



HAL
open science

Sleep Restriction, Sleep Hygiene, and Driving Safety The Importance of Situational Sleepiness

Pierre Philip, Jacques Taillard, Jean-Arthur Micoulaud-Franchi

► **To cite this version:**

Pierre Philip, Jacques Taillard, Jean-Arthur Micoulaud-Franchi. Sleep Restriction, Sleep Hygiene, and Driving Safety The Importance of Situational Sleepiness. *Sleep Medicine Clinics*, 2019, 14, pp.407 - 412. 10.1016/j.jsmc.2019.07.002 . hal-03489081

HAL Id: hal-03489081

<https://hal.science/hal-03489081>

Submitted on 21 Dec 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Sleep restriction, sleep hygiene, and driving safety: the importance of situational sleepiness

AUTHOR NAMES AND DEGREES

Pierre Philip MD, PhD^{1,2,3}, Jacques Taillard PhD^{1,2} and Jean Arthur Micoulaud MD, PhD^{1,2,3}

AUTHOR AFFILIATIONS

1 USR CNRS 3413 SANPSY Sommeil, Addiction et NeuroPSYchiatry, Bordeaux, France.

2 SANPSY, USR 3413, Université Bordeaux, Bordeaux, France.

3 Sleep Clinic, CHU de Bordeaux, Pôle Neurosciences Cliniques, Bordeaux, France.

AUTHOR CONTACT INFORMATION

Pierre Philip

SANPSY, USR 3413, CHU de Bordeaux, Place Amelie Raba Leon, 33000 Bordeaux, France

Pr.philip@free.fr

Jacques Taillard

SANPSY, USR 3413, CHU de Bordeaux, Place Amelie Raba Leon, 33000 Bordeaux, France

jack.taillard@gmail.com

Jean-Arthur Micoulaud-Franchi

SANPSY, USR 3413, CHU de Bordeaux, Place Ameli Raba Leon, 33000 Bordeaux, France

jarthur.micoulaud@gmail.com

CORRESPONDING AUTHOR

Pierre Philip

SANPSY, USR 3413, 13^{ème} étage Pellegrin, CHU de Bordeaux, Place Amelie Raba Leon, 33000 Bordeaux, France

Pr.philip@free.fr

DISCLOSURE STATEMENT

None to declared

KEYWORDS

Sleepiness; Driving accident; Sleep restriction; Sleep hygiene

KEY POINTS

- Chronic sleep restriction impacts drivers in developed countries
- Sleepiness at the wheel is a better predictor of accident risk than the Epworth sleepiness scale
- Inappropriate line-crossings are strong warnings of future sleep-related accidents
- Road safety campaigns should address not only acute but also chronic sleep deprivation all year long

SYNOPSIS

Sleep related accidents are a frequent cause of death and injury in the world. Poor sleep hygiene is responsible for sleep deprivation, which is clearly associated with an increased risk of accidents. Evidence shows that self-reported sleepiness at the wheel and reporting of inappropriate line-crossings are very strong predictors of accident risk. While the Epworth sleepiness scale is widely used in clinical practice, it is not the best to evaluate driving risks. Simple questions on the occurrence of near misses and sleepiness at the wheel should be asked systematically to address the issue of fitness to drive.

Introduction

Traffic accidents are an increasing cause of death and injury in the world, initially in western societies but now more and more in the developing countries (1). Although the passive safety of vehicles has increased enormously, human behaviors frequently remain inappropriate for safe driving. Many countries have launched road safety campaigns in recent decades to decrease mortality and morbidity on their roads. Alcohol and excessive speed are known to be major killers, and the health status of drivers is now receiving attention as a cause of accidents. Sleepiness at the wheel is clearly associated with an increased risk of accidents (2). Extended or nocturnal driving is associated with accidents, but few studies have differentiated fatigue, which is usually seen as being due to driving time, from sleepiness, which is due to reduced sleep, extended time awake and/or being awake at the circadian trough (3) (4). Sleep hygiene is also a key issue to explain sleep-related accidents (2). This article examines the definition of sleepiness to predict accident risk mainly in terms of sleep hygiene and the chronobiological determinants of traffic accidents. However, sleep apnea syndrome is also associated with traffic accidents as well as other diseases like insomnia and narcolepsy (4).

