Université de Montréal

Driving with Obstructive Sleep Apnea

Policies, behaviors and screening measures

par Dorrie Rizzo

Faculté de Médecine

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Résumé

Le syndrome de l'apnée du sommeil (SAS) est un trouble grave qui se produit lorsque le débit respiratoire d'une personne est interrompu ou réduit de façon répétée pendant le sommeil, entraînant des baisses intermittentes de la saturation artérielle en oxygène. Le SAS a été caractérisé comme l'un des troubles médicaux les plus courants entraînant une somnolence diurne excessive. La somnolence et/ou la fatigue au volant sont des risques d'accidents de la route potentiellement mortels et peuvent remettre en question la capacité d'une personne à détenir un permis de conduire. Le SAS demeure un trouble du sommeil qui fait l'objet d'un large débat au sein des organismes responsables de la politique routière, en raison de nombreuses contradictions dans la littérature scientifique. Le but de cette thèse de doctorat est de revoir les positions des principaux pays leaders en matière des facultés de conduite des chez les conducteurs atteints du SAS et de proposer une approche d'évaluation au cas par cas qui tient compte des différences comportementales et des expériences individuelles chez ces patients.

Nos travaux ont mis en lumière qu'il existe une variabilité au simulateur de conduite, sur les comportements au volant, ainsi que sur le nombre d'infractions commisses, entre les personnes atteintes du SAS. La fatigue joue également un rôle important dans les comportements de conduite qui semble refléter une expérience distincte de celle de la somnolence. De plus, notre étude ne révèle pas de profils de conduite différents entre les conducteurs atteint du SAS qui étaient adhérents ou non au traitement du trouble respiratoire du sommeil avec un appareil de pression positive continue; en effet les données n'ont pas mis en évidence de différence, soit une diminution de la fatigue, de la somnolence ou des infractions au code de la route après 6 mois de traitement. Enfin, notre étude suggère l'usage d'une nouvelle mesure, plus accessible que les examens routiers et aux tâches de simulateur de conduite, qui inventorierait les infractions au code de la route répertoriées par une agence gouvernementale officielle dans un contexte ciblé d'estimation des risques de conduite chez le sujet avec SAS. Cet outil simple, si un accès privilégié était disponible, pourrait être utile aux cliniciens pour aider à l'identification d'un conducteur à risque atteint du SAS et pourrait offrir

aux cliniciens une alternative aux examens routiers et aux tâches de simulateur de conduite couteux et chronophages.

Mots-clés : Syndrome de l'apnée du sommeil, comportements au volant, somnolence, fatigue.

Abstract

Obstructive sleep apnea (OSA) is a serious disorder that occurs when a person's flow of breathing is repeatedly interrupted or reduced during sleep, leading to intermittent drops in blood oxygen saturation. OSA has been characterized as among the most common of medical disorders causing excessive daytime sleepiness. Sleepiness and/or fatigue at the wheel are unquestionably a risk for potentially fatal road accidents and a cause for questioning one's ability to hold a driver's license. OSA remains a sleep disorder that is widely debated among traffic policy-makers due to conflicting research findings available to them. The present study reviews the position of leading driving policy-making countries regarding driving competence among individuals with OSA; it proposes a case-by-case assessment approach that considers experiential and behavioural individual differences among individuals with OSA.

This study demonstrates that there is considerable variability both in the driving simulator task, on actual driving behaviors and the number of driving violations among individuals with OSA; this makes it difficult to identify a risk profile in the sample. Fatigue, as an experience distinct from sleepiness, appears to play a significant role in driving behaviors. In addition, the present data do not reveal different driving profiles between drivers with OSA who were either adherent or non-adherent to continuous positive air pressure treatment of the sleep disorder, nor do the data show that treatment decreases fatigue, sleepiness, or the number of self-reported driving violations after 6 months of treatment. Finally, this study introduces a new and more accessible measure that mirrors all possible violations listed by the official government driving agency. This simple tool can be useful for clinicians to help identify a risky driver with OSA and may present an alternative to expensive and time-consuming road tests and driving simulator tasks.

Keywords: Obstructive sleep apnea, driving behaviors, sleepiness, fatigue.

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AASM: American Academy of Sleep Medicine

AHI: Apnea-hypopnea index

BMI: Body mass index

CPAP: Continuous positive airway pressure

DBQ: Driver Behavior Questionnaire

DVI: Driving Violations Inventory

EEG: Electroencephalogram

EOG: Electrooculargram

ESFS: Empirical Sleepiness and Fatigue Scale

ESS: Epworth Sleepiness Scale

MSLT: Multiple Sleep Latency Test

N.S.: Non-significant

OSA: Obstructive sleep apnea

SAAQ : Société de l'assurance automobile Québec

SOL: Sleep onset latency

SpO2: Oxygen desaturation index

SSC: Sleep Symptom Checklist

TST: Total sleep time

WASO: Wake after sleep onset

Liste des abréviations

Cf. : Comparer

Etc. : Et cætera

Ex. : Par exemple

T., N. & C.♥ ♥♥

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Introduction

According to the Centers for Disease Control and Prevention, an estimated 1 in 25 adult drivers report having fallen asleep while driving in the previous 30 days.1 It is estimated that drowsy driving was responsible for claiming 846 lives in 2014 in the U.S. alone.2 The literature shows that drivers with untreated sleep disorders, such as Obstructive sleep apnea (OSA), are more likely to drive drowsy. The American Academy of Sleep Medicine (AASM) claims that fatigue and sleepiness are inherent public safety risks and that government officials, medical professionals, and law enforcement officers should work together to address this issue.3 The following 3 chapters aim to further our understanding of driving and OSA in order to better identify those individuals with OSA who are the riskier drivers.

The first chapter is an integrative review paper that introduces the subsequent chapters. It describes the characteristics of OSA along with its cognitive and physiological effects. The purpose of the review is to present the different driving policies regarding OSA that are currently being adopted, citing sources that influenced the decision-making process of these guidelines. The chapter also discusses the need for more accurate and expedient measures to assess driving risk.

The second chapter is an original research paper that reflects on the different symptomatic experiences in drivers with newly diagnosed OSA. The focus is on sleepiness and fatigue as separable symptom constructs, and how CPAP treatment later affects these experiences. To assess driving behavior and risk, data were collected from official SAAQ driving records, polysomnography, and questionnaires.

The third chapter, also an original research paper, introduces a simple measure developed for clinicians as a screening tool to assess fitness to drive in individuals with OSA. We evaluate whether the derived Driving Violations Inventory (DVI) can (a) identify driving behaviors that are specific to higher and lower risk drivers, and (b) verify whether DVI responses are associated with the commonly employed from the driving simulation variables

The American Academy of Sleep Medicine has been advocating to include government officials, medical professionals, and law enforcement officers in addressing driving safety issues; the present study represents a response to driving safety concerns.

Chapter 1

Determinants of policy decisions for non-commercial drivers with OSA:

an integrative review

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Determinants of policy decisions for non-commercial drivers with OSA

An integrative review

Abstract

Excessive daytime sleepiness and reduced cognitive functioning secondary to obstructive sleep apnea (OSA) have been identified as an important health-related risk in commercial transportation with, possibly, an increased chance of road accidents. This has resulted in a variety of policies and restrictions imposed on commercial drivers. Here we review current knowledge to assess whether available data are sufficient to guide policy decisions concerning restrictions for non-commercial drivers. The review shows that there is a lack of uniformity among different consensus conferences and guidelines as to how to deal with drivers with OSA. Clear guidelines are limited and few are evidence based. It is unclear which aspect of OSA is the most valid measure of severity (e.g., apnea-hypopnea index vs oxygen desaturation index). Traditionally, sleepiness has been invoked as a major risk factor for impaired driving. Recently, there also has been an awareness that daytime fatigue, as distinct from sleepiness, has an impact on driving behavior. However, the precise effect of fatigue on driving, as well as its role in the formulation of guidelines, remain to be evaluated. We conclude that there are at least two major difficulties for the driving recommendation process: a) there is no accurate metric quantifying severity of driving risk associated with OSA, and b) there are substantial individual differences among those with OSA, both experiential and behavioral. We present implications from this review for future research and policy formulation.

Introduction

Obstructive sleep apnea (OSA) is common and often underrecognized in the general population. It affects up to 10% of the middle-aged population and potentially up to 50% of adults over age 60.[1,2] Symptoms of OSA are widespread and include cognitive dysfunction, depression, anxiety, memory problems and insomnia. Also related to OSA are health risks such as hypertension and obesity, or illnesses such as diabetes and cardiovascular disorders.[3-7] Of particular relevance to driving, excessive daytime sleepiness secondary to OSA has been identified as an important health-related risk in commercial transportation[8-13] with, possibly, an increased chance of road accidents due to impairments in vigilance, concentration, memory, and executive function.[14] The objective of the present review is to summarize the state of knowledge about OSA and risk-related driving behavior among non-commercial drivers. We will attempt to assess current limitations regarding sleep disorder and driving research (e.g., low ecological validity, unclear guidelines for non-commercial drivers with OSA) and present potential directions, including: identification of risky drivers, modification of risky driving behaviors and prediction of potentially dangerous driving circumstances. To this end, we will evaluate the current state of knowledge on driving policies for individuals with OSA and whether it is sufficient to guide policy decisions about non-commercial drivers who suffer from OSA.

We will first describe the physiological and cognitive effects of OSA with a focus on potential consequences for neurocognitive and behavioral functioning that can be relevant for driving tasks and behaviors in non-commercial drivers. This is followed by a section on the association of motor vehicle accidents and risk-related behaviors for drivers with OSA. The final section critically reviews how fitness to drive has been evaluated in OSA patients and the implications for future advances.

What is OSA and why is it so important to diagnose?

OSA is a serious sleep disorder characterized by recurrent episodes of partial or complete collapse of the upper airway during sleep and is associated with physiological

changes and destabilization of respiratory control.[2] The reduction of airflow often leads to changes in gas exchange and recurrent arousals from sleep. This chronic condition is a severe risk factor for morbidity and mortality, mainly due to intermittent drops in blood oxygen saturation.[2,15,16] Intermittent hypoxia is reported to promote oxidative stress by increasing production of reactive oxygen species and angiogenesis, increasing sympathetic activation with blood pressure elevation, and both systemic and vascular inflammation with endothelial dysfunction. All these are variably related to risk of chronic morbidity and mortality in the form of cardiovascular disease, metabolic dysfunction, cognitive decline, and selected cancer progression.[17-20]

When an apnea or hypopnea event is prolonged, the effort to restore breathing causes cortical arousal and consequent disruption of the sleep architecture and of its continuity.[16,21] Because OSA causes both hypoxia and sleep disruption, its impact is widespread, affecting multiple organs and regulatory systems.[16] Untreated OSA can lead to high blood pressure, stroke, heart failure, diabetes, depression, and other serious health issues.[22-31] Over time, repetitive hypoxia may lead to structural changes in the brain which maintain breathing instability during sleep.[16,17,21,32]

Under normal circumstances, the majority of sensory outputs capable of modifying breathing are down-regulated at sleep onset. The control of breathing transitions to being predominantly chemical in which the level of carbon dioxide in the blood is a critical mediator for regulating ventilation.[16] In the case of OSA, rapid return to arousal during an apnea event is essential to restore breathing. However, too frequent arousals during sleep create instability in respiratory control and may contribute to risk of sleepiness during wakefulness. The instability of breathing control also affects the systemic circulation and oxygen delivery. One study suggests that the structural changes in OSA may consist of a mixture of irreversible atrophy, cell death and non-lethal pathology (i.e., inflammation); this seems to contribute to central nervous system dysfunction as well as to psychological and physiologic comorbidities.[33] More specifically, results showed abnormalities in metabolite ratios in frontal lobe white matter and in the hippocampus of individuals with severe OSA, compared to healthy controls.[33]

