastegui[a,*], Mathieu Jaspar[a], Alexandre Ghuysen[b], Anne-Sophie Nyssen[a]

[a] Cognitive Ergonomics Laboratory, University of Liège, Belgium
[b] Emergency Department, University Hospital Centre of Liège, Belgium

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ABSTRACT

There is a growing body of studies indicating that extended shift duration has an adverse effect on fatigue, consequently leading to reduced work performance and higher risk of accident. Following modern fatigue risk management systems (FRMS), acceptable performance could be maintained by the mobilization of appropriate mitigation strategies. However, the effective deployment of such strategies assume that workers are able to assess their own level of fatigue-related impairments. In this study, we sought to determine whether emergency physicians' subjective feelings of sleepiness could provide accurate knowledge of actual fatigue-related impairments while working extended shifts. We conducted a prospective observational study with a within-subjects repeated measures component. We collected sleep logs, sleepiness ratings and reaction times on a Psychomotor Vigilance Task (PVT) at different time points during shifts. Our results show that the PVT is sensitive to sleep loss and fatigue, with a 10% increase in mean reaction time across the shift. Subjective sleepiness, however, showed no significant association with time since awakening and was not a significant predictor of PVT performance. Our results are consistent with experimental studies showing that individuals tend to underestimate fatigue-related impairments when sleep deprived or functioning under adverse circadian phase. The discrepancy between subjective sleepiness and actual fatigue-related impairments may give workers the illusion of being in control and hinder the deployment of mitigation strategies. Further research is needed to determine the relative weight of circadian phase shifting and cumulative sleep deprivation in the decline of self-knowledge in extended shifts.

1. Introduction

A growing body of literature indicates that schedules involving long working hours substantially increase sleep pressure and fatigue (Akerstedt and Wright, 2009). Consequently, long working hours are associated with reduced performance (Caruso, 2014) and higher risk of errors and accidents (Folkard and Lombardi, 2006). The estimated risk of occupational injury is 147% higher when working more than 12 h per days compared to traditional 8-h working days (Salminen, 2016). The adverse effects of extended hours per day is even stronger when combined with more than 40 h of work a week (Caruso et al., 2004) or night work (Wirtz, 2010). Nevertheless, extended shifts are still permitted in current working hours' directives and implemented in various organizational contexts. It is estimated that one in twenty workers in Europe is involved in such extended hours work (Harrington, 2001). Reasons for maintaining long working hours include high cost of transporting employees, logistic difficulties or scarce qualified staff resources (Kodz et al., 2003).

Over the past decade, increasing attention has been devoted to the development of strategies to manage fatigue-related risk in contexts where it is not possible or desirable to reduce working hours (Barger et al., 2018; Martin-Gill et al., 2018; Studnek et al., 2018). Fatigue risk management systems (FRMS) emerged as comprehensive approaches to mitigate the detrimental effect of fatigue on work performance and safety (Dawson et al., 2012). Moving away from the traditional hours-of-service restrictions, FRMS are particularly popular in sectors involving 24-h operations such as the aviation industry or emergency services. FRMS propose guidelines on harvesting, developing, implementing and monitoring fatigue mitigation strategies. These strategies encompass not only organizational controls but also personal strategies used while on duty. Examples of mitigation strategies include load-shedding, task reallocation or error monitoring strategies (Bérastégui et al., 2018). The main strength of FRMS resides in its ecological approach of harvesting candidate strategies currently used

* Corresponding author.
E-mail address: p.berastegui@uliege.be (P. Berastegui).

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Table 1
Summary of data collection.

Measures	Beginning of shift	Middle of shift	End of the shift
Sleep diary	x		
Spiegel Sleep Inventory	x		
Karolinska Sleepiness Scale	x	x	x
Psychomotor Vigilance Task	x	x	x

within the work group. Strategies that are found to be effective are further integrated into formal standard operating procedures. However, the success of a FRMS does not only depend on the effectiveness of selected strategies but also assume that workers are able to assess their own level of fatigue-related impairments. Only accurate fatigue-related risk perception would allow workers to spot contexts where the deployment of mitigation strategies is required to maintain adequate performance.

It is of crucial importance to rely on sensitive instruments to measure and monitor fatigue-related risk in 24-h operations (Patterson et al., 2018). An extensive body of experimental research has established a clear link between subjective feelings of fatigue and actual performance decrements typically associated with fatigue. Such reports suggest that the general population exhibit accurate estimation of fatigue-related impairments (Kaida et al., 2006). However, recent studies suggest that factors involved in extended working hours may affect the ability to accurately self-assess fatigue-related impairments. Bermudez et al. (2016) showed that subjective alertness was particularly inaccurate at predicting performance on a vigilance task when participants were performing under adverse circadian phase. Zhou et al. (2012) also reported a greater deviation between subjective ratings and actual performance during the biological night. Chronic sleep restriction was reported to negatively distort the subjective sense of fatigue-related impairments (Van dongen et al., 2003; Durmer and Dinges, 2005). Specifically, it was found that chronically sleep restricted individuals tend to underestimate the performance decrements associated with fatigue (Zhou et al., 2012). Since long working hours is known to increase the risk of sleep restriction (Salminen, 2016; Ohtsu et al., 2013) and to disrupt circadian rhythms (Johnson and Lipscomb, 2006), it is arguable that workers regularly involved in extended shift may become blunt to the perception of fatigue-related impairments. Despite its precursor role in any mitigation processes, little attention has been devoted to the study of fatigue-related risk perception in 24-h operations.