Although both the European Union and the United States have launched public campaigns to make their citizens aware of the risk of drowsy driving (e.g., the U.S. National Sleep Foundation "Drive Alert–Arrive Alive" campaign, "wake up bus" in Europe), the identification of specific drivers or behaviors at risk of traffic accidents remains a problem. In this review, we present an update on the relationship between sleep restriction and traffic accidents and underline the importance of the definition of sleepiness to address the exact risk of this symptom.

Physiological factors modulating sleepiness

Sleepiness is a complex symptom that may be confused with fatigue. Technically, sleepiness occurs when chronobiological or homeostatic sleep pressure increases to force the brain to go from a state of arousal to a state of sleep. Alerting systems are then stimulated and somewhat prevent the occurrence of sleep.

The first and most common factor involved in sleepiness is extended wakefulness or sleep deprivation, which significantly increases homeostatic pressure and generates excessive daytime sleepiness. The homeostatic drive is regulated by the release of adenosine, which fixes to specific brain receptors. The amount of these receptors is genetically determined and very variable between subjects (5) (6).

Sleepiness is also driven by the circadian system, which is controlled in part by the suprachiasmatic nucleus located in the hypothalamus and is entrained/synchronized essentially by the light/dark cycle. It generates circadian rhythms which dip and rise at different times of the day. It imposes the timing of periods of sleepiness during the night and wakefulness during the day (7). In adults, the strongest wake drive occurs in the early evening prior to the onset of the nocturnal sleep period and has been called the "forbidden zone for sleep". The strongest sleep drive occurs in the early morning prior to the onset of the diurnal wake period (8). Cognitive performance remains stable during a usual waking day (~17 h of wakefulness) and then declines during the usual nighttime after midnight, with the maximum decrement occurring near the 24th hour of wakefulness, i.e. the early morning (9).

Quantifying sleepiness: differences between neutral and “at risk” sleepiness

Sleepiness can be defined as a subjective perception or as an objective measure via electrophysiological measurements. The Stanford Sleepiness Scale (SSS) (10) and the Karolinska Scale (11) have been used in many sleep deprivation protocols and in healthy subjects. They measure instantaneous sleepiness via very straightforward questions. Because they focus on a very short period of time, they hardly reflect the mean level of sleepiness over days or weeks, yet this data is required to quantify the impact of poor sleep hygiene.

Behavioral scales were developed in the 90s to quantify sleepiness. Their rationale was to explore specific activities or periods of the day which could promote sleepiness. The Epworth Sleepiness Scale (ESS) (12) is the most famous and combines stimulant and passive conditions, e.g. “how likely are you to doze off or fall asleep” during “Watching TV” versus “Sitting and talking to someone”? Its authors wanted to capture the average amount of sleepiness to which patients are exposed. It was also an ingenious way to reproduce clinical evaluation over long periods of time (i.e. a few weeks) in order to quantify the positive impact of the treatment of sleep disorders. However, regarding accident risk, these scales tend to provide composite scores that do not reflect the inability to remain awake or how easy it is to fall asleep in non-stimulating conditions.

There is a great need for scales able to quantify “at risk” sleepiness especially in the context of driving, which concerns millions of adults worldwide. Accident risk is the result of a cognitive inability to pursue driving because of the onset of sleepiness. It is therefore very important to use situational scales to better quantify the severity of excessive daytime sleepiness in the precise situation where the subject is exposed to the risk. Considering the predictive value of accident risk, results obtained with the ESS have been contradictory. For

example, Connor (13) found a strong correlation between SSS scores and accident risk but no relationship between chronic sleepiness and traffic accidents. Other authors (14) (4) found a relationship between ESS scores and the risk of traffic accidents among non-professional drivers. More importantly, professional drivers had to reach a severe level of sleepiness before reporting a real accident risk (see figure below), so ESS scores rendered more a binary yes/no evaluation with a cutoff above 16 than a progressive measure of accident risk.