Although the metabolite concentrations were not significantly correlated with neurocognitive test results, significant correlations were found with the severity of OSA.[33] Cognitive functioning (attention, reaction time, memory, executive function, mental status, visual function) is associated with driving outcome measures in studies measuring crash risk.[34,35]

Potential physiological and cognitive effects of OSA-induced sleep and respiratory disruption

It has been demonstrated that neurocognitive deficits occur with high frequency in OSA. These deficits can affect any cognitive domain, such as learning, memory, and attention and can increase the risk of dementia in older adults.[36] One study found that slower reaction time, decreased brain activation in areas involved in arousal and attention, impaired response selection, motor response, and decision making were all significantly associated with the apnea/hypopnea index (AHI), but not with the oxygen desaturation index (SpO2).[37] These findings imply that it is the AHI and the neurological component of OSA that drives impaired performance rather than SpO2 levels. Another study on the cognitive profile of OSA reported that as compared with controls, patients with OSA have more lapses and/or increased reaction times in tasks requiring sustained attention, selective attention or vigilance.[5] On the other hand, aspects of language were preserved and no specified deficit was found for psychomotor speed. This researcher suggests that vigilance and attention deficits could influence other cognitive aspects (e.g., executive function, episodic memory, psychomotor speed, fine motor coordination).[5]

Importantly, the previous study also noted that common comorbidities found in OSA patients (i.e., obesity, diabetes, hypertension, etc.) are known to be independently associated with cognitive deficits and may also contribute to the decline of neurocognitive function in OSA patients. Such observed associations highlight the complex interrelationship of systems and risk factors. Sleep disordered breathing, disrupted sleep, insulin resistance, psychological or physiological stress, obesity, and hypertension may all be implicated as risk factors for

cognitive impairment. Cognitive deficits in patients with OSA have been well demonstrated, but the pathophysiology of these deficits is still controversial.

OSA and risk-related driving behavior in non-commercial drivers

There have been significant recent advances in understanding the role of OSA in non-commercial driving performance and in individuals with OSA and their related risk (e.g.,[38-43]). Nevertheless, evidence-based recommendations remain a challenge.[44] Motor vehicle crashes in non-commercial drivers are too few to support the need for expeditious diagnostic evaluations or removal of driving privileges.[44,45] Both the American Thoracic Society and the Canadian Thoracic Society have noted that there is no compelling evidence supporting the need to restrict driving privilege of patients with OSA.[46,47] This was based on the examination of current evidence, which is of moderate quality due to lack of definitive studies and limited accessibility to regional motor vehicle crash registries.

Despite the lack of evidence, important policies are currently established around the world, influencing how health practitioners are to treat their patients with OSA. As summarized in Table 1, various research and policies have been developed, independently, in Australia, Belgium, Canada, France, and the U.S.A. Although these are among the leading countries in driving research, such policies have been built on the best evidence available at that time and most derive from consensus based on opinion and experience. It is to be noted that the European Union has issued a basic document that constitutes a minimum set of rules that every member state needs to follow that were not included in Table 1.[47,48] These recommendations for non-commercial drivers focus on screening, assessment tools and treatment plans that are already considered by the listed national guidelines provided in Table 1.

Current clinical guidelines and policies regarding OSA and driving

American Thoracic Society

Clinical practice guidelines provided by the American Thoracic Society state that moderate to severe daytime sleepiness could be one indication of high-risk driving.[47] This statement highlights the importance of assessing sleepiness in newly diagnosed OSA patients, whatever the level of OSA severity.

Canadian Thoracic Society and Canadian Sleep Society

These two societies published position papers which state that there are no clear clinical guidelines for non-commercial drivers and that assessment should be made on a case-by-case basis.[46] Apnea/hypopnea index, self-report sleepiness measures and objective daytime performance measures all show at best weak correlation with motor vehicle crash risk[46]. The recommendation is that a qualified sleep specialist would be best able to assess driver risk related to OSA.

Obstructive sleep apnoea working group

In 2013, in Brussels, this group published the new standards and guidelines for drivers with obstructive sleep apnoea syndrome.[49,50] Recommendations focus on commercial drivers and suggest periodic training sessions on OSA, physiology of sleep, vigilance, sleepiness at the wheel, and other related topics. The recommendations were based on information about the characteristics and risks of OSA and the association between OSA and (assumed) increased risk for motor vehicle crashes. These recommendations were primarily directed toward various interest groups (e.g., commercial drivers, employers of commercial drivers, medical professionals, road police departments and related personnel).

Aerospace medical association

Although not directly related to driving, a recent position paper on transportation related occupations argues that the associations between OSA, obesity and cognitive impairments are strong enough to recommend OSA screening of individuals who are morbidly

obese.[49] Based on commercial driver data, these researchers highly recommend such screening for the airplane pilots, with the goal of improving aviation safety.

Although some of the above-mentioned studies and recommendations were based on commercial drivers, they have had an influence on European and North-American policies related to non-commercial drivers, whose driving practices are quite different.

OSA and motor vehicle crashes

A survey covering 19 European countries collected self-reported sleep-related data that included driving behavior, history of drowsy driving and accidents in non-commercial drivers. The data implicated self-reported drowsy driving as a major safety hazard. Individual determinants of falling asleep while driving were younger age, male gender, driving exposure, higher daytime sleepiness and high risk of OSA.[50] Both American and Australian studies reported inattentiveness, fatigue and sleepiness as major contributors to police-reported motor vehicle crashes leading to death and injury.[51,52] A second Australian study supported the association between OSA and increased daytime sleepiness, and decreased vigilance, with a 2- to 7-fold increased risk of motor vehicle crashes. However, results from that study indicated that only 40% of subjects with OSA who were non-commercial drivers displayed impaired performance on a driving simulator task after provocation by sleep loss or alcohol.[53]

Ward et al.[54] investigated whether the risk of motor vehicle car crashes was higher in patients with OSA than in the general community and, if so, the nature of the risk. Participants were recruited from a sleep research centre, prior to clinical and polysomnographic evaluation. Using polysomnography, driving simulation and questionnaires, the researchers evaluated relationships between self-reported near-misses and self-reported motor vehicle car crashes with OSA severity, degree of daytime sleepiness, and other potential risk factors. Results for 2673 participants with OSA showed that: 1) subjects with untreated OSA (AHI >5 events per hour) self-reported crashes at a rate three times higher (0.06 motor-vehicle crashes/year) than the healthy individuals (0.02 motor-vehicle crashes/year); 2) among the predominantly male, middle-aged, and obese participants,11% with OSA reported having a crash because they felt sleepy or fell asleep behind the wheel; 3) 26% of participants reported at least one near-miss

due to sleepiness; and 4) 32% reported having fallen asleep behind the wheel. In addition, a strong overall association between sleepiness and increased rate of reported near-misses was found.

OSA, obesity, and motor vehicle crashes

According to the World Health Organization, in 2014, 13% of the world's adults were obese. OSA is estimated to affect over 100 million adults in the world. In 2007, a group of researchers stated that obesity is the most important risk factor for OSA and that it is estimated that 70% of patients with OSA are obese.[55] An important study by Teràn-Santos et al.[56] showed a strong association between OSA (measured by AHI) and increased driving accidents among non-commercial drivers, after adjustment for potential confounders such as body-mass index. However, the researchers did not evaluate whether obesity itself was a risk factor for road accidents. This was later addressed in a review by Kay and McLaughlin,[57] who reported that obesity is associated with increased crash risk and increased risk of serious or fatal injury, but that treatment of OSA improved driving performance and reduced crash risk, independent of obesity. Given the high prevalence of OSA in obese individuals, the review highlights the likelihood of obese drivers falling asleep while driving or having impaired critical driving-related abilities such as reduced vigilance (i.e., attentional lapses measured by electroencephalogram (EEG)).[57]

One relatively recent study found that obese individuals with OSA had a twofold higher risk of traffic accidents than healthy comparison individuals. Increased neck circumference and excessive daytime sleepiness were predictors of higher accident risk in non-commercial drivers with OSA.[58] Another study did not find an association between body mass index (BMI) or hypoxemia and risk of near-miss or crash but did find an association between neck circumference, (another commonly used measure for obesity) and crash risk.[59-61]

In a prospective study examining the association between obesity and cognition, Gunstad et al.[62] found that many obese patients showed impaired performance on cognitive testing before having bariatric surgery. Specifically, obese patients had cognition scores in the low average to average range as compared to normative test data. Data also showed that

patients who underwent surgery had improved memory performance at 12-week of follow-up (within the average or above average range for all cognitive tests) while those who did not have the surgery had a decline in memory performance.[62] Of relevance to driving, the obese patients who underwent bariatric surgery improved on attention, compared to obese patients who did not undergo the surgery. In addition, they reported that patients without hypertension who underwent bariatric surgery had better short delay recall at 12-week than those with hypertension.[62] A systematic review by Sarkhosh et al.[63] concluded that for obese patients with OSA, bariatric surgery improves or resolves OSA in a majority of such patients. The potential outcome of bariatric surgery is valuable as a proof of concept for demonstrating the effects of obesity on cognitive functioning.

A 2008, study proposed three key factors in the association between obesity and OSA: 1) obesity may narrow the airway resulting in the block of airflow, 2) higher leptin has an impact on the distribution of fat, and 3) obesity may also be a result of OSA (ex.: lack of energy).[64] These findings are supported in a more recent systematic review which highlighted OSA as a disorder associated with morbidity.[63] Obesity has been shown to be associated with subjective and objective sleepiness independent of sleep apnea.[65] Daytime sleepiness and fatigue are frequent complaints among obese individuals, even among those who do not demonstrate OSA.

OSA and driving behavior: sleepiness and fatigue

A recent important finding demonstrated considerable interindividual variation in daytime sleepiness and neurobehavioral impairment among OSA patients.[53] It was found that participants with and without OSA were significantly different on psychomotor vigilance tasks (mean auditory reaction time test, lapse frequency test). It was also shown that driving simulator performance varied widely among patients with OSA: 60% of OSA patients showed trait-like resistance to performance impairment in a driving simulation task when stressed with sleep restriction or alcohol. They were also able to sustain attention and steer normally to avoid crashes during a 90-minute simulated country drive.[56] The researchers found that degree

of impairment was not explained by OSA severity (i.e., AHI, hypoxemia, frequency of arousals), that many patients with OSA reported little or no daytime sleepiness, and that many individuals with OSA had driven for several years without incident.[53] Paradoxically, the study also showed that some individuals with mild AHI were more affected by sleepiness.

Last year, the National Sleep Foundation published a consensus statement that healthy individuals who have slept for 2 h or less in the preceding 24 h are too impaired to operate a motor vehicle without risk of motor vehicle accidents.[66] A Canadian study involving a random sample of commercial drivers revealed that chronic short sleep duration is a risk factor for neurobehavioral performance impairments, while the results for OSA were less clear.[65] The study consistently showed that neurobehavioral performance has a differential susceptibility to the effects of sleep deprivation, and that the performance of some individuals is quite impacted by sleep deprivation whereas other subjects are relatively resistant. Recommendations were made to not only test commercial drivers for OSA, but to assess sleep durations among commercial drivers.[46]

In addition to sleepiness, other behavioral aspects of OSA may include, as mentioned, neurocognitive deficits (vigilance, concentration, memory impairments, and executive function), psychological problems (anxiety, depression) and a history of driving accidents.[14] However, people with OSA do not have a uniform pattern of sleepiness nor of neurocognitive deficits, and they are capable of some behavioral resilience.[4] Measuring the deficits in OSA remains a challenge because it is unclear whether oxygen desaturation (i.e., SpO2 levels) or sleep fragmentation (i.e., apnea-hypopnea index or arousal index) is associated with cognitive dysfunction. Consequently, identifying a specific subgroup of individuals who are more resistant or vulnerable to cognitive deficits is also a challenge when severity of OSA alone is taken into account.