The current study investigates the association between self-reported ratings of sleepiness and actual performance decrements on a neurobehavioral task in emergency physicians working extended shifts. In Europe, emergency physicians routinely work up to 24 h in a row coupled with a weekly working time of up to 72 h, and thus constitute a particularly suitable population for the study. We postulate that 1) self-perceived sleepiness is not an accurate predictor of actual fatigue-related impairments, and that 2) discrepancies between subjective ratings and actual performance amplify with time spent awake and time of day.

Table 2
Descriptive statistics

Variable	Mean	SD	Median	Min	Max
Age	36.89	10.73	34	25	65
Working Experience	7.36	6.58	6	1	23
Mean Reaction Time	445	45	444	342	570
Karolinska Sleepiness Scale	2.80	1.16	3	1	7
Sleep Duration	7.39	1.00	7.25	5.25	10
Sleep Quality	21.84	4.02	22	12	29
Time Since Awakening	7.30	4.55	6.92	1.03	16.28

2. Materials and methods

2.1. Study design and participants

A prospective observational study was conducted over a 5-month period in the Emergency Department (ED) of the Liège University Hospital Centre. The hospital is a tertiary-care centre with an ED volume of 92,775 patients in 2015. Emergency physicians routinely work extended shifts, coupled with a weekly working time of up to 72 h. Day shift starts from 8:30 a.m. to 6:30 p.m. and night shift starts from 6:30 p.m. to 8:30 a.m. Physicians are regularly assigned to work both shifts in a row for a total working time of 24 h. The study was conducted jointly by the ED and the Cognitive Ergonomics Laboratory of the University of Liège and was approved by the relevant ethics Committees. All emergency physicians were informed about the study and participated on a voluntary basis. Twenty-eight out of 32 physicians agreed to participate in the study. In accordance with the Declaration of Helsinki, all participants gave their written informed consent prior to their inclusion in the study. Participants were free to withdraw from the study at any time.

2.2. Procedure

Following informed consent, participants were provided with a triaxial accelerometer (GENEActiv Original) and a smartphone (Huawei Y560) preinstalled with an application specifically designed for the study. Participants were invited to participate the day prior to testing. Physicians were asked to wear the accelerometer device on the non-dominant wrist throughout the shift, starting the night before testing. The application contained a sleep diary, the Karolinska Sleepiness Scale (KSS), the Spiegel Sleep Inventory (SSI) and the Psychomotor Vigilance Task (PVT). Physicians were instructed to complete the sleep diary and the SSI at the beginning of each shift and to complete the KSS followed by the PVT at the beginning, middle and end of each shift (Table 1). Physicians were also asked to indicate if they had a nap during the shift and when. We collected data for regular day shifts (8:30 a.m. to 6:30 p.m.) and 24 h shifts (8:30 a.m. to 8:30 a.m.). We disposed of 8 smartphones and accelerometers that were distributed between participants during the study period. Physicians participated in the study during five to twelve shifts (see Table 2).

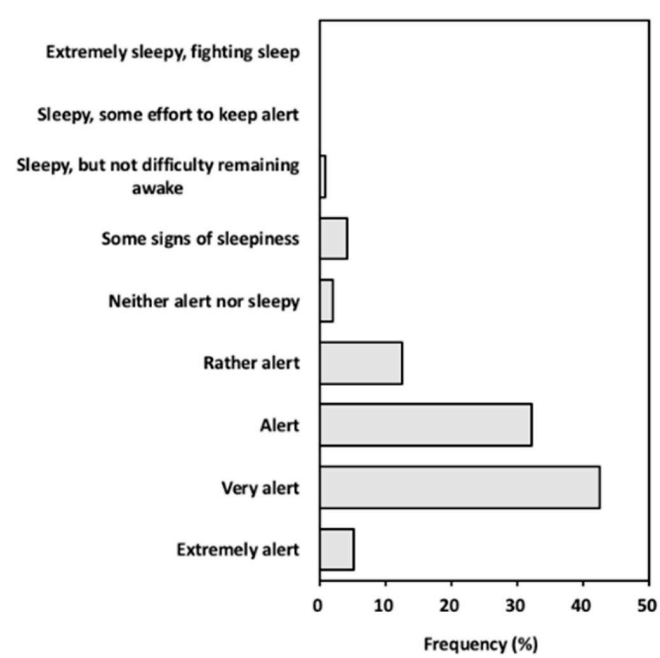

Fig. 1. Frequency histogram of Karolinska Sleepiness Scale ratings.

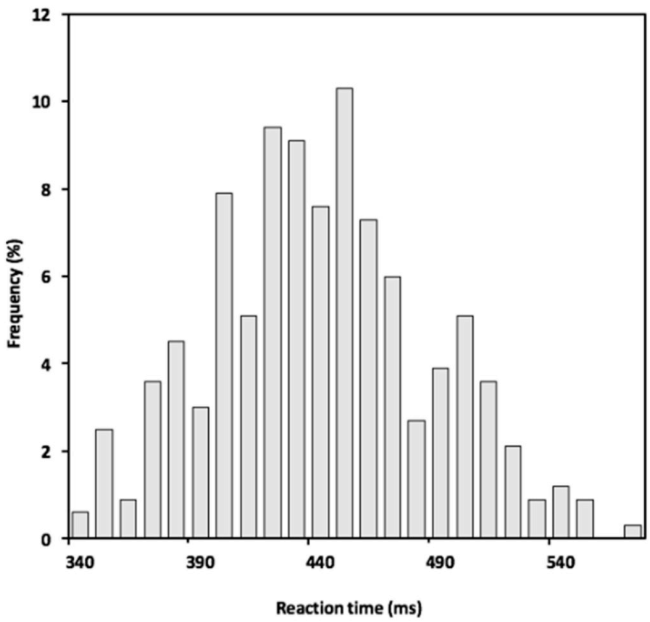

Fig. 2. Frequency histogram of mean reaction times on the Psychomotor Vigilance Task.