Conscious of the issues related to the shortcomings of the ESS, Hobson et al (15) developed a specific variant of the scale in order to better predict accident risk in a specific group of parkinsonian patients. The scale results from the combination of the ESS and the Inappropriate Sleep Composite Score (ISCS), a scale consisting of 4 items that allows assessment of sleep propensity in situations where it is particularly unusual to fall asleep, such as driving, eating a meal, working and doing housework. The items are scored from 0 to 3 and are summed. The validity of the Hobson variant regarding the impact on everyday functioning shows that it predicts accident risk better than the ESS. However, it has only been used for patients with Parkinson's disease on dopamine agonists.

A meta-analysis published in 2017 (16) provided new perspectives to evaluate the “at-risk” dimension of excessive daytime sleepiness in a robust simple way. A single question is asked about the propensity to fall asleep in an inappropriate situation, particularly an at-risk one such as driving. After a systematic review of the different ways of evaluating sleepiness at the wheel, the authors suggested that the following question: “Have you experienced in the previous year at least one episode of severe sleepiness at the wheel that made driving difficult or forced you to stop the car?” was optimal to predict the accident risk associated with driving. They found that sleepiness at the wheel was associated with a mean increased risk of motor vehicle accidents (pooled OR 2.51 [95% CI 1.87; 3.39]) in a sample of more than 50,000 participants.

Sleep hygiene and driving risk

Rest/Activity Patterns

Non-professional drivers

In the 1990s, Philip and colleagues conducted a series of studies investigating the role of sleep deprivation and sleepiness at the wheel among large populations of highway drivers. At that time when air conditioning was not widespread in automobiles in Europe, public health campaigns recommended leaving early in the morning or late at night to avoid heat and traffic jams. A first study (17) demonstrated that time of departure was closely related to sleep restriction and that sleep-related episodes at the wheel were quite frequent in this population of drivers. Several publications over a 20-year period accumulated more evidence about the link between sleep hygiene and accident risks not only in summertime drivers but also in drivers on the highway all year long (4, 18, 19). Other groups in different countries (USA, New Zealand) confirmed the importance of sleep deprivation or nocturnal driving in the occurrence of sleep-related accidents ((13), (20).

Experimental studies have clearly shown the impact of sleep deprivation or extended wakefulness on real driving performances (21) in healthy subjects. Vakulin et al (22) tested in untreated obstructive sleep apnea (OSA) subjects the impact of sleep deprivation compared to a control group of healthy subjects during a driving simulation task. Patients with OSA crashed more frequently than control participants (1 vs. 24 participants; odds ratio [OR], 25.4; $P = 0.03$) and crashed more frequently after sleep restriction (OR, 4.0; $P < 0.01$) than after normal sleep. Braking reaction time was also slower after sleep restriction than after normal sleep. More recently, Gottlieb et al (23) used a large cohort to confirm the relative impact of restricted sleep and positive apnea/hypopnea index to predict accidental risk. Sleeping 6 hours per night was associated with a 33% increased crash risk, compared to sleeping 7 or 8 hours per night. These associations were present even in those who did not report excessive sleepiness. The population-attributable fraction of motor vehicle crashes was 10% due to sleep apnea and 9% due to sleep duration less than 7 hours. These results demonstrate that OSA patients should be very careful regarding their sleep hygiene.

While a major focus in the 90s was the association of acute sleep deprivation and nocturnal driving, profound societal changes in recent years have significantly changed sleep-wake patterns. The advent of the smartphone and social networks has increased nocturnal and 24/7 activities. Several studies in the US and Europe have thrown light on what constitutes mean sleep duration. As incredible as it may seem, it was not until 1995 that general recommendations on mean sleep duration in adult and infant populations were published ((24). Adults should sleep between 7 and 9 hours and never less than 7 hours. While the US

data might be considered as reassuring regarding chronic sleep deprivation (25), the situation in Europe is somewhat different. Quera Salva published an article showing a reduction in sleep over a 15-year period among French drivers (26). They found that usual sleep duration decreased among French drivers between 1996 and 2011. Interestingly, this reduction was associated with an increase in sleepiness as measured by the ESS. The number of drivers with an ESS score above 15 increased 2.5-fold over the 15-year period. Not only behavioral but also situational sleepiness increased over time. Sleepiness forcing the driving to stop driving increased from 5.6% in 1996 to 14% in 2014.