Notably, the literature indicates that not only many individuals with OSA are not sleepy, but also that fatigue is another very common symptom associated with OSA.[67] In 2008, Bailes et al.[68] identified four subgroups among individuals with OSA characterized by combinations of high and low levels of daytime fatigue and daytime sleepiness. Of particular interest are

those individuals who experienced high fatigue scores, with and without high sleepiness scores. This configuration was associated with the most negative consequences for daytime performance, such as problematic perceived health-related and psychological functioning.[68] Of equal interest was the substantial number of individuals with relatively low daytime sleepiness and fatigue scores (i.e., below clinical cut-offs) who, despite an unmistakable OSA diagnosis, appeared not to complain of diminished functioning or quality of life, and to be similar to individuals in a healthy comparison group.[3] Much of the literature does not make the distinction between fatigue and sleepiness[41] and common language generally confounds the two constructs, e.g., by applying the word "tired" to one or the other.

Another research stream has focused on exogenous, task-induced factors that interact with endogenous characteristics to produce drowsiness and diminish driving performance. For example, time-on-task and time-of-day effects have been associated with fatigue and deterioration of driving performance.[69-72] Similarly, the impact of a monotonous, undemanding road environment on driver fatigue and driving errors has been demonstrated in driving simulation studies in which the road environment was varied (e.g.[71]).

Most of the literature on driving behavior in patients with OSA refers to sleepiness behind the wheel, nodding off, near-miss road accidents, actual road accidents and cognitive impairment. No studies were found addressing driving offenses in non-commercial drivers with OSA (e.g., where commercial drivers were specifically excluded.[72,73] Further research is needed to compare self-reported driving offenses and official driving records among non-commercial drivers, with and without OSA, and to examine how risky driving behaviors among non-commercial drivers compare in these two groups in general, and in groups of individuals with OSA in particular.

Assessing fitness to drive

The prevalence, burden, and management of sleep disorders are too often ignored or overlooked by patients and clinicians. A contributing factor is that many individuals experiencing daytime sleepiness fail to discuss either night time or daytime sleep-related

problems with their physicians.[68,74] Because the link between sleep problems and sleep disorders, such as OSA, has not been made, sleep disorders are often under diagnosed and untreated, making this group of illnesses a serious health concern. A recent Australian paper discusses the importance of education and instruction among potentially dangerous drivers.[75] They found that unsafe drivers are likely to withhold from their physicians information that could potentially lead to an OSA diagnosis if they thought that the medical condition could jeopardize their driver's license. Results of that study found that more unsafe drivers will self-report to the authorities with education and encouragement to do so.[75]

A number of studies show that among primarily commercial drivers, OSA often impairs driving performance and increases the risk of being involved in an accident.[76] Recently, a study looked at data from the very first large-scale, employer-mandated program to screen, diagnose, and monitor OSA treatment adherence in the US trucking industry. The American paper found that commercial drivers with OSA who were not adherent to CPAP treatment had a fivefold increase in the risk of preventable heavy truck crashes compared to matched controls.[77] Moreover, after successful treatment, drivers with OSA had similar crash risk rates as those of controls. More importantly, truck drivers who refused treatment were decommissioned by the mandated employer, but likely found employment elsewhere.[77]

For non-commercial drivers, driving is also an essential part of everyday life and a license to drive plays an important role in social functioning (i.e., employment). Current practice for giving advice to individuals with OSA is to link severity of OSA with sleepiness scores (i.e., Epworth sleepiness scale) in assessing driving risk.[78] A Swedish large-scale cohort study found that age, driving distance, sleepiness score (ESS), short habitual sleep time and the use of hypnotics are associated with increased road accidents, and that severity of OSA was poorly associated with road accidents among non-commercial drivers.[79] Furthermore, their data showed that whether they had a history of road accidents prior to OSA diagnosis or not, the severity of OSA was similar.[79]

The literature notwithstanding, clinicians tend to base their decisions on historical and behavioral self-report. Road testing is not feasible for assessing fitness to drive because it is

time consuming, expensive, and potentially hazardous.[80] Driving simulators are very expensive and not widely available.[81] An office-based driving simulator task could potentially aid in a clinician's decision-making when assessing driving risk[81], but this may also not be feasible for most practitioners. In 2013, a group of researchers carried out a study where 118 patients, newly diagnosed with sleep apnea, completed a questionnaire about their driving behavior and undertook a driving test on the simulator. Nodding at the wheel was admitted by 35 percent but subsequently only 38 percent of those who nodded at the wheel failed the driving simulation task (i.e., crash). This suggested that the experimental driving test has poor ecological validity.[78] Clearly, the question of how to develop more accurate and expedient measures to assess driving risk is complex and needs to take into account more than daytime sleepiness or the presence and severity of a sleep disorder. Concomitant factors such as medication use and chronic illnesses should also be considered when assessing driving risk.[82-87]

Conclusions

There is a lack of uniformity from different consensus and guidelines as to how to deal with the issue of driving by individuals with OSA. Clear guidelines are limited and few are evidence based. Even if recommendations were to be based on existing research, the conclusions from various studies were often inconsistent. For example, some suggested that there be some sort of cut-off in terms of sleep apnea severity to remove untreated OSA patients off the road in order to reduce, but not eliminate the risk completely, of road accidents involving OSA patients. Others suggested that it was unclear which aspect of OSA was the most accurate severity measure, e.g., fragmented sleep vs oxygenation.[4,88] There are at least two major difficulties for the driving recommendation process; a) there is no accurate metric quantifying severity of driving risk associated with OSA, and b) studies have demonstrated substantial experiential and behavioral individual differences among patients with OSA (cf.[53]).

Sleepiness while driving is undoubtedly a key issue, but, again, there exists a range of contextual complexities. Fatigue remains a term to be differentiated from sleepiness in both

the literature and clinical practices/guidelines. Certainly, this review suggests that excessive daytime sleepiness (which could itself be due either to structural brain changes or to transient, context-related states) is not the only potential risk engendered by untreated OSA.

Implications for future research directions

It is acknowledged that OSA is very common in the adult population worldwide and that individuals with OSA who are not being diagnosed and treated are at an increased risk of dangerous driving. Fatal car crashes provide a strong rationale for advancing driving safety research. Nevertheless, developing a set of guidelines for drivers with OSA remains a challenge since it is still unclear which aspects of OSA are associated to risky driving among non-commercial drivers. To develop comprehensive evidence-based recommendations to guide policy decisions, future research directions could include:

1) Identify and differentiate which aspects of driving risk are due to cognitive and sensorimotor deficits caused by OSA-related changes in brain structure and which are due to transient somnolence and/or fatigue states among non-commercial drivers. One would also need to examine the modifying role of context for both these aspects. Furthermore, there is only speculation, but little data on whether structural brain changes that have been associated with OSA in fact cause particular types of driver error.

2) Develop a better understanding of the interaction between OSA and its comorbidities (i.e., the metabolic syndrome components of hypertension, diabetes, and obesity) that may, themselves, lead to brain pathology and altered driving performance.

3) Conceptualize driving risk as a constellation of symptoms along with their severity or impact. A better understanding of experiential and contextual factors (ex.: cultural context) and how these may be related to driving behaviors and risk assessment in people diagnosed with OSA, could be helpful in developing profiles of driving risk in individuals with OSA. Accurate risk profiles would also provide the basis for

developing techniques to manage driving risk, so that evaluations of driving risk could include recommendations of techniques to improve driving safety.

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Tableau I.Current driving policies developed and adopted by leading countries in driving research.

Country	***National Driving Policies***	***Research influencing policy-making***
Australia	A person is not fit to hold an unconditional licence if[89]: (1) the person has OSA (on a diagnostic sleep study and moderate to severe excessive daytime sleepiness), or; (2) the person has frequent self-reported episodes of sleepiness or drowsiness while driving, or; (3) the person has had motor vehicle crash/es caused by inattention or sleepiness, or; (4) the person, in opinion of the treating doctor, represents a significant driving risk as a result of a sleep disorder. A conditional licence may be considered by the driver licensing authority subject to periodic review, taking into account the nature of the driving task and information provided by the treating doctor as to whether the following criteria are met[89]: the person is compliant with treatment; and the response to treatment is satisfactory	Howard, M. E., Jackson, M. L., & Stevenson, M. (2015). Who Needs Sleep Apnea Treatment for Safety Critical Tasks—Are We There Yet? *Sleep*,*38*(3), 331. Vakulin, A., Catcheside, P. G., Baulk, S. D., Antic, N. A., Banks, S., Dorrian, J., & McEvoy, R. D. (2014). Individual variability and predictors of driving simulator impairment in patients with obstructive sleep apnea. *J Clin Sleep Med*, *10*(6), 647-55. Vakulin, A., D'Rozario, A. L., & Grunstein, R. R. (2012). Driving Impairment and Accident Risk in Sleep Apnea: We Need Better Assessment Tools. J Sleep Disor: Treat Care 1: 1. *of*, *2*, 2. Desai, A. V., Wilsmore, B., Bartlett, D. J., Unger, G., Constable, B., Joffe, D., & Grunstein, R. R. (2007). The utility of the AusEd driving simulator in the clinical assessment of driver fatigue. *Behavior research methods*, *39*(3), 673-681.

Belgium	A person with OSA who experiences sleepiness is unfit to drive and is responsible for seeking the advice of a neurologist to assess driving capacity and formulate conditions to drive [90]. The patient with OSA can be declared fit to drive after effective treatment of one month. If the patient remains asymptomatic after a 2-year period, a certificate can be issued for an indefinite period of time. Anyone with OSA (moderate or severe) who is adherent with treatment can obtain a driving license. Before State Members deny issuing or extending a driving license, patients with suspected moderate to severe OSA should seek further medical advice. It may be instructed not to drive until the diagnosis is confirmed. In addition, the above are subject to mandatory periodic review of vigilance performance at least every three years for non-commercial drivers and at least annually for truck and bus drivers.	McNicholas, W. T., & Rodenstein, D. (2015). Sleep apnoea and driving risk: the need for regulation. *European Respiratory Review*, *24*(138), 602-606. Braeckman, L., Verpraet, R., Van Risseghem, M., Pevernagie, D., & De Bacquer, D. (2011). Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drivers. *Chronobiology international*,*28*(2), 126-134. Rodenstein, D. (2009). Sleep apnea: traffic and occupational accidents–individual risks, socioeconomic and legal implications. *Respiration*, *78*(3), 241-248. Wittmann, V., & Rodenstein, D. O. (2004). Health care costs and the sleep apnea syndrome. *Sleep medicine reviews*, *8*(4), 269-279. O'Hanlon JF. That is the extent of the driving fatigue problem? In: Driving fatigue in road traffic accidents. Brussels: Commission of the European Communities; 1978.
Canada	No current Canadian position on driving and OSA[46]. There are significant provincial variations in fitness-to-drive recommendations. In 2014, a first Canadian position statement addressing the issue of OSA and driving at a national level was published as a joint task force by the Canadian Thoracic Society and the Canadian Sleep Society. *Note*: references pertain to studies influencing the position paper.	Ayas, N., Skomro, R., Blackman, A., Curren, K., Fitzpatrick, M., Fleetham, J., Morrison, D. (2014). Obstructive sleep apnea and driving: A Canadian Thoracic Society and Canadian Sleep Society position paper.*Canadian respiratory journal*, *21*(2), 114-123. Bigelow, P. L., Myers, A. M., Crizzle, A. M., Gooderham, S., Shubair, M., Thiffault, P., Brayham, A. (2014). Health and wellness of commercial motor vehicle drivers in Canada:

		Literature review, discussion and directions for further research. *Transport Canada*. Motor Carrier Safety Advisory Committee. Federal Motor Carrier Safety Administration. Final Report: OSA (MCSAC/MRB February 2012 Meeting) (Task 11-05). <https://www.fmcsa.dot.gov/advisory-committees/mcsac/final-report-obstructive-sleep-apnea-task-11-05> (Accessed May 5, 2016). George, C. F., Boudreau, A. C., & Smiley, A. (1996). Simulated driving performance in patients with obstructive sleep apnea. *American journal of respiratory and critical care medicine*, *154*(1), 175-181.
France	OSA is a medical condition likely incompatible with obtaining, maintaining or may lead to the issuing of a limited driver's license[91]. A driver's license should not be granted or renewed for applicants or drivers suffering from a condition associated with functional disability and are a risk to road safety. The decision to issue or renew a license is made following a review of the Medical Commissions Department or a licensed physician. These bodies are entitled to add conditions and restrictions on driving licenses or to request information to better assess the risk. Prior to each medical examination, the driver must provide an accurate description	Åkerstedt, T., & Philip, P. (2015). Sleep Disorders, Cognition, Accidents, and Performance. In *Sleep Medicine* (pp. 487-494). Springer New York. Philip, P., Sagaspe, P., Lagarde, E., Leger, D., Ohayon, M. M., Bioulac, B., Taillard, J. (2010). Sleep disorders and accidental risk in a large group of regular registered highway drivers. *Sleep medicine*, *11*(10), 973-979.

	of medical history, any current pathology and any medications taken. A test conducted by a driving school may be requested. The medical officer or the medical committee may, after initial examination and if they consider it appropriate, request a review by the Appeal Medical Board.	
USA	No current U.S. position on driving and OSA. Each U.S. state sets its own medical standards for non-commercial drivers. National Highway Traffic Safety Administration regulations do not specifically address OSA. The recommendations regarding licensure are likely to be based on an inadequate research data, therefore more studies are required[92]. For commercial motor vehicle drivers, regulations state that a person with a medical history or clinical diagnosis of any condition likely to interfere with their ability to drive safely cannot be medically qualified to operate a vehicle in interstate commerce (OSA is not specifically addressed). The Federal Motor Carrier Safety Association *recommends* that when a person is diagnosed with OSA, he/she should (1) contact the medical qualifying examiner to determine his/her fitness to operate a commercial motor vehicle and to be advised on treatment, (2) be qualified by the medical examiner to determine a driver's medical fitness for duty (the disqualifying level of	Mukherjee, S., Patel, S. R., Kales, S. N., Ayas, N. T., Strohl, K. P., Gozal, D., & Malhotra, A. (2015). An official American Thoracic Society statement: the importance of healthy sleep. Recommendations and future priorities.*American journal of respiratory and critical care medicine*, *191*(12), 1450-1458. Colvin, L. J., & Collop, N. A. (2015). Commercial Motor Vehicle Driver Obstructive Sleep Apnea Screening and Treatment in the United States: An Update and Recommendation Overview. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine*,*12*(1), 113-125. Kay, G. G., & McLaughlin, D. (2014). Relationship between obesity and driving. *Current obesity reports*, *3*(3), 336-340. Lal, C., Strange, C., & Bachman, D. (2012). Neurocognitive impairment in obstructive sleep apnea. *CHEST Journal*, *141*(6), 1601-1610. Steinberg, C. (2002). A study of prevalence of sleep apnea among commercial truck drivers (No. FMCSA-RT-02-080). Hiestand, D. M., Britz, P., Goldman, M., & Phillips, B. (2006). Prevalence of symptoms and risk of

	OSA is moderate to severe), and (3) adhere treatment provided by their doctor[93].	sleep apnea in the US population: results from the national sleep foundation sleep in America 2005 poll. *CHEST Journal*,*130*(3), 780-786. Langlois, P. H., Smolensky, M. H., Hsi, B. P., & Weir, F. W. (1985). Temporal patterns of reported single-vehicle car and truck accidents in Texas, USA during 1980-1983. *Chronobiology International*, *2*(2), 131-140.

Objectives and Hypotheses

Objectives

OSA is the most common medical disorder that causes excessive daytime sleepiness, increasing the risk for drowsy driving, according to the American Thoracic Society.[47] Unclear clinical guidelines make driving recommendations a difficult task for medical practitioners and policy-makers alike. In addition, fatigue remains a term to be differentiated from sleepiness in both the literature and clinical practices/guidelines.

The preceding integrative review has demonstrated that there are at least two major difficulties for the driving recommendation process; a) studies have demonstrated substantial experiential and behavioral individual differences among patients with OSA, and b) there is no accurate metric quantifying severity of driving risk associated with OSA.

The following two research articles address these issues by assessing whether levels of fatigue and sleepiness differ in individuals with OSA from those without OSA and how they relate to driver performance. Furthermore, this research will assess the effectiveness of CPAP treatment on improving fatigue and sleepiness in drivers with OSA. To address the need for accurate metric quantifying severity of driving risk, we explore whether self-reported driving violations can be used as an accurate assessment of driving risk.

Hypotheses

1. Individuals with OSA who are riskier drivers can be identified with psychobehavioral profiles and specific sleep-related parameters.
2. Drivers with OSA who experience less fatigue and sleepiness will have similar driving behaviors as individuals without OSA.
3. OSA treatment (CPAP) will decrease dangerous driving risk in sleepy and fatigued drivers.
4. Questioning drivers with OSA on which of the driving violations listed by the SAAQ they have committed will accurately assess driving risk.

Chapter 2

The role of fatigue and sleepiness in drivers with obstructive sleep apnea

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The role of fatigue and sleepiness in drivers with obstructive sleep apnea

Fatigue and sleepiness as two separate concepts

Abstract

The present investigation examines the role of daytime sleepiness and fatigue and how these relate to driving behaviors and risk assessment in people newly diagnosed with obstructive sleep apnea (OSA). We recruited 47 individuals, (24 female, 23 male), between the ages of 25 and 71 (mean age= 51, SD=11.28). Of those, 24 individuals were newly diagnosed with OSA and 23 individuals were in a comparison sample with similar proportions of biological sex and ages, who tested negative for OSA. All participants completed questionnaire measures related to sleep, psychological adjustment, driving behavior, sleepiness and fatigue, immediately after their follow-up appointment. We collected data on driving violations from registered driving records for the 5 years preceding their enrolment in the study, as well as sleep-related data for all participants. Results show that individuals with OSA (M=1.08, SD=1.38) do not commit more driving violations than control participants (M=0.64, SD=1.26). Although drivers with OSA indicate significantly worse scores for fatigue (M=7.73, SD=3.71) compared with controls (M=4.26, SD=3.66), there was no significant difference for sleepiness between drivers with OSA (M=10, SD=3.57) and Controls (M=8, SD=3.69). An association between Driving violations and sleepiness was found for drivers with OSA – $r(24) = -.45$, $p < .05$— but not for Controls – $r(23) = -.22$, $p > .05$. Fatigue, and sleepiness should be assessed as distinct constructs, and each should be taken into account separately in studies of driving risk.

Introduction

It has been demonstrated that excessive daytime sleepiness is a common symptom of obstructive sleep apnea.[94] However, recent studies indicate that fatigue is also a very common complaint.[95,96] Although health care providers and patients tend to use the terms interchangeably, the concepts of fatigue and sleepiness are not completely overlapping, and, in fact, can be measured separately.[94,97-99] It is generally believed that sleepiness is the most important cause of highway accidents[76,100], however, driver fatigue has been linked to reduced performance efficiency. Fatigue has been found to predict increased risk for error and lapses[101,102] and to be a major cause of road accidents with implications for road safety.[103] Treatment for OSA appears to reduce nocturnal sleep fragmentation, however it is unclear whether it is daytime sleepiness or fatigue that is being modified.[97]

In this paper, we define fatigue as increased feelings of tiredness, decreased energy, motivation, and alertness.[104] It has also been represented as a physical state of muscular exhaustion.[103] Fatigue has been associated with a decline in cognitive task performance (i.e. accuracy, reaction time) after prolonged periods of demanding cognitive activity.[104] Depressive symptoms are strong predictor of fatigue and independently associated with worse fatigue in patients with OSA.[105] Fatigue resolves after a period of rest.[106] Sleepiness is defined as difficulty in maintaining wakefulness, even while carrying out activities, and is related to circadian and homeostatic influences (i.e. sleep pressure).[107] Excessive daytime sleepiness can be defined as the desire or tendency to fall asleep at an inappropriate time.[94] Notably, it is, typically, sleepiness that is invoked in perceived driving risk among individuals

with OSA,[100,108,109] although, there are some studies that highlight the independent association of sleepiness and fatigue on driving behavior and risk.[98,110]

This paper discusses the concepts of fatigue and sleepiness as separate constructs and investigates psychobehavioral associations with driver performance. The primary objective of the present investigation was to explore perceived fatigue and sleepiness as independent aspects of OSA, in a sample of non-commercial drivers. The specific questions addressed are: Do levels of fatigue and sleepiness differ in individuals with OSA from those without OSA? Do the constructs of fatigue and sleepiness relate differentially to driver performance? A second objective was to investigate the effect of treatment for OSA. The specific questions addressed are: Does treatment for OSA reduce experienced fatigue and sleepiness? Does treatment for OSA have an impact on driver performance?

Material and methods

Participants

In an experimental prospective study design, we recruited 24 individuals (mean age=51.4, SD=10.9, 12 females, 12 males) who were newly diagnosed with OSA by an AASM sleep medicine specialist after completing a polysomnography (PSG). Within this group, the mean AHI was moderate (mean=36.3, SD=25.3) and the mean yearly driving distance was 17631.3 km (SD=18628.5). A control group of 23 individuals who had similar proportions of age (mean =50.57, SD=11.86), biological sex (12 females, 11 males) and yearly driving kilometres (mean = 13007.8 km, SD=20878.1 km) was also recruited. The comparison sample had no complaints of fatigue, sleepiness or sleep problems Control participants were recruited

either at the sleep clinic (e.g. accompanying partners, family members, friends) (n=6), or from the community through posters (n=17). We verified that no Control participant had OSA and that the different recruitment approaches yielded no differences on sleep parameters (Sleep Questionnaire), quality of life (SF-36), psychological profiles (Sleep Symptom Checklist) or driving parameters (Driving Questionnaire), i.e. control participants recruited from sleep clinics were not statistically different from control participants recruited from the community. We collected baseline questionnaire data (T1) immediately after recruiting participants. All participants were then reassessed six months later (T2). This time lapse allowed participants with OSA to be re-tested after 6 months of being adherent to CPAP treatment, if treatment was accepted.[111]

Exclusion criteria were: being a professional driver, inability to understand English or French, not having a valid driving license for at least 5 years, severe or acute medical or psychiatric condition, cardiovascular disease with end-organ effects (e.g., history of heart attack, stroke, and congestive heart failure) and substance abuse.

Material

Background Information Form [112]. This measure gathers information on gender, age, marital status, living conditions, income information and education.

Polysomnography (PSG). Participants with OSA were assessed by PSG in a sleep laboratory certified by the American Academy of Sleep Medicine and used standardized methods of evaluation. Apnea events and associated arousals were scored manually by registered technicians according to scoring rules established by the American Academy of

Sleep Medicine 2012 [113]. We did not obtain the PSG data for participants in this study. The PSG reports were seen by an AASM sleep specialist who then evaluated their sleep.