3. Materials

Fatigue-related impairments. The Psychomotor Vigilance Task is a widely used reaction time task used to objectively assess changes in sustained attention associated with sleep loss or time on task (Lee et al., 2010; Basner and Dinges, 2011). Sustained attention can be defined as the ability to direct and focus cognitive activity on specific stimuli (DeGangi and Porges, 1990). Sustained attention is a basic requirement for information processing and thus is required in the execution of many tasks. It enables the maintenance of vigilance, selective and focused attention, response persistence and continuous effort despite changing conditions. The PVT is a widely used instrument in sleep research and reflect the effect of sleep pressure developing with time spent awake (Beijamini et al., 2008). We measured sustained attention using an Android-based touchscreen version of Psychomotor Vigilance Task (Kay et al., 2013). Participants were presented with stimuli that occur at random intervals with an inter-stimulus intervals (ISI) between 2 and 10 s. If the participant touched the screen before the start of the stimulus, the response was ignored and a warning signal was shown. We used a 5-min version instead of the standard 10-min PVT for time constraints concerns. Research shown that 5-min PVT is a reasonable substitute in applied settings where use of the standard 10-min PVT is not feasible or desirable, provided that an appropriate outcome variable is used (Lamond et al., 2005; Roach et al., 2006). Mean response time has been shown to be reasonably similar between the two versions of the PVT (Roach et al., 2006). Reaction times were used to compute mean reaction time for each PVT trial. Following Basner & Dinges (Basner and Dinges, 2011), responses without a stimulus or RTs < 100 ms were counted as false starts and excluded from data analysis.

Subjective sleepiness. Self-reported sleepiness was measured by the Karolinska Sleepiness Scale (KSS), a nine-point Likert scale ranging from "very alert" to "very sleepy, fighting sleep". The KSS has been widely used in the study of shift work and there is an extensive body of literature linking KSS scores to objective measures of sustained attention (Kaida et al., 2006; Åkerstedt et al., 2014; Gorgoni et al., 2014). Time on task was demonstrated to produce similar results on reaction times and sleepiness ratings, suggesting that subjective feelings of sleepiness may be an accurate predictor of fatigue-related impairments (Kaida et al., 2006; Gorgoni et al., 2014).

Sleep quality. Sleep quality was measured using the Spiegel Sleep Inventory (Spiegel and Weitzman, 1981), a self-administered questionnaire that inquiries about the previous night via six items on sleep initiation, quality and length; nocturnal awakenings; dreams; and feeling refreshed in the morning. A score below 15 suggests pathologic sleep whereas a score above 20 is considered good sleep.

Sleep duration. Physicians were asked to report previous day bedtime and awakening time. Accelerometer data was downloaded using the Geneactiv software and used to cross-validate data from sleep diaries. Combining the objective data from the accelerometer data with the subjective data from the sleep diaries provides a more accurate assessment of the actual sleep duration (Girschik et al., 2012; Lockley et al., 1999; Littner et al., 2003).

3.1. Statistical analysis

28 emergency physicians participated to the study. Data were gathered during 114 regular day shifts and 68 24 h shifts for a total of 182 shifts. All PVT scores and KSS ratings recorded after a rest break (typically between 1:00 a.m. and 4:00 a.m.) were excluded from the analysis. Preliminary analysis showed variability in testing times as well as a significant amount of missing data. Consequently, it was decided to consider testing time as a continuous predictor rather than a categorical variable. We obtained 326 observations after accounting for excluded and missing data. All statistical analyses were conducted using SPSS 22.0 software (IBM Corporation, Armonk, NY). We conducted linear mixed-effects regression models with maximum likelihood estimation. Subjects were specified as a random intercept to control for their associated intraclass correlation (Pinheiro and Bates, 2000). We centered variables before calculating cross-product terms following guidelines established by Aiken and West (1991), subtracting the mean of the variable such that the means of the centred variables were zero.

We first evaluated if reaction time or sleepiness ratings were

Table 3
Linear Mixed Model Analyses with Mean RT and KSS as dependant variables, and subject as a random intercept.

Measure	Mean RT				KSS			
	Estimate	SE	t	95% CI	Estimate	SE	t	95% CI
(constant)	539.55	45.13			6.50	1.22		
Fixed effects								
Time of Day	**-9.47**	**4.82**	**-1.97**	**-18.96 – 0.018**	-0.12	0.14	-0.91	-0.39 – 0.14
Time Since Awakening	**12.07**	**4.81**	**2.51**	**2.60 – 21.52**	-0.11	0.13	-0.84	-0.15 – 0.38
Sleep Duration	**-8.69**	**3.12**	**-2.78**	**-14.83 – -2.54**	-0.003	0.089	-0.39	-0.18 – 0.17
Sleep Quality	0.87	0.86	1.01	-0.83 – 2.57	**-0.125**	**0.024**	**-5.17**	**-0.173 -0.077**
Random effects								
Subject	816.28	287.95			0.30	0.13		
Residual	1035.27	85.24			0.97	0.08		

Note. Reaction times (RT) measured in milliseconds. Time of day, time since awakening and sleep duration measured in hours. SE = standard error. Significant effects are indicated by boldface.