More recently and still in France, Leger and co-authors showed in a large representative sample of the French population (n=12370) that sleep deprivation was growing with a mean sleep duration under 7 hours of sleep (27). Thirty-eight% of the sample reported suffering from a sleep debt at night. This finding should be related to behavioral changes explaining sleep-related accidents. Driving is frequently associated with extensive wakefulness, which induces sleepiness at the wheel. Studying large populations of drivers, we demonstrated that long-distance driving was very frequently associated with sleep curtailment. Extensive wakefulness is also associated with nocturnal driving, which alters driving performances and leads to highway line-crossings. Inappropriate line-crossings are strong predictors of accidental risk (28).

Many studies have assessed the predictive value of self-reported sleepiness at the wheel and the predictive value of the driving risk. In a meta-analysis, Bioulac et al (16) analyzed ten cross-sectional studies (51,520 participants), six case-control studies (4904 participants), and one cohort study (13,674 participants) to evaluate the danger of self-reported sleepiness at the wheel. Sleepiness at the wheel was associated with an increased risk of motor vehicle accidents (pooled OR 2.51 [95% CI 1.87; 3.39]). A significant heterogeneity was found between the individual risk estimates ($Q = 93.21$; $I^2 = 83\%$), possibly due to the different definitions used in the studies. The authors therefore recommended using the specific question “Have you experienced in the previous year at least one episode of severe sleepiness at the wheel that made driving difficult or forced you to stop the car?”

Professional drivers

Sleep deprivation affects not only the general population of automobile drivers but also many professional drivers worldwide. A study of professional truck drivers (29) demonstrated a mean duration of sleep of 4.78 hours/day in a 5-day period. Fifty-six percent of drivers

presented at least 6 non-continuous minutes of electroencephalographic (EEG)-recorded sleep while driving. The vast majority of these micro-sleep episodes occurred during the late night and early morning. Interestingly, the episodes of sleep at the wheel were not associated with accidents, so actual sleep at the wheel in trained professionals does not necessarily mean an accident in 100% of cases. A possible explanation is that automatic behaviors allow drivers to remain on the road when they sleep lightly for very brief periods (29). Nevertheless, sleep restriction is dangerous and involves a significant driving risk for most drivers. More recently, Sunwoo and colleagues (30) performed a cross-sectional study comparing sleep habits and sleep problems in 110 truck drivers with 1001 matched controls from the general population of South Korea. Multivariate regression analysis was performed to determine whether commercial vehicle (CMV) drivers were independently associated with these sleep problems compared with controls. As found in other publications, the prevalence of high OSA and insomnia was very high with 35.5% and 15.2%, respectively, which was significantly higher than the 12.2% and 4.1% found in controls, respectively ($P < 0.001$ for both). Although CMV drivers had higher ESS scores than controls, the prevalence of daytime sleepiness did not differ between the two groups (19.1% vs. 16.8%, $P = 0.54$). After adjusting for covariates, CMV drivers had 3.68-fold higher odds (95% CI 2.29-5.84) of having OSA and 2.97-fold higher odds (95% CI, 1.46-6.06) of suffering from insomnia compared with controls. However, the degree of daytime sleepiness was not independently associated with CMV drivers. The prevalence of OSA and insomnia in CMV drivers was higher than that in the general population. Daytime sleepiness was associated with increased BMI, depression, OSA, and short sleep duration, which confirm the strong links between sleep hygiene and excessive daytime sleepiness in this specific population. Interestingly, OSA is very common in professional drivers, because of their high BMI and the fact that many are middle-aged males.