Self-reported CPAP treatment adherence of OSA subjects was assessed by telephone interview and was defined as the average duration of machine use, as well as percent of nights used. We asked participants: 1) Are you using prescribed CPAP treatment, 2) For how many hours per night, 3) How many days per week, and 4) Since when? A participant was considered adherent if they reported following their prescribed treatment at least 4 hours per night, at least 80% of the time, in the 6 months preceding post-treatment testing.[114-116]

Sleep Symptom Checklist (SSC) [68]***.*** The SSC is a 21-item survey of a broad range of symptoms that are both directly and indirectly related to sleep disorders. It is easily completed by patients of all ages. Participants rate each symptom for its severity from 0 (not at all) to 3 (very severe) based on their experience during the previous month [68]. Temporal stability of the severity ratings was found to be acceptable (total $r = 0.79$, $p < .01$). Cronbach's alpha was 0.74. Factor analysis yielded four distinct subscales: Insomnia, Daytime Distress, Sleep Disorder, and Psychological Maladjustment (including items related to anxiety and depression). The SSC was also used as a screening measure to rule-out the presence of sleep disorder symptoms for Control participants.

Sleep Questionnaire [117]***.*** This brief retrospective measure inquires about usual sleep experiences during the past typical month, including Non-Refreshing Sleep, Sleep Quality, Time in Bed, Total Sleep Time [TST), Sleep Onset Latency (SOL), and Wake After Sleep Onset (WASO) during a typical week in the past month. This tool also assesses frequency (0-7 days/week) of non-refreshing sleep, difficulty falling asleep and getting back to sleep after

nocturnal awakenings. The Sleep Questionnaire has been validated in both English and French in our research. Data indicate good test-retest reliability: r values range from .58 to .92 for intervals ranging from 2 weeks to 15 months [118]. High correlations between equivalent scores on this measure and on the Sleep Diary were also found (e.g., r = .83, .64, and .69 for TST, SOL, and WASO, respectively [119].

Epworth Sleepiness Scale. This is a brief self-administered retrospective questionnaire of behavioral aspects of sleep tendency. It is the measure most commonly used in studies of OSA. Participants rate how likely they are to doze off or fall asleep in eight different situations commonly encountered in daily life on a 4-point scale (0=never doze off, 3=high chance of dozing) [120]. Scores are summed and vary from 0 to 24. The measure has high 5-month test–retest reliability (r =.82), as well as high internal consistency (Cronbach's a=.88) [120].

***Empirical Sleepiness and Fatigue Scales*.** This measure was developed by our team [68] through correlation and factor analysis of items from four popular measures purporting to measure sleepiness and fatigue. The two Empirical Scales represent different constructs that were found to have distinctive patterns of associations and were only minimally correlated with each other in three different samples (r ranged from .06 to .33). The Empirical Sleepiness Scale consists of 6 items from the Epworth Sleepiness Scale (items are scored on a 4-point scale, with a minimum total score of 0 and a maximum score of 18). Higher scores indicate greater sleepiness. The Empirical Fatigue Scale consists of 1 item from the Fatigue Severity Scale [121] and 2 from the Chalder Fatigue Scale [122]; scoring uses a 6-point Likert scale (1 = strongly disagree, 6 = strongly agree), with a minimum score of 3 and a maximum score of 18. Higher scores indicate greater fatigue or diminished energy. Both Scales have good test-retest

reliability (r = .69, to .91) as well as internal consistency (Cronbach's alpha scores range from .74 to .95).

Quality of Life: SF-36 Health Survey [123]***.*** This popular 36-item measure was used to assess quality of life in eight health domains: limitations in (1) physical activities because of health problems; (2) social activities because of physical or emotional problems; (3) usual role activities because of physical health problems; (4) bodily pain; (5) general mental health (psychological distress and well-being); (6) limitations in usual role activities because of emotional problems; (7) vitality (energy and fatigue); and (8) general health perceptions. Reliability data, based on both patient and non-patient samples [123] range from .64 to .96. The SF-36 has demonstrable validity in that the subscales were found to correlate with ability to work, utilization of health services, as well as other mental health and quality of life measures. Low scores on all subscales indicate disability due to illness; high scores indicate better functioning due to relatively good health.

Beck Depression Inventory (BDI-II). The 7 item PC Subscale of the BDI-II [124]was used to evaluate the affective and cognitive symptoms of depression independent of fatigue, sleepiness, insomnia and agitation. Beck et al. report that the test-retest reliability for PC Subscale is .82, while its internal consistency is .86. Items are scored on a 4-point scale (0-3). Scores are summed and produce a range from 0 to 21. Higher scores indicate greater depression. The PCI Subscale has no questions that inquire about non-refreshing sleep and, as a result, it measures distinct domains unique to depression. The 21 item BDI is one of the most frequently used measures of depression. As in the original version, the BDI-II also scores items on a 4-point scale (0-3). Scores are summed and produce a range from 0 to 63. Higher scores

indicate greater depression. A score over 20 is usually considered indicative of clinical depression, while scores of 13 or less are generally considered non-depressed. Scores from 14 to 19 are generally considered "mildly depressed." The scale has excellent psychometric properties (internal consistency: r = .92; test-retest reliability: r = .93). A new feature of the BDI-II is the 7 item Primary Care (PC) subscale which evaluates the affective and cognitive symptoms of depression independent of fatigue, sleepiness, insomnia and agitation. Test-retest reliability for this subscale is .82, while internal consistency is .86.[125]

Société de l'assurance automobile du Québec (SAAQ) registered driving accident and violation reports. Frequency of accidents and violations recorded by police for the Quebec provincial automobile vehicle licensing board (SAAQ) are reported. These items comprise all violations included in the Quebec Road Safety Code. Participants gave consent to obtain their 5-year accident and violation record from the SAAQ. Records on the previous 5 years were obtained from a SAAQ officer for all participants at T1, and for the previous 6 months at T2 [126].

Manchester Driver Behavior Questionnaire (DBQ) [127]***.*** This is a self-report questionnaire assessing driving incidents (i.e., errors and violations) used to measure driver behaviors. Participants are asked to indicate how often they commit each of 28 behaviors on a six-point scale (0 = never; 5 = nearly all the time). We used a version adapted to Canadian driving. Our study utilizes four factors developed by Sullman et al. in 2002: Errors, Lapses, Aggressive and Ordinary violations [128].

Driving Violations Inventory.[129] This is a self-report questionnaire, developed by our team, used to compare self-reported driving violations with registered driving violations using items from the SAAQ accident and violation reports records. Participants are asked to indicate

how often they commit each of the violations on the registered SAAQ violations list using a six-point scale (0 = never; 5 = nearly all the time). This measure has high internal consistency (Cronbach's a=.94).

Procedure

Time 1 (T1) - Baseline. 24 participants newly diagnosed with OSA and 23 Control participants (Controls) were recruited from one of two sleep clinics in Montreal. Participants newly diagnosed with OSA were made aware of the study by their sleep medicine specialist at their follow-up appointment after polysomnography. They were asked for consent to have a member of the research team contact them to explain the study and request their participation. When OSA was diagnosed, the treatment offered was continuous positive airway pressure (CPAP). Once the sleep medicine physician prescribed treatment, it usually took several weeks to arrange a meeting with a sleep medicine technician, to choose a device that suited the patient. This time interval allowed us to complete all assessments at T1 for the OSA group before CPAP treatment was begun. Participants consented to allow us to obtain their 5-year violation and accident record from the SAAQ.

Time 2 (T2) –Participants with OSA only. To minimize attrition we followed recommendations noted by Tansey et al. [130]. These include: collection of detailed contact information; sending out reminder letters with times and location of follow-up visits, placing a reminder phone message the day before a visit, making phone calls to maintain contact at least every 3 months during the interval between T1 and T2, and updating contact information at each phone call. In the 6 -month period between T1 and T2, OSA participants were followed

with usual medical care, without intervention from any of our team members. If participants were offered CPAP treatment, they met with technicians to purchase and receive their prescribed CPAP treatment. After 6 months (T2), the OSA group was re-tested: (1) self-reported adherence to the CPAP treatment was evaluated in an open-ended interview (2) the questionnaire package was completed, (3) we collected SAAQ accident and violation records for the previous 6 months for T2 participants.

Ethical approval

The protocol was approved by the McGill University Research Ethics Board, the Université de Montréal Research Ethics Board as well as by the Research Ethics Boards of the Jewish General Hospital. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Statistical analysis

To analyze the overall differences between OSA and Controls, t-tests were performed on fatigue, sleepiness, driving behaviors, depression, anxiety, nocturnal sleep parameters (WASO, TST, Sleep efficiency) and most aspects of health-related quality of life. Items from the ESFS were factor analyzed together with the single objective SAAQ driving records item: number of driving violations in registered driving records, for all participants. To address self-reported adherence to CPAP treatment's impact on sleepiness, fatigue and driving safety, paired t-tests were carried out to analyze pre- and post-treatment self-report data.

Results

Analyses on T1 data (baseline)

Mean scores in Table 1 and t-test results show that drivers with OSA had significantly worse scores on fatigue and 4 aspects of health-related quality of life: physical functioning, role limitations due to physical health, body pain, general health, and energy/fatigue. There were no statistically significant differences between groups for sleepiness, driving violations, mood or sleep parameters. Our sample of participants with OSA did show correlations for fatigue and depression measures, $r(24)=.471$, $p<.05$, as well as sleepiness and depression, $r(24)=.427$, $p<.05$ (table 2).

We then explored relationships between night time, daytime, health-related quality of life and mood variables with driving violations and the DBQ subscales in the OSA and Control groups. As shown in Table 2, in the OSA group, daytime sleepiness was negatively correlated with registered driving violations, $r(24) = -.45$, $p < .05$, whereas AHI was positively correlated with registered driving violations, $r(24) = .42$, $p < .05$. Furthermore, in the OSA group, sleep disorder symptoms were positively correlated, $r(24) = .46$, $p < .05$, with self-reported violations. In the Control group, psychological symptoms were strongly correlated with ordinary violations, driving errors and lapses while driving, $r(24) = .54$ to $.68$, $p < .01$. Additionally, driving errors were also associated with insomnia, $r(24) = .42$, $p < .05$, and self-reported driving violations were associated with sleepiness for Controls, $r(24) = .42$, $p < .05$ (Table 3).

To evaluate whether poor driving was more closely linked to sleepiness or fatigue, all nine items of the Empirical Sleepiness and Fatigue Scale (ESFS) were factor analyzed together

with the single objective item: number of registered driving violations in registered driving records, for all participants. A Maximum Likelihood factor analysis of the 10 items, using Oblimin rotations, was conducted with 3 distinct factors linking registered driving violations to the Empirical sleepiness and fatigue scale items, explaining 53.91% of the variance. An Oblimin rotation provided the best-defined factor structure, where all items were retained. All items had primary loadings over .3. Violations from registered driving records had a loading of .364, however it was a primary loading. The factor loadings are presented in Table 4. The number of driving violations item loaded with all 3 items of the ESFS that were specific to fatigue.

Analyses on T2 data (6 month later)

In the OSA group, 13 drivers reported being adherent and 11 reported being non-adherent to treatment. Because of the small sample sizes, we opted for independent sample t-tests. We first wanted to analyze whether drivers who were later adherent to CPAP treatment had different profiles at baseline compared with drivers who later did not adhere to treatment. Table 5 demonstrates that for both groups there were no significant differences on AHI, number of registered driving violations, number of self-reported violations, total DBQ score, fatigue, and sleepiness (all n.s.).

Subsequently, we expected that self-reported violations, fatigue and daytime sleepiness would be improved with CPAP treatment. We conducted paired-sample t-tests on pre- and post-treatment data on all three variables for drivers who were adherent to treatment (table 6). Self-reported CPAP adherence had no significant effect on subjective

driving violations, fatigue, nor on daytime sleepiness (all n.s.). Unfortunately, violations from driving records were too few to be statistically analyzed.