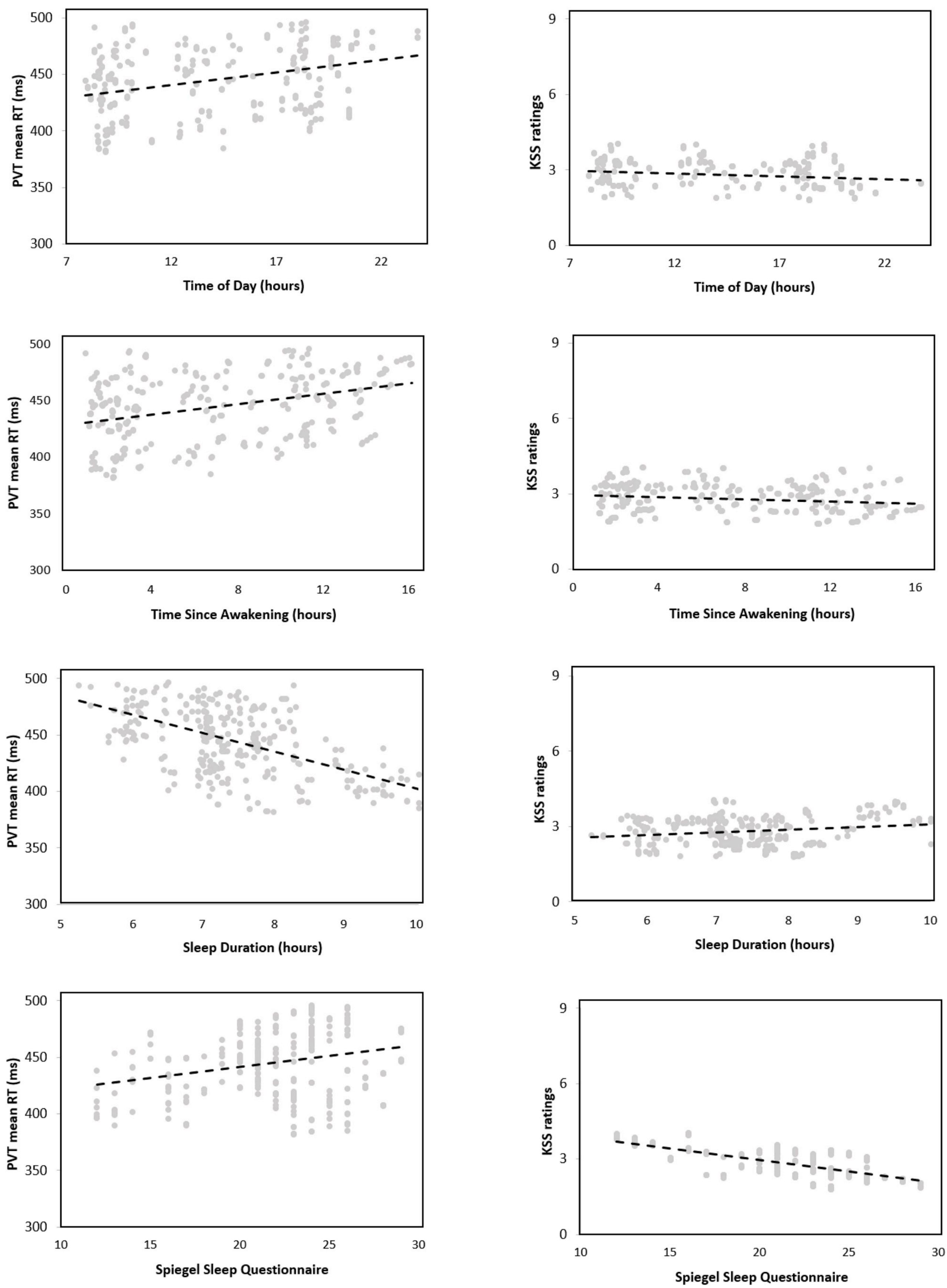

Fig. 3. Predicted values of the Linear Mixed Model Analyses. Bold line: mean prediction.

Table 4
Linear Mixed Model Analyses with Mean RT as dependant variables and subject as a random intercept.

Measure	Estimate	SE	t	95% CI
(constant)	452.94	6.27		
Fixed effects				
Karolinska Sleepiness Scale	0.28	1.84	0.15	-3.34 – 3.89
Time Since Awakening	**2.78**	**0.41**	**6.73**	**1.96 – 3.59**
Karolinska * Time Since Awakening	-0.15	0.35	-0.43	-0.84 – 0.54
Random effects				
Subject	1038.78	331.51		
Residual	886.76	289.23		

Note. Dependant variable = mean reaction times (RT) measured in milliseconds. SE = standard error. Significant effects are indicated by boldface.

Table 5
Linear Mixed Model Analyses with Mean RT as dependant variables and subject as a random intercept.

Measure	Estimate	SE	t	95% CI
(constant)	453.15	6.21		
Fixed effects				
Karolinska Sleepiness Scale	0.25	1.85	0.13	-3.39 – 3.88
Time of Day	**12.71**	**1.88**	**6.48**	**8.47 – 15.87**
Karolinska * Time of Day	-0.99	1.62	−0.61	-4.18 – 2.20
Random effects				
Subject	1086.78	88.85		
Residual	865.81	282.58		

Note. Dependant variable = mean reaction times (RT) measured in milliseconds. SE = standard error. Significant effects are indicated by boldface.

significantly determined by time of day, time since awakening, sleep duration and sleep quality. Then we conducted additional models to test whether sleepiness rating was a significant predictor of reaction time after controlling for time of day and time since awakening.