Shiftwork, time on task and driving

Cognitive performance remained stable during a usual waking day (for ~17 h of wakefulness) and then declined during the usual nighttime (after midnight) with the maximum decrement occurred near the 24th h of wakefulness (early morning) (31) (9). The risk of accidents related to sleepiness or man-caused catastrophes is greater during the night and especially between 3 am and 5 am than during the day (32), hence the notion of 'black times' (33). Barger et al (34) conducted a prospective nationwide, Web-based survey in which 2737 residents in their first

postgraduate year (interns) completed 17,003 monthly reports that provided detailed information about work hours, work shifts of an extended duration, documented motor vehicle crashes, near-miss incidents, and incidents involving involuntary sleeping. The odds ratios for reporting a motor vehicle crash and for reporting a near-miss incident after an extended work shift, as compared with a shift that was not of extended duration, were 2.3 and 5.9, respectively. In a prospective analysis, every extended work shift that was scheduled in a month increased the monthly risk of a motor vehicle crash by 9.1% and increased the monthly risk of a crash during the commute from work by 16.2%. In months in which interns worked five or more extended shifts, the risk that they would fall asleep while driving or while stopped in traffic was significantly increased (odds ratios, 2.39 and 3.69 respectively).

The same team in a more recent real driving study (3) showed that participants tested after daytime work and after a nightshift had a significantly higher rate of lane excursions, blink duration, and number of slow eye movements during postnight-shift drives compared with postsleep drives. This performance decrement can be related to the circadian phase but also to the cumulative effect of workload and sleep pressure. Time on task is an additive risk, and we showed that extensive nocturnal driving dramatically worsens driving performance. Eight hours of nocturnal driving increased 6-fold the number of inappropriate highway line-crossings compared with a 2-hour nocturnal driving session (3 to 5 am)(21). These results suggest that fatigue related to driving duration is amplified at night, so maximal driving duration should be shorter at night than during the day.

Sleep duration, work duration, time on task and shift work schedules are key factors to control to reduce behavioral sleepiness at the wheel. As described previously in the conceptual approach to situational sleepiness, one cannot rule out the importance of economic constraints in professional drivers and self-reported sleepiness at the wheel. Objective evaluation of excessive daytime sleepiness via the Maintenance of Wakefulness Test can be a good strategy in this setting.

Future considerations

Although much has already been done in this field, many questions remain unanswered. At the diagnostic level there is still no simple objective measure to quantify the risk to drivers, unlike other accident risk factors that- can be easily assessed, such as by using a breathalyzer for alcohol testing. Ideally, we need a “somnotest” to quantify the driving risk, but up to now driving simulators or EEG measures have provided only indirect and variable estimations of the driving risk and are obviously not practicable for use outside the clinic or laboratory.

Connected car technologies might be the future to evaluate drivers' behaviors.

A growing body of evidence is showing that self-reported sleepiness at the wheel and the reporting of inappropriate line-crossings are very strong predictors of accident risk. These two questions should be systematically asked when addressing the issue of fitness to drive. While the ESS is widely used in clinical practice, it is not the best scale to evaluate driving risks (16).

The impact of extensive driving is also a key factor in the research agenda because of the high prevalence of sleep deprivation in professional drivers, especially in the US where they are paid by miles driven. After addressing the issues of acute sleep deprivation, we also need to consider sleep hygiene in the longer term. Road safety campaigns on the risks of chronic sleep deprivation and drowsy driving need to be released in every country.

It is also important to consider that poor sleep hygiene not only affects "healthy drivers" but may occur in patients suffering from sleep disorders like OSA(see figure 2). Because of the large prevalence of these patients, they should be educated to the same standards as healthy drivers.

Defining at-risk phenotypes regarding situational sleepiness is probably the next step in order to personalize safety campaigns. The use of health technologies to monitor sleep hygiene could help achieve this goal.