A chi-square test of goodness-of-fit was performed to determine whether fatigue and sleepiness were equally reported in the adherent and non-adherent groups. Fatigue and sleepiness were equally distributed in this sample, at baseline, X2 (2, N = 13) = 1.42, p = .23, and 6 months later, X2 (2, N = 13) = 1.53, p = .22. Specifically, 69.2% of adherent participants who used CPAP >4 hours per night, at least 80% of the time, in the 6 months preceding post-treatment testing, experienced sleepiness at baseline. After 6 months of CPAP therapy, 46.2% of the adherent participants still experienced sleepiness. Those who experienced sleepiness were the primary determinants of residual sleepiness 6 months later. To perform this comparison, prorated scale scores of the 6 sleepiness-related items in the ESFS (derived from the ESS) were computed to represent the 8 items of the ESS scale. On the other hand, 53.8% of adherent participants experienced fatigue at baseline, and, after 6 months of CPAP therapy, 23.1% of the adherent participants still experienced fatigue. To perform this comparison, we analyzed the 3 items from the ESFS that pertain to fatigue. Cutoff scores from Bailes, Libman [131] determined who was considered to be fatigued.

Discussion

Consistent with previous studies looking at daytime fatigue and daytime sleepiness as independent problems in apnea patients[3,99], the present study demonstrated that levels of fatigue were higher for individuals with OSA than for those without. The factor analyses demonstrated that the number of driving violations item loaded with all 3 items of the ESFS

that were specific to fatigue. In contrast, levels of sleepiness were not shown to differ between the OSA and control groups. This was unexpected as previous studies showed that it is the excessive sleepiness that needed to be managed in the context of drivers with OSA.[132,133]

In addition, our data did not show different driving profiles between drivers with OSA who were either adherent or non-adherent to treatment, nor did our data show that CPAP treatment decreased fatigue, sleepiness or the number of self-reported driving violations after 6 months of treatment. This finding is novel and has not been previously assessed. Larger sample sizes would be needed to properly assess the important relationship between treatment of OSA and driving performance.

There was considerable variability among individuals with OSA, and we were unable to identify a risk profile in our sample. Although other research has implicated problematic daytime sleepiness in increased crash risk, and individuals with OSA have commonly been designated as prototypically sleepy, most (92%) drivers with OSA in our sample had not been involved in a motor vehicle crash in the past 5 years. Results of our investigation clearly showed that based on the results of the Empirical Fatigue and Sleepiness Scale, an important percentage of individuals with OSA (30.8%) do not experience excessive daytime sleepiness. Many prior studies have also demonstrated that not all OSA patients experience excessive sleepiness.[134-137] In fact, it is suggested that the presence of insomnia, level of alertness and metabolic conditions may have stronger associations with OSA than with sleepiness. For patients with OSA who do not experience sleepiness, recent studies reported that daytime sleepiness possibly relates to the domain and extent of cognitive impairment in OSA; CPAP

treatment has little effect on the improvement of cognitive deficits, which can have an important impact on driving performance.[138]

Furthermore, sleepiness in this group was not consistently related to driving violations. Registered driving violations significantly correlated with sleepiness for individuals with OSA, whereas a factor analysis on individual items of the ESFS identified 3 clear patterns of response associating fatigue with the number of registered driving violations (Table 4). Substantively, Table 2 shows self-reported sleepiness was associated with AHI, $r(24)=.42$, $p<.05$ (an objective measure of OSA severity), drivers with OSA reported significantly higher scores on fatigue, compared to controls, $t(47)=3.23$, p.01. However, drivers with OSA did not commit more driving violations than Controls overall.

Also, drivers with OSA had self-reported daytime sleepiness that was negatively correlated with registered driving violations, whereas their AHI was positively correlated with registered driving violations. Possibly, variable correlation between objective measurement and subjective experience might explain some of the discrepancy between aspects of our data and previous reports, especially for the OSA population[139,140] Although these findings are novel and have not been previously assessed, a larger sample would be needed to further the research examining the correspondence between self-report and objective measures of driving behavior.

Several studies suggest that excessive fatigue in obstructive sleep apnea patients may be strongly influenced by depressive symptoms and not apnea severity. In our sample of participants with OSA as well, fatigue and depression, as well as sleepiness and depression, measures were correlated. These findings concur with Lal and Craig (2001) that fatigue and

sleepiness measures that include psychological adjustment aspects seem promising for the development of a countermeasure device.[103]

The present report has few limitations. The numbers of road accidents obtained from the SAAQ registry involving our participants were so few that we were limited in our capacity to measure the association between registered dangerous driving and OSA. Much of our driving behavior data was based on self-report, which may have resulted in report bias. In another study we did compare self-reported and registered driving violations. We found that individuals with OSA over reported driving violations, while the comparison individuals with no OSA underreported driving violations.[141] Registered driving violations are only representative of the violations for which participants were caught. Driving violations were certainly committed but were not reflected in their registered driving records. Furthermore, our relatively small sample size did not allow for biological sex comparisons; future studies would benefit from a larger sample and attention to potential biological sex differences.

Conclusions

Fatigue plays a key role in driving behaviors, although the extent remains unclear. Our findings suggest that fatigue is as important a determinant of poorer driving performance as is sleepiness and AHI are for OSA severity. Future research in the area of driver fatigue should not only consider the methodological limitations of this study, but also include basic cognitive measures, such as alertness and response time, which underlie driver performance and risk.[103]

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Tableau II.Independent sample t-tests comparing driving behaviors in individuals with and without OSA

	OSA		Control		
	M	SD	M	SD	*t*-test
Official driving violations	1.08	1.38	0.64	1.26	ns
Self-reported violations	13.90	12.36	12.17	10.31	ns
DBQ total score	87.98	22.24	86.00	18.97	ns
Sleepiness	10.00	3.57	8.00	3.69	ns
Fatigue	7.73	3.71	4.26	3.66	3.227 **
Depression	0.58	0.83	0.23	0.43	ns
Anxiety	0.83	0.82	0.64	0.73	ns
WASO	0.86	0.94	0.55	0.52	ns
Sleep efficiency	0.83	0.20	0.91	0.08	ns
TST	6.75	1.99	6.82	0.66	ns
SF-36:					
Physical functioning	70.00	27.62	93.91	7.68	-4.080 ***
Role limitations due to physical health	64.58	40.99	94.57	10.54	-3.466 **
Body pain	50.08	23.36	75.96	18.01	-4.263 ***
General health	62.04	18.60	74.04	16.74	-2.327 *
Energy/fatigue	47.40	18.44	66.52	18.12	-3.587 **
Social functioning	71.35	25.66	83.70	21.13	ns
Role limitations due to emotional problems	72.22	41.31	84.06	26.34	ns
Emotional well-being	65.17	19.61	72.87	16.18	ns

*p <.05. **p <.01. ***p <.001.

Note. M=Mean. SD=Standard Deviation. OSA=Obstructive Sleep Apnea.

Tableau III.Correlations between driving violations, daytime functioning and sleep parameters for individuals with OS

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Official driving violations													
2. Self-reported violations	-0.076												
3. Aggressive driving (DBQ)	0.126	-0.313											
4. Ordinary infractions (DBQ)	0.08	-0.311	.884**										
5. Errors (DBQ)	0.029	-0.155	.740**	.770**									
6. Lapses (DBQ)	0.107	-0.366	.540**	.621**	.819**								
7. Beck Depression Inventory (total)	-0.132	-0.016	0.325	0.331	0.259	0.16							
8. Fatigue	-0.106	0.268	0.063	0.105	0.159	0.028	.471*						
9. Sleepiness	-.450*	0.34	-0.074	-0.01	-0.172	-0.236	.427*	.459*					
10. Sleep efficiency	0.079	0.299	-0.159	-0.153	-0.223	-0.346	-0.155	-0.21	-0.22				
11. TST	-0.182	0.383	-0.02	-0.244	0.19	-0.009	-0.046	0.089	-0.05	-0.066			
12. WASO	-0.087	0.044	-0.086	0.195	-0.023	0.01	0.144	.469*	0.372	-0.134	-0.28		
13 AHI	.418*	-0.112	-0.048	-0.031	-0.247	-0.107	-0.013	0.025	-0.152	0.167	-.468*	.465*	

*Correlation significant at the .05 level (bilateral).
** Correlation significant at the .01 level (bilateral).

Tableau IV.Correlations between driving behavior, daytime functioning and sleep parameters for control group

	Official driving violations	Self-reported Violations	Aggressive driving	Ordinary infractions	Driving errors	Lapses while driving
Sleep symptom checklist:						
Insomnia	0.174	-0.131	0.159	0.322	.424*	0.278
Daytime symptoms	-0.043	0.069	-0.09	0.031	0.078	-0.029
Sleep Disorder symptoms	0.413	0.158	0.015	0.124	0.158	0.08
Psychological symptoms	0.085	0.175	0.319	.645**	.675**	.539**
Fatigue	0.046	-0.011	-0.112	-0.138	-0.177	-0.265
Sleepiness	-0.223	-.424*	-0.154	-0.147	-0.278	-0.353
Sleep efficiency	0.165	0.084	0.037	-0.046	-0.036	0.119
TST	-0.254	0.089	-0.227	-0.209	-0.142	0.063
WASO	-0.24	-0.136	0.179	0.276	0.099	0.002

**p<.01. *p <.05 (bilateral).

Tableau V. Exploratory Factory Analysis Factor Loadings for Actual Driving Violations and Sleepiness and Fatigue Scale items (n=47)

	Factors		
	1	2	3
Sitting and reading (ESS)	**0.925**		-0.293
Watching TV (ESS)	**0.698**		-0.286
As a passenger in a car for an hour when circumstances permit (ESS)	**0.501**	0.485	-0.421
I lacked energy (SFM)	0.484	**0.849**	-0.517
I started things without difficulty but got weak as I went on (SFM)	0.28	**0.792**	-0.287
Exercise brought on my fatigue (FSS)		**0.538**	
Official driving violations		**0.364**	
Sitting quietly after lunch without alcohol (ESS)	0.532	0.326	**-0.931**
Sitting, inactive in a public place (e.g., theatre, meeting) (ESS)	0.522	0.266	**-0.621**
Sitting and talking to someone (ESS)			**-0.452**

Note . Loadings less than 0.20 were excluded. Factor loadings in bold type were considered for cluster interpretation. Extraction method: Maximum likelihood. Rotation method: Oblimin with Kaiser normalisation.