4. Results

4.1. Descriptive statistics

Participants were 28 (17 men and 11 women) emergency physicians working at the Emergency Department (ED) of the Liège University Hospital Centre (Table 2). Participants' median age was 34 with a median working experience in the ED of six years. KSS (see Figure 1) and PVT data (see Figure 2) were collected between 1.03 and 16.28 h since awakening (M = 7.30, SD = 4.55). Mean reaction time on the PVT was 445 ms (SD = 45) and mean KSS ratings was 2.80 (SD = 1.16). Physicians reported sleeping an average of 7.39 (SD = 1.16) hours per night, with a mean sleep quality of 21.84 (SD = 4.02) as measured by the SSI.

4.2. Mixed models

The first model tested if time of day, time since awakening, sleep duration and sleep quality were significant predictors of mean reaction time on the Psychomotor Vigilance Task (Table 3). It was found that time since awakening significantly predicted mean reaction time, $F(1, 271) = 6.31$, $p = .01$, as did sleep duration, $F(1, 297) = 7.74$, $p < .01$, and time of day, $F(1, 272) = 3,86$, $p = .04$. As expected, participants' mean reaction time increased with time of day and time since awakening, and decreased with sleep duration. However, the main effect of sleep quality was not significant, $F(1, 292) = 1.02$, $p = .31$. The second model tested if time of day, time since awakening, sleep duration and sleep quality significantly predicted participant's sleepiness ratings on the Karolinska Sleepiness Scale (Table 3). It was found that sleep quality significantly predicted sleepiness ratings, $F(1, 166) = 26.69$, $p < .01$. Sleepiness ratings increased as sleep quality decreased. However, main effects of sleep duration, $F(1, 194) = 0.02$, $p = .96$, time of day, $F(1, 182) = 0.83$, $p = .36$, and time since awakening, $F(1, 180) = 0.70$, $p = .40$, were not significant (see Figure 3).

The third model tested if participants' sleepiness ratings on the Karolinska Sleepiness Scale significantly predicted mean reaction tim 9e on the Psychomotor Vigilance Task after controlling for time since awakening (Table 4). Consistent with the above, it was found that time since awakening significantly predicted mean reaction time, $F(1, 304) = 45.25$, $p < .01$. However, the main effect of Karolinska Sleepiness Scale, $F(1, 318) = 0.02$, $p = .88$, and the interaction with time since awakening, $F(1, 309) = 0.19$, $p = .67$, were not significant (see Figure 4).

The last model tested if participants' sleepiness ratings on the Karolinska Sleepiness Scale significantly predicted mean reaction time on the Psychomotor Vigilance Task after controlling for time of day (Table 5). Consistent with the above, it was found that time of day significantly predicted mean reaction time, $F(1, 304) = 41.94$, $p < .01$. However, the main effect of Karolinska Sleepiness Scale, $F(1, 318) = 0.02$, $p = .89$, and the interaction with time since awakening, $F(1, 309) = 0.37$, $p = .54$, were not significant (see Figure 5).

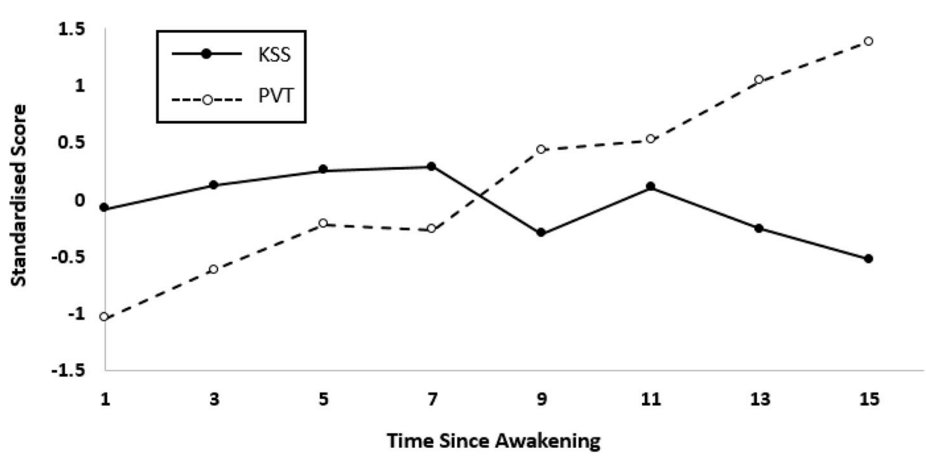

Fig. 4. Standardised scores of KSS and PVT as a function of Time Since Awakening.