REFERENCES

1. Lagarde E. Road traffic injury is an escalating burden in Africa and deserves proportionate research efforts. *PLoS medicine*. 2007;4(6):e170.
2. Connor J, Whitlock G, Norton R, Jackson R. The role of driver sleepiness in car crashes: a systematic review of epidemiological studies. *Accid Anal Prev*. 2001;33(1):31-41.
3. Lee ML, Howard ME, Horrey WJ, Liang Y, Anderson C, Shreeve MS, et al. High risk of near-crash driving events following night-shift work. *Proc Natl Acad Sci U S A*. 2016;113(1):176-81.
4. Philip P, Sagaspe P, Lagarde E, Leger D, Ohayon MM, Bioulac B, et al. Sleep disorders and accidental risk in a large group of regular registered highway drivers. *Sleep Med*. 2010;11(10):973-9.
5. Retey JV, Adam M, Honegger E, Khatami R, Luhmann UF, Jung HH, et al. A functional genetic variation of adenosine deaminase affects the duration and intensity of deep sleep in humans. *Proc Natl Acad Sci U S A*. 2005;102(43):15676-81.
6. Retey JV, Adam M, Gottselig JM, Khatami R, Durr R, Achermann P, et al. Adenosinergic mechanisms contribute to individual differences in sleep deprivation-induced changes in neurobehavioral function and brain rhythmic activity. *J Neurosci*. 2006;26(41):10472-9.
7. Czeisler CA, Weitzman E, Moore-Ede MC, Zimmerman JC, Knauer RS. Human sleep: its duration and organization depend on its circadian phase. *Science*. 1980;210(4475):1264-7.
8. Lavie P. Ultrashort sleep-waking schedule. III. "Gates" and "forbidden zones" for sleep. *Electroencephalography and Clinical Neurophysiology*. 1986;63:414-25.
9. Taillard J, Philip P, Claustrat B, Capelli A, Coste O, Chaumet G, et al. Time course of neurobehavioral alertness during extended wakefulness in morning- and evening-type healthy sleepers. *Chronobiology International*. 2011;28(6):520-7.
10. Hoddes E, Dement WC, Zarcone V. The development and use of the Stanford Sleepiness Scale (SSS). *Psychophysiology*. 1972;9:150.
11. Gillberg M, Kecklund G, Akerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. *Sleep*. 1994;17(3):236-41.
12. Johns MW. A new method for measuring daytime sleepiness: The Epworth sleepiness scale. *Sleep*. 1991;14(6):540-5.
13. Connor J, Norton R, Ameratunga S, Robinson E, Civil I, Dunn R, et al. Driver sleepiness and risk of serious injury to car occupants: population based case control study. *Bmj*. 2002;324(7346):1125.
14. Howard ME, Desai AV, Grunstein RR, Hukins C, Armstrong JG, Joffe D, et al. Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *American Journal of Respiratory and Critical Care Medicine*. 2004;170(9):1014-21.
15. Hobson DE, Lang AE, Martin WR, Razmy A, Rivest J, Fleming J. Excessive daytime sleepiness and sudden-onset sleep in Parkinson disease: a survey by the Canadian Movement Disorders Group. *Jama*. 2002;287(4):455-63.
16. Bioulac S, Franchi JM, Arnaud M, Sagaspe P, Moore N, Salvo F, et al. Risk of Motor Vehicle Accidents Related to Sleepiness at the Wheel: A Systematic Review and Meta-Analysis. *Sleep*. 2017;40(10).
17. Philip P, Ghorayeb I, Stoohs R, Menny JC, Dabadie P, Bioulac B, et al. Determinants of sleepiness in automobile drivers. *Journal of Psychosomatic Research*. 1996;41:279-88.
18. Philip P, Taillard J, Gilleminault C, Quera Salva MA, Bioulac B, Ohayon M. Long distance driving and self-induced sleep deprivation among automobile drivers. *Sleep*. 1999;22:475-80.
19. Sagaspe P, Taillard J, Bayon V, Lagarde E, Moore N, Boussuge J, et al. Sleepiness, near-misses and driving accidents among a representative population of French drivers. *Journal of Sleep Research*. 2010;19(4):578-84.
20. Sagberg F. Road accidents caused by drivers falling asleep. *Accid Anal Prev*. 1999;31(6):639-49.
21. Sagaspe P, Taillard J, Akerstedt T, Bayon V, Espie S, Chaumet G, et al. Extended driving impairs nocturnal driving performances. *PLoS One*. 2008;3(10):e3493.
22. Vakulin A, Baulk SD, Catcheside PG, Antic NA, van den Heuvel CJ, Dorrian J, et al. Effects of alcohol and sleep restriction on simulated driving performance in untreated patients with obstructive sleep apnea. *Ann Intern Med*. 2009;151(7):447-55.
23. Gottlieb DJ, Ellenbogen JM, Bianchi MT, Czeisler CA. Sleep deficiency and motor vehicle crash risk in the general population: a prospective cohort study. *BMC Med*. 2018;16(1):44.
24. Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, et al. Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the Recommended Amount of Sleep for a Healthy Adult: Methodology and Discussion. *Sleep*. 2015;38(8):1161-83.
25. Basner M, Dinges DF. Sleep duration in the United States 2003-2016: first signs of success in the fight against sleep deficiency? *Sleep*. 2018;41(4).