Tableau VI.Analysis of variance comparing driving behaviors and AHI between CPAP adherent and CPAP non-adherent drivers

	Adherent		Non-adherent		*F*-value	Sig.
	M	SD	M	SD	ANOVA	
Sleep Variables						
Apnea-Hyponea Index	38.69	27.46	33.45	23.54	0.25	0.625
Fatigue	7.04	3.49	8.55	3.96	0.98	0.332
Sleepiness	9.50	3.29	10.59	3.95	0.54	0.468
Sleep Efficiency	0.84	0.11	0.81	0.28	0.14	0.707
Driving-Related Variables						
Aggressive Driving (DBQ)	14.08	2.60	15.45	5.48	0.65	0.428
Ordinary Infractions (DBQ)	25.00	6.36	28.27	10.83	0.85	0.367
Errors (DBQ)	23.62	4.23	28.18	7.32	3.64	0.070
Lapses (DBQ)	20.15	6.90	20.82	6.32	0.06	0.809
DBQ Total Score	80.15	8.96	97.23	29.45	3.96	0.059
Near Misses (in the last year)	1.69	0.48	2.27	0.47	8.92	0.007
Registered Driving Violations (SAAQ)	1.08	1.44	1.09	1.38	0.00	0.981
Self-Reported Driving Violations (DVI)	10.08	4.97	18.41	16.74	2.94	0.101
Psychological Variables						
Difficulty Concentrating	3.85	1.57	5.45	2.29	4.14	0.054
Beck Depression Inventory	12.69	7.88	13.27	10.21	0.02	0.877

Note. N=24

Tableau VII.Independent sample t-tests comparing driving violations, fatigue and sleepiness, before and after CPAP >4 hours a night (n=13)

	Pre-treatment		Post-treatment		
	M	SD	M	SD	*t*-test
Self-reported violations	9.36	5.08	9.00	9.90	ns
Fatigue	6.86	3.77	4.41	4.02	ns
Sleepiness	8.59	2.65	7.91	3.65	ns

Chapter 3

Self-reported driving violations as a putative mirror measure of real-world driving quality in individuals with and without Obstructive Sleep Apnea

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Self-reported driving violations as a putative mirror measure of real-world driving quality in individuals with and without Obstructive Sleep Apnea

The Driving Infractions Inventory

Abstract

Sleepiness is recognized as an important risk factor for risky driving and motor vehicle accidents. This study explores whether self-reported driving violations can be used as an accurate assessment of driving risk in individuals with obstructive sleep apnea (OSA). We recruited 29 participants with OSA and 29 age- and biological sex-matched controls, obtained governmental sourced driving records for all participants and administered a monotonous driving simulator task to measure driving performance. We administered the Driving Violations Inventory (DVI) to all participants—a self-report measure that asks participants to record which of the official list of violations were committed. Data from DVI were compared with official driving records and with driving simulator results. Drivers with OSA did not have more registered driving violations than the control group. The overall number of self-reported violations was highly correlated with the driving simulator lateral position variable only for drivers with OSA. There were no significant associations between the number of official driving violations and simulator deviation of the lateral position for either group. Our findings indicate that the DVI is an accessible measure that could mirror some of the risk associated with impaired driving behavior in general, perhaps particularly for individuals with OSA.

Background

Obstructive Sleep Apnea (OSA) is a highly prevalent disorder that affects at least 10% of adult males and 5% of adult females[142,143]. This sleep-disordered breathing is highly prevalent, with important public health outcomes[144]. Severe OSA is associated with sleepiness, car crashes, depressed mood, cardiovascular and cerebrovascular morbidity, cognitive and metabolic dysfunction, and accelerated mortality[145]. The disorder is primarily based on recurring episodes of partial or complete upper airway occlusion during sleep with associated sleep fragmentation; its most prominent daytime symptom is excessive sleepiness. Sleepiness itself is recognized as a major risk factor for risky driving and has been reported to account for 5-7% of all motor vehicle accidents[146,147], however, the role of sleepiness, as well as other risk-related factors and co-morbidities in increased accident risk among individuals with OSA is not yet fully understood[148-153]. In fact, the role and implications of daytime sleepiness and fatigue as distinct constructs in individuals with OSA needs to be further explored[154].

Multiple experimental studies using driving simulators or real city roads have made the link between driving performance and OSA[38,40,155-157]. For example, lateral position on the road (diverging away from the center-line, "weaving") is the traditional and most reliable indicator of decreased alertness in driving[158,159]. One study demonstrated that patients with severe OSA commit driving violations more frequently than age-matched control subjects during real world driving tests, suggesting greater inattention and thus potentially higher motor vehicle accident risk[11]. Another study indicated that naturalistic driving-related performance in less sleepy individuals with OSA, does not readily translate into safer driving [76,160,161]. However, studies on driving violations and non-commercial drivers with OSA are scarce (none since

2014)—mainly focusing on crash risk[76,88,162,163]—and access to official driving records is very challenging. One challenge is that official driving records only report violations committed and caught by officials; these may be very few over a five-year span (as we have found) and thus make statistical analysis difficult.

The objective of the present study was to evaluate self-reported driving violations as a measure of real-world driving quality and to assess if it could be a more useful research tool than either driving simulation data or official driving records. Specifically, we explored whether self-reported driving violations can be used as an accurate assessment of driving risk. We approached this question with the following steps:

(1) We obtained official driving records—including violations and accidents— for both participants with OSA as well as for healthy control subjects;

(2) We designed and used the Driving Violations Inventory (DVI), a self-report measure that asks participants to record which of the official list of violations were committed;

(3) We administered a monotonous driving simulator task to measure driving performance;

(4) Data from the self-report measure were compared with official driving records, obtained from governmental sources and with driving simulator results.

Methods

Ethics Approval

The present study was part of a larger investigation on OSA and risky driving carried out in our laboratory[164,165] The protocol was approved by the McGill University Research Ethics

Board, the Université de Montréal Research Ethics Board as well as by the Research Ethics Boards of the Jewish General Hospital. We were granted permission by the *Société de l'assurance automobile du Québec* (SAAQ)—the provincial body regulating driver's licenses, in Quebec, Canada—to obtain driving records for all participants. Potential participants were informed about all aspects of the study, including obtaining official government driving records.

Participants

We recruited 58 individuals who were non-commercial drivers, (mean age= 50.78, SD=11.13) through a sleep clinic. Of these, 29 (15 females, 14 males) were newly diagnosed with OSA, between the ages of 25 and 65. We selected adults under the age of 65 in order to avoid the many health conditions that are more prevalent in the over 65 age group. A comparison sample of 29 individuals (Control Group), matched for age and biological sex, with no complaints of fatigue, sleepiness or sleep problems was either recruited at the sleep clinic (e.g. accompanying partners, family members, friends) after sleep apnea was ruled-out (n=10), or from the community through posters (n=19). We verified that the different recruitment approaches yielded no differences on sleep parameters, quality of life, psychological profiles or driving parameters, i.e. control participants recruited from sleep clinics were not statistically different from control participants recruited from the community.

Potential participants were informed of all aspects of the study and screened for eligibility. Exclusion criteria were: inability to function in English or French, not having a valid driving license for at least 5 years, severe or acute medical or psychiatric condition, and cardiovascular

disease with end-organ effects (e.g., heart attack, stroke, and congestive heart failure). To rule out the presence of fatigue or sleepiness, Control Group participants were administered the 7 item Sleep Disorder subscale of the Sleep Symptom Checklist (SSC), and were administered the Breabon MediByte® home monitoring device to confirm the absence of OSA (Apnea-Hyponea Index less than 5). We evaluated all control participants at baseline. All participants completed a questionnaire battery related to driving behaviour and psychological adjustment; we obtained official accident and driving violations records for all participants. Participant demographics results are available in Table 1.

Procedure

Participants with OSA were made aware of the study by their sleep specialist at their follow-up appointment after their polysomnography sleep study. They were asked for consent to have a member of the research team contact them to explain the study and request their participation. Control participants were contacted directly by the researchers.

All potential participants were sent two copies of the information and consent form, a questionnaire package, and a self-addressed stamped envelope to return completed materials to our laboratory.

When the completed questionnaires were returned, we verified that we had permission to retrieve the 5-year accident record from the SAAQ records for all the participants, both with OSA and their age- and biological sex-matched participants without OSA.

When OSA is diagnosed, the usual treatment offered is continuous positive airway pressure (CPAP). Once the sleep specialist prescribes treatment, it usually takes several weeks to

arrange meetings with a sleep medicine technician to choose a device that suits the patient. This time interval allowed us to complete all assessments for the OSA group before CPAP treatment began.

Measures

Polysomnography (PSG). Unrelated to this study's protocol, participants suspected of having OSA were prescribed an over-night sleep study by a sleep medicine physician. Nocturnal PSG was used to obtain sleep parameter scores (i.e., frequency of nocturnal arousals, total sleep time, sleep onset latency, wake after sleep onset, and sleep efficiency) as well as OSA related factors (i.e., nocturnal profile of oxygen saturation (O2%), apnea hypopnea index (AHI) and respiratory event -related arousal from sleep). Participants were monitored in a supervised, participating sleep laboratory from 10:00 PM to 7:00 AM. Monitoring included: electrooculargram (EOG), electroencephalogram (EEG), bilateral anterior tibialis and chin electromyogram (EMG), electrocardiogram (ECG), pulse oximetry, nasal and oral airflow with thermistor and nasal pressure cannulae, microphone for snoring, and respitrace bands for measurement of respiratory effort. Apnea events and associated arousals were scored manually per scoring rules established by the American Academy of Sleep Medicine. An apnea event was defined as cessation of breathing lasting 10 seconds or more. Hypopneas were scored when there is a 30% or more decrease in airflow with 3% or more oxygen desaturation or a subsequent cortical arousal. Scoring sleep began at lights out and stopped when the participant arose in the morning. The sleep laboratory is certified by the American Academy of Sleep Medicine and uses standardised methods of evaluation. We analyzed the following

information from the participants' polysomnography records: basal oxygen saturation (SpO2%), respiratory distress index (RDI), and apnea hypopnea index (AHI).

Home Polysomnography Assessment (Braebon, MediByte ©). Type 3 portable monitor for screening of OSA in Control participants. This device has been compared with overnight laboratory polysomnography and found to provide a close estimate of the apnea/hypopnea index (AHI) as well as excellent diagnostic sensitivity and specificity for OSA in a sample of patients with suspected OSA[166]. This device records pulse oximetry, nasal airflow with nasal pressure cannulae, microphone for snoring, and respitrace bands for measurement of respiratory effort. Records underwent automated scoring which was validated by visual inspection of the raw data disclosed in 10-minute epochs. Healthy control group participants underwent home sleep recording to screen for the presence of OSA. Participants slept at home and, on a night without any unusual upper respiratory tract symptoms such as acute nasal congestion, recorded the time between when they turned off the lights to go to sleep and the time they awoke in the morning. Respiratory disturbance indices were adjusted for any time spent with invalid recording or persistent movement suggesting wakefulness.

Demographics: Background Information Form[167-169]. This measure collects information on biological sex, age, marital status, living conditions, and employment.

Driving Violations Inventory. Inventory of 32 driving violations listed by the SAAQ[170]. Participants are asked to indicate how often they committed each of the violations on a six-point scale (0 = never; 5 = nearly all the time). Cronbach's alpha is 0.94. (Inventory presented in Figure 1).

Official driving records. Official driving records from the SAAQ. 32 driving violations can be recorded by the SAAQ for each participant, including information on demerit points and frequency of driving violations. For each participant, data on accidents are provided by frequency and rated by severity (not severe to deadly).

Driving Simulator[71,171]***.*** Driving simulation tests were conducted at the Université de Montréal's driving simulator laboratory. The simulator consisted of a complete automobile, including fully functional pedals and dashboard, a high-resolution projector, and a large screen. Simulated highway images were designed using actual Canadian geometric route design standards. The moving images were generated by a compatible computer. During a simulation test, the location of the pedals and the location and speed of the vehicle were recorded. A potentiometer attached to the steering column allowed detailed recording of steering wheel movements[171]. Data were analyzed at 3 time periods: after 20, 40, and 60 minutes. Three measures were obtained for each of the 3 time periods (mean lateral position, mean speed, and mean orientation of steering wheel (lower scores indicate better performance).

Analyses

A Mann-Whitney U test was conducted to compare self-reported driving violations and officially recorded driving violations. Correlations were also performed to verify whether higher (i.e. worse) scores on the DVI were associated with higher experimental or simulator standard deviation values for lateral position in the driving simulator. We also performed a Fisher's exact test to evaluate which driving violations in the DVI were more reported by each of the groups. Finally, a discriminant analysis was used to test the hypothesis that participants with OSA would differ significantly from individuals without OSA on self-report items in the DVI. We also performed a Wald test in the context of logistic regression where we allowed for the program to determine whether items from the DVI revealed that a certain predictor

variable was significant or not. We then performed a discriminant analysis to verify whether the DVI is an appropriate tool for identifying participants with OSA. Finally, correlations were performed on a subset of participants (OSA groups n=13, Control group n=7) who were available to complete the monotonous driving simulation task to verify whether higher (i.e. worse) scores on the DVI would be associated to higher experimental or simulator standard deviation values for lateral position in the driving simulator task. Attrition for this section of the analyses was related to participant availability and whether they experienced motion sickness during the task.

Results

Participants in both groups reported significantly more violations than were officially recorded: Individuals with OSA reported 7.35 times and control subjects reported 12.65 times more violations than in their officially recorded file. However, given the non-normal nature of our data distribution, a Mann-Whitney test indicated that there were no differences between individuals with OSA (Mdn=8) and control (Mdn=7) subjects for self-reported driving violations, p =.591, and official registry recorded violations (Mdn=0; Mdn=0, respectively), p =.124. Frequency counts revealed that the OSA group reported a total of 250 driving violations; the Control group reported 253 driving violations. Frequency counts from official driving records revealed 34 official driving violations for the OSA group, and 20 driving violations for the Control group. Odds ratio analyses indicated that the difference between groups was not statistically significant ($\chi^2(1, N = 58) = 3.43$, $p = .064$, odds ratio = .058).

Binary data comparisons on self-reported violations between groups revealed that 3 items from the DVI showed differences between the OSA and Control groups with a p-value lesser than 0.1. First, there is a trend for control participants endorsing item 14—Failure to come to a mandatory stop at a level crossing (p=0.070), where the odds of an individual with OSA reporting this violation is less than the odds of a control participants reporting this violation (odds ration 0.26). On the other hand, item 25—Sudden braking without cause (Fisher's exact test p=0.003)—showed that the odds of an individual with OSA reporting this item are 6.8 times higher than that of a control participant (95%CI 2.0-22.9). However, item 30—Driving with the presence of alcohol in the body (Fisher's exact test p=0.024)—showed that the odds of an individual with OSA endorsing this driving violation are less than that of a control participant (odds ratio 0.22, 95%CI 0.07-0.75). Entered explanatory variables item 14 (p=.027), item 25 (p=.005) and item 30 (p=.294) showed that they correctly predicted 69% of group memberships for all subjects. The test showed a model that correctly predicted 82.8% of group memberships. The variables retained by the Wald test in this model were item 2 (p=.014), item 14 (p=.003), item 23 (p=.034) and item 25 (p=.002).

To verify whether the DVI is an appropriate tool for identifying participants with OSA, we performed a discriminant analysis using the inventory's scores for all participants. The overall Chi-square test was significant (Wilks λ = .330, Chi-square = 44.851, df = 29, Canonical correlation = .818, p <. 05); 91.2% of the cases were correctly reclassified into their original categories. In other words, of the 29 cases that were predicted to be in the OSA group, 26 were correctly predicted, and 3 were incorrectly predicted.

Analyses on the driving simulator data revealed that for participants with OSA, the overall number of self-reported violations was strongly correlated with the standard deviation lateral position variable of the driving simulator, $r(13) = .64$, $p < .05$ (Table 2). There was no such association for Control participants (Table 3). Moreover, there were no significant associations between the number of official driving violations and experimental standard deviation lateral position for either group. The standard deviation of lateral position is significantly higher for participants with OSA (M=.653, SD=.062) than for Controls (M=.588, SD=.039); $t(18)=2.539$, $p = .034$ (see table 4 for means). A previous report has suggested that the last 20 minutes of the hour-long task may account for those differences, where participants with OSA may possibly be particularly sensitive to longer driving periods[172]. A larger sample size would be needed to verify this.

Limitations

Although data on accidents were collected, the number was too low to be considered for statistical analyses (5 total, for n=58). The data presented in this paper are more a reflection of drivers' aptitudes and potential risk of committing driving violations than of actual accident or crash risk.

Also, Control participants were matched for age and biological sex. While matching is intended to reduce confounding, we also wanted to benefit from a gain in efficiency. The linear regression may have yielded a significant model, but, in reality, a higher percentage of men are diagnosed with OSA.[173] Though, more studies are beginning to show that women with OSA are being overlooked.[174]

In the driving simulator task, a deterioration over time was demonstrated for participants with OSA after 40 minutes of driving. Due to the low number of participants, we did not elaborate on this, but it would be interesting to verify with a larger sample in the future.

Lastly, the DVI is a self-reported measure. Our data shows that all participants reported several times more driving offenses than the number of offenses found in their driving records; It is likely that outside of an experimental confidentiality context, individuals may be more reluctant to disclose driving misbehaviors. It is known that self-reported data is a reflection of participants' response styles, response sets and memory.[175]

Conclusions and discussion

The DVI, is a novel measure that mirrors all possible violations listed by an official government driving agency. Our findings indicate that, it is accessible, meaningful, and. may be a simple tool to help identify a risky driver who is likely to weave while driving. The latter is an acknowledged potential warning sign of driving performance and accident risk[176]

Identifying drivers with OSA who may be at risk of dangerous driving is a challenge for primary care practitioners. Questioning the driver or the driver's passenger about frequency of sudden braking or weaving might indicate that further evaluation is needed. Our data suggest that drivers with OSA may need more frequent rest stops to maintain driving quality.

Notably, all participants, with and without OSA, reported significantly more driving violations than recorded in their official driving files; no differences were found in the number of driving violations between participants with OSA and control subjects. This is a reminder that driving records represent only a percentage of driving violations - those that are witnessed

by a law enforcer. Participants with OSA did report 41% more driving violations than did individuals without OSA. This difference was found not statistically significant, but further evaluation in the context of a larger sample is indicated.

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Tableau VIII.Correlations between driving violations and lateral position for OSA group (n=13)

	Lateral position	Self-reported driving violations
Self-reported driving violations	.638*	
Actual driving violations	.385	.067

**. The correlation is significant at the 0,05 level (bilateral).*

Tableau IX.Correlations between driving violations and lateral position for Control group (n=7)

	Lateral position	Self-reported driving violations
Self-reported driving violations	-.002	
Actual driving violations	-.293	.006

**. The correlation is significant at the 0,05 level (bilateral).*

Tableau X.Means and standard deviations of driving violations and lateral position

	OSA		Controls	
	Means	SD	Means	SD
Self-reported driving violations (DVI)	8.62	5.07	8.72	7.16
Actual driving violations (SAAQ)	1.17	1.36	0.69	1.17
Lateral Position (driving simulator)	0.65	0.06	0.59	0.04

Figure 1.Driving Infractions Inventory

For each item below, please indicate how often this has happened in the past five (5) years.	**0 = *never* 1 = *hardly ever* 2 = *occasionally* 3 = *quite often* 4 = *frequently* 5 = *nearly always***					
1. Excessive Speeding by 11 to 20 km/h	0	1	2	3	4	5
2. Excessive Speeding by 21 to 30 km/h	0	1	2	3	4	5
3. Excessive Speeding by 31 to 45 km/h	0	1	2	3	4	5
4. Excessive Speeding by more than 45k/h	0	1	2	3	4	5
5. Excessive speeding through road work	0	1	2	3	4	5
6. Prohibited passing on the left	0	1	2	3	4	5
7. Prohibited passing on the right	0	1	2	3	4	5
8. Prohibited passing in a lane reserved for oncoming traffic	0	1	2	3	4	5
9. Accelerating when being passed	0	1	2	3	4	5
10. Passing a bicycle too closely in a travel lane	0	1	2	3	4	5
11. Zigzagging to pass	0	1	2	3	4	5
12. Failure to obey a red traffic light	0	1	2	3	4	5
13. Failure to obey a stop sign	0	1	2	3	4	5
14. Failure to come to a mandatory stop at a level crossing	0	1	2	3	4	5
15. Failure to stop before turning right at a red traffic light (where permitted)	0	1	2	3	4	5
16. Passing a school bus	0	1	2	3	4	5
17. Failure to obey the order or signal of a peace officer, school crossing guard or flag person	0	1	2	3	4	5
18. Prohibited driving in reverse	0	1	2	3	4	5
19. Prohibited crossing of a line marking off lanes	0	1	2	3	4	5
20. Speeding or reckless driving	0	1	2	3	4	5
21. Driving for a wager or stake or in a race	0	1	2	3	4	5
22. Prohibited use of a tunnel by a vehicle carrying dangerous substances	0	1	2	3	4	5
23. Driving at a speed too fast for weather or road conditions	0	1	2	3	4	5
24. Tailgating	0	1	2	3	4	5
25. Sudden braking without cause	0	1	2	3	4	5
26. Failure to yield to pedestrians and cyclists at an intersection	0	1	2	3	4	5
27. Failure to yield to oncoming traffic	0	1	2	3	4	5
28. Failure to wear a seat belt	0	1	2	3	4	5
29. Failure of a driver involved in an accident to do his or her duty	0	1	2	3	4	5
30. Driving with the presence of alcohol in the body	0	1	2	3	4	5
31. Failure to provide a breath sample	0	1	2	3	4	5
32. Driving while using a hand-held device that includes a telephone function	0	1	2	3	4	5

Conclusions et discussion

Discussion

Daytime sleepiness has long been known to be a consequence of untreated OSA.[120] According to a recent study, OSA is also associated with decreased vigilance and 2- to 7-fold increased risk of motor vehicle crashes.[53] It has been demonstrated that neurocognitive deficits occur with a high frequency in OSA. These deficits can affect any cognitive domain, such as learning, memory, and attention.[177] Ayalon, Ancoli-Israel [37] have found that the frontal and parietal cortices are abnormal in OSA patients. Moreover, they performed fMRIs in patients with OSA and showed decreased brain activation in cingulate, frontal, and parietal regions during the performance of sustained attention tasks as compared with control subjects.[37] That study also found that slower mean reaction time, with decreased brain activation in areas involved in arousal and attention, response selection, motor response, and decision making were significantly associated with AHI. Interestingly, the present study found that AHI was correlated with the number of registered driving violations (Table 11, in appendix). This study also showed that drivers who were adherent to CPAP treatment were initially reporting fewer near-misses in the last year, and less difficulty concentrating than did the non-adherent group at baseline (Table 12, in appendix). However, the present results did not support the hypothesis that CPAP treatment would improve driving performance.

The cognitive profile of OSA identifies attention, episodic memory, working memory and executive function as the cognitive domains most affected. More specifically, individuals with OSA show impairment on sustained, selective and divided attention: when compared to controls, Individuals with OSA manifest more lapses and/or longer reaction times in tasks requiring sustained attention, selective attention or vigilance.[5] Furthermore, it has been shown that sleep disorders may compromise an individual's alertness/vigilance and driving performance.[178]

Driver fatigue has been described as a feeling of tiredness and reduced alertness when driving which impairs capability and willingness to perform the driving task.[179] However commonly used self-reported measures may confound fatigue with other symptoms of sleep apnea (ex.: excessive fatigue in obstructive sleep apnea patients may be strongly influenced by depressive symptoms and not apnea severity). Currently, measurements of fatigue include psychological measurements (i.e. self-reported fatigue), video measurement (i.e. facial expression, reaction time, steering errors and lane deviation), and physiological measurements such as electroencephalography (EEG, i.e. brain signal measurement), electrooculography (i.e. eye tracking), and electrocardiography (i.e. heart rate variability associated with fatigue). EEG is considered to be a significant and reliable method of detecting fatigue, as it detects changes in brain wave activity associated with fatigue.[180] A countermeasure for fatigue based on brain activity that monitors fatigue when performing tasks such as driving is a practical approach for lowering risks of fatigue-related accidents. Such a measure could be used in a real driving context, and perhaps go as far as alerting drivers when they may be at risk.

In contrast, it has been confirmed in experimental