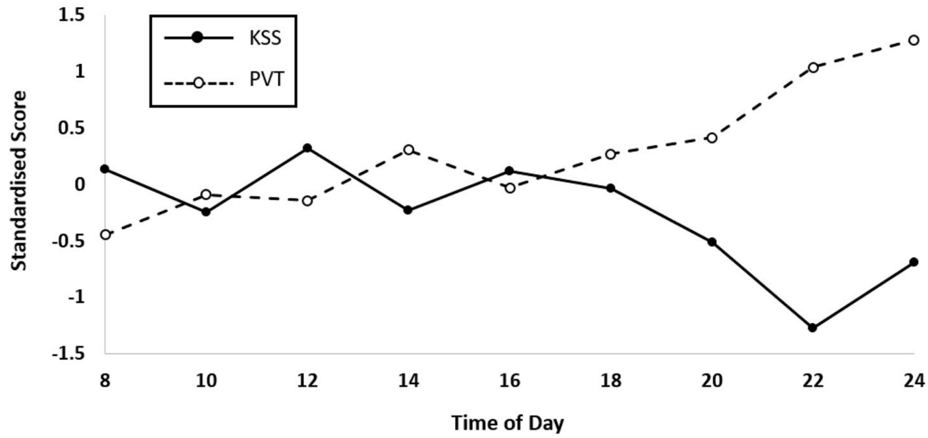

Fig. 5. Standardised scores of KSS and PVT as a function of Time of Day.

5. Discussion

In this study, we sought to determine whether subjective feelings of sleepiness could provide accurate knowledge of fatigue-related impairments of workers involved in extended shifts. To this end, we compared performance on a reaction time task to sleepiness ratings of emergency physicians. We found that extended working hours affected reaction time and subjective ratings to different extents. Consistent with previous studies (Lamond et al., 2005), time since awakening was significantly associated with reaction time, showing a 10% increase over a 16-h period. We also found that slower reaction times were associated with shorter sleep duration the preceding night. These results demonstrate the sensitivity of the PVT to sleep loss and fatigue associated with extended working hours. Physicians' sleepiness ratings while on duty, however, showed no significant association with time since awakening or sleep duration. KSS scores were stable over time while reaction times got steadily slower, suggesting that subjective sleepiness is not sensitive enough to capture changes in sustained attention over a 16-h period. Further analysis confirmed that self-perceived sleepiness was not a significant predictor of PVT performance. However, no significant interaction of time of day or wake duration were found despite the increasing discrepancy between objective performance and subjective sleepiness over time.

Extended shift combined with night work is known to disrupt circadian rhythms and reduce sleep opportunity (Johnson and Lipscomb, 2006; Lee et al., 2010). Therefore, our results are consistent with experimental studies showing that individuals tend to underestimate fatigue-related impairments when sleep deprived or functioning under adverse circadian phase (Bermudez et al., 2016; Zhou et al., 2012; Van dongen et al., 2003; Cohen et al., 2010). Surprisingly, sleep quality of the preceding night was significantly associated with KSS ratings, but not with PVT performance. Previous studies already demonstrated that sleep quality misperception exists in individuals with chronic fatigue syndrome (Jackson and Bruck, 2012). Neu et al. (2007) showed that CFS patients reported poorer subjective sleep quality than controls while objective sleep quality parameters did not differ significantly. Altogether, our results point toward a discrepancy between objective and subjective measures of fatigue-related variables in individuals working extended hours. This adds to the literature demonstrating that objective and subjective measures represent distinct concepts, and should not be considered as equivalent (Franzen et al., 2008; Frey et al., 2004; Leproult et al., 2003; Dinges et al., 1987).

Accurate fatigue-related risk perception is as a precondition to the effective management of fatigue in 24-h operations. Discrepancies between subjective feelings of fatigue and actual fatigue-related impairments may give workers the illusion of being in control and hinder the deployment of mitigation strategies. Beyond harvesting and refining effective strategies, FRMS should ascertain that workers are able to spot contexts where the deployment of mitigation strategies is required. Moreover, organizations need to be provided with reliable and timely information to ensure workers are performing at adequate levels of alertness. Reliable screening techniques enable organizations to continuously monitor fatigue-related risk and ensure that appropriate corrective actions are implemented promptly. The 5-min version of the Psychomotor Vigilance Task revealed to be both convenient and sensitive to changes in alertness occurring during extended working hours. However, the substantial amount of missing values suggest that there also may be moments when it is impractical to ask workers to take 5 min to complete a neurobehavioral task. In these circumstances, the use of a single-item subjective rating is especially relevant. Although our results highlight the limits of relying on subjective ratings, it has been demonstrated that awareness of fatigue-related impairments can be improved with tasks that provide a feedback on cognitive performance (Dorrian et al., 2003). Equally important is raising awareness on the distortion that may exist between subjective feelings and actual impairments. Education regarding these factors may be integrated in FRMS in order to improve individual's ability to predict fatigue-related impairments.

Our study has some limitations. The emergency department is characterized by a highly disruptive, time-pressured environment (Levin et al., 2007) with both unpredictable and at times high-intensity workload periods (Skinner et al., 1997). In this context, we faced difficulties in gathering data at specific timestamps during the shift, as initially planned. To address this issue, it was decided to consider testing time as a continuous predictor rather than a categorical variable. Nonetheless, collected data are not equally distributed throughout 24-h, fewer values typically occurring late in the night to the early following morning. It is arguable that participants' lack of compliance by the end of shift is partly attributable to overwhelming subjective sleepiness. Moreover, it was decided to exclude PVT scores and KSS ratings recorded after a rest break due to the lack of self-reported data regarding rest duration. Taken together, these factors could result in concealing the potential moderator effect of wake duration on perception of fatigue-related impairments. Further studies extending beyond 16-h wake duration are needed to further explore the influence of extended shifts on fatigue-related risk perception. Also, further research is required to determine the relative weight of circadian phase shifting and cumulative sleep deprivation in the decline of fatigue-related risk perception in extended shifts. Finally, studies involving larger samples are necessary in order to evaluate the potential moderator effect of individual characteristics such as age or working experience.