26. Quera-Salva MA, Hartley S, Sauvagnac-Quera R, Sagaspe P, Taillard J, Contrand B, et al. Association between reported sleep need and sleepiness at the wheel: comparative study on French highways between 1996 and 2011. *BMJ Open*. 2016;6(12):e012382.
27. Leger D, Zeghnoun K, Richard JB, Bouchequet P, Elbaz M, Chennooui M. Prevalence And Sociodemographics Associated With Total Sleep Time In France And Insomnia In 12370 Individuals. *Sleep*. 2019;42(Suppl 1):A169-A70.
28. Philip P, Chaufton C, Taillard J, Sagaspe P, Leger D, Raimondi M, et al. Maintenance of Wakefulness Test scores and driving performance in sleep disorder patients and controls. *Int J Psychophysiol*. 2013;89(2):195-202.
29. Mitler MM, Miller JC, Lipsitz JJ, Walsh JK, Wylie CD. The sleep of long-haul truck drivers. *N Engl J Med*. 1997;337(11):755-61.
30. Sunwoo JS, Shin DS, Hwangbo Y, Kim WJ, Chu MK, Yun CH, et al. High risk of obstructive sleep apnea, insomnia, and daytime sleepiness among commercial motor vehicle drivers. *Sleep Breath*. 2019.
31. Dijk DJ, Duffy JF, Czeisler CA. Circadian and sleep/wake dependent aspects of subjective alertness and cognitive performance. *J Sleep Res*. 1992;1(2):112-7.
32. Reinberg A, Smolensky MH, Riedel M, Touitou Y, Le Floc'h N, Clarisse R, et al. Chronobiologic perspectives of black time--Accident risk is greatest at night: An opinion paper. *Chronobiol Int*. 2015;32(7):1005-18.
33. Folkard S. Black times: Temporal determinants of transport safety. *Accident Analysis & Prevention*. 1997;29:417-30.
34. Barger LK, Cade BE, Ayas NT, Cronin JW, Rosner B, Speizer FE, et al. Extended work shifts and the risk of motor vehicle crashes among interns. *N Engl J Med*. 2005;352(2):125-34.

Figure legends

Figure 1. Accident risk related to subjective sleepiness (ESS). Circles represent odds ratio (OR) for one or more accidents and triangles the ORR for multiple accidents. Error bars represent 95 % confidence intervals for ORs. ORs are adjusted for age, average daily alcohol intake and hours of driving per week. ESS = Epworth sleepiness scale. (From Howard ME, Desai AV, Grunstein RR, Hukins C, Armstrong JG, Joffe D, et al. Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *American Journal of Respiratory and Critical Care Medicine*. 2004;170(9):1014-21; with permission.)

Figure 2

Sleepiness at the wheel as common final pathway to evaluate risk of motor vehicle accidents