Declarations of interest

None.

References

Aiken, L.S., West, S.G., 1991. Multiple Regression: Testing and Interpreting Interactions. Sage, Newbury Park.
Akerstedt, T., Wright, K.P., 2009. Sleep loss and fatigue in shift work and shift work disorder. Sleep Med Clin 4 (2), 257–271.
Åkerstedt, T., Anund, A., Axelsson, J., Kecklund, G., 2014. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J. Sleep Res. 23 (3), 240–252.
Barger, L.K., Runyon, M.S., Renn, M.L., Moore, C.G., Weiss, P.M., Condle, J.P., Flickinger, K.L., Divecha, A.A., Coppler, P.J., Sequeira, D.J., Lang, E.S., Higgins, J.S., Patterson, P.D., 2018. Effect of fatigue training on safety, fatigue, and sleep in emergency medical services personnel and ther shift workers: a systematic review and meta-analysis. 22 (Suppl. 1), 58–68.
Basner, M., Dinges, D.F., 2011. Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. Sleep 34 (5), 581–591.
Beijamini, F., Silva, A.G., Peixoto, C.A., Louzada, F.M., 2008. Influence of gender on psychomotor vigilance task performance by adolescents. Braz. J. Med. Biol. Res. 41 (8), 734–738.
Bérastégui, P., Jaspar, M., Ghuysen, A., Nyssen, A.S., 2018. Fatigue-related risk management in the emergency department: a focus-group study. Intern Emerg Med. 13 (8), 1273–1281.
Bermudez, E.B., Klerman, E.B., Czeisler, C.A., Cohen, D.A., Wyatt, J.K., Phillips, A.J., 2016. Prediction of vigilant attention and cognitive performance using self-reported alertness, circadian phase, hours since awakening, and accumulated sleep loss. PLoS One 11 (3), e0151770.
Caruso, C.C., 2014. Negative impacts of shiftwork and long work hours. Rehabil. Nurs. 39 (1), 16–25.
Caruso, C.C., Histchcock, E.M., Dick, R.B., Russo, J.M., Schmit, J.M., 2004. Overtime and extended work shifts: recent findings on illnesses, injuries, and health behaviors. Retrieved from. https://www.cdc.gov/niosh/docs/2004-143/pdfs/2004-143.pdf.
Cohen, D.A., Wang, W., Wyatt, J.K., et al., 2010. Uncovering residual effects of chronic sleep loss on human performance. Sci. Transl. Med. 2 (14), 14ra3.
Dawson, D., Chapman, J., Thomas, M.J., 2012. Fatigue-proofing: a new approach to reducing fatigue-related risk using the principles of error management. Sleep Med. Rev. 16 (2), 167–175 Kodz J, Davis S, Lain D, Strebler M, Rick J, Bates P, Cummings J, Meager N, Anxo D, Ginestre S. (2003). Working long hours: A review of the evidence. Volume 1 – main report, London: Department for Trade and Industry.
DeGangi, G., Porges, S., 1990. Neuroscience Foundations of Human Performance. American Occupational Therapy Association, Rockville, MD.
Dinges, D.F., Orne, M.T., Whitehouse, W.G., Orne, E.C., 1987. Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. Sleep 10 (4), 313–329.
Dorrian, J., Lamond, N., Holmes, A.L., et al., 2003. The ability to self-monitor performance during a week of simulated night shifts. Sleep 26 (7), 871–877.
Durmer, J.S., Dinges, D.F., 2005. Neurocognitive consequences of sleep deprivation. Semin. Neurol. 25 (1), 117–129.
Folkard, S., Lombardi, D.A., 2006. Modeling the impact of the components of long work hours on injuries and "accidents. Am. J. Ind. Med. 49 (11), 953–963.
Franzen, P.L., Siegle, G.J., Buysse, D.J., 2008. Relationships between affect, vigilance, and sleepiness following sleep deprivation. J. Sleep Res. 17 (1), 34–41.
Frey, D.J., Badia, P., Wright, K.P., 2004. Inter- and intra-individual variability in performance near the circadian nadir during sleep deprivation. J. Sleep Res. 13 (4), 305–315.
Girschik, J., Fritschi, L., Heyworth, J., Waters, F., 2012. Validation of self-reported sleep against actigraphy. J. Epidemiol. 22, 462–468.
Gorgoni, M., Ferlazzo, F., Ferrara, M., et al., 2014. Topographic electroencephalogram changes associated with psychomotor vigilance task performance after sleep deprivation. Sleep Med. 15 (9), 1132–1139.
Harrington, J.M., 2001. Health effects of shift work and extended hours of work. Occup. Environ. Med. 58 (1), 68–72.
Jackson, M.L., Bruck, D., 2012. Sleep abnormalities in chronic fatigue syndrome/myalgic encephalomyelitis: a review. J Clin Sleep Med 8 (6), 719–728.
Johnson, J.V., Lipscomb, J., 2006. Long working hours, occupational health and the changing nature of work organization. Am. J. Ind. Med. 49 (11), 921–929.
Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., Fukasawa, K., 2006. Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin. Neurophysiol. 117 (7), 1574–1581. https://doi.org/10.1016/j.clinph.2006.03.011.
Kay, M., Rector, K., Consolvo, S., Greenstein, B., Wobbrock, J., Watson, N., Kientz, J., 2013. PVT-touch: Adapting a Reaction Time Test for Touchscreen Devices. Pervasive Computing Technologies for Healthcare. IEEE, pp. 248–251.
Kodz, J., Davis, S., Lain, D., Strebler, M., Rick, J., Bates, P., Cummings, J., Meager, N., Anxo, D., Ginestre, S., 2003. Working Long Hours: A Review of the Evidence 1 Department for Trade and Industry, London main report.
Lamond, N., Dawson, D., Roach, G.D., 2005. Fatigue assessment in the field: validation of a hand-held electronic psychomotor vigi-lance task. Aviat. Space Environ. Med. 76, 486–489.
Lee, I.S., Bardwell, W.A., Ancoli-israel, S., Dimsdale, J.E., 2010. Number of lapses during the psychomotor vigilance task as an objective measure of fatigue. J Clin Sleep Med 6 (2), 163–168.
Leproult, R., Colecchia, E.F., Berardi, A.M., Stickgold, R., Kosslyn, S.M., Van cauter, E., 2003. Individual differences in subjective and objective alertness during sleep deprivation are stable and unrelated. Am. J. Physiol. Regul. Integr. Comp. Physiol. 284 (2), R280–R290.
Levin, S., Aronsky, D., Hemphill, R., Han, J., Slagle, J., France, D.J., 2007. Shifting toward balance: measuring the distribution of workload among emergency physician teams. Ann. Emerg. Med. 50 (4), 419–423.
Littner, M., Kushida, C.A., Anderson, W.M., Bailey, D., Berry, R.B., Davila, D.G., Hirshkowitz, M., Kapen, S., Kramer, M., Loube, D., Wise, M., Johnson, S.F., 2003. Standards of Practice Committee of the American Academy of Sleep Medicine. Practice parameters for the role of actigraphy in the study of sleep and circadian rhythms: an update for 2002. Sleep 26 (3), 337–341.
Lockley, S.W., Skene, D.J., Arendt, J., 1999. Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. J. Sleep Res. 8, 175–183.
Martin-Gill, C., Barger, L.K., Moore, C.G., Higgins, J.S., Teasley, E.M., Weiss, P.M., Condle, J.P., Flickinger, K.L., Coppler, P.J., Sequeira, D.J., Divecha, A.A., Matthews, M.E., Lang, E.S., Patterson, P.D., 2018. Effects of napping during shift work on sleepiness and performance in emergency medical services personnel and similar shift workers: a systematic review and meta-analysis. Prehospital Emerg. Care (Edicón Española) 22 (Suppl. 1), 47–57.
Neu, D., Mairesse, O., Hoffmann, G., et al., 2007. Sleep quality perception in the chronic fatigue syndrome: correlations with sleep efficiency, affective symptoms and intensity of fatigue. Neuropsychobiology 56 (1), 40–46.
Ohtsu, T., Kaneita, Y., Aritake, S., et al., 2013. A cross-sectional study of the association between working hours and sleep duration among the Japanese working population. J. Occup. Health 55 (4), 307–311.
Patterson, P.D., Higgins, J.S., Van Dongen, H.P.A., Buysse, D.J., Thackery, R.W., Kupas, D.F., Becker, D.S., Dean, B.E., Lindbeck, G.H., Guyette, F.X., Penner, J.H., Violanti, J.M., Lang, E.S., Martin-Gill, C., 2018. Evidence-based guidelines for fatigue risk management in emergency medical services. Prehospital Emerg. Care (Edicón Española) 22 (Suppl. 1), 89–101.
Pinheiro, J., Bates, D., 2000. Mixed-Effects Models in S and S-PLUS. Springer-Verlag, New York.
Roach, G.D., Dawson, D., Lamond, N., 2006. Can a shorter psychomotor vigilance task be used as a reasonable substitute for the ten-minute psychomotor vigilance task? Chronobiol. Int. 23, 1379–1387.
Salminen, S., 2016. Long working hours and shift work as risk factors for occupational injury. Ergon. Open J. 9 (1), 15–26.
Skinner, D., Swain, A., Peyton, R., et al., 1997. Airway management. In: Cambridge Textbook of Emergency Medicine. Cambridge University Press, Cambridge, pp. 22–61.
Spiegel, R., 1981. Sleep and sleeplessness in advanced age. In: In: Weitzman, E.D. (Ed.), Advances in Sleep Research 5 SP Medical and Scientific Books, New York.
Studnek, J.R., Infinger, A.E., Renn, M.L., Weiss, P.M., Condle, J.P., Flickinger, K.L., Kroemer, A.J., Curtis, B.R., Xun, X., Divecha, A.A., Coppler, P.J., Bizhanova, Z., Sequeira, D.J., Lang, E., Higgins, J.S., Patterson, P.D., 2018. Effect of task load interventions on fatigue in emergency medical services personnel and other shift workers: a systematic review. Prehospital Emerg. Care (Edicón Española) 22 (Suppl. 1), 81–88.
Van dongen, H.P., Maislin, G., Mullington, J.M., Dinges, D.F., 2003. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 26 (2), 117–126.
Wirtz, A., 2010. Lange Arbeitszeiten. Untersuchungen zu den gesundheitlichen und sozialen Auswirkungen langer Arbeitszeiten. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin. Retrieved from. http://oops.unioldenburg.de/volltexte/2010/996/pdf/wirlan10.pdf.
Zhou, X., Ferguson, S.A., Matthews, R.W., et al., 2012. Mismatch between subjective alertness and objective performance under sleep restriction is greatest during the biological night. J. Sleep Res. 21 (1), 40–49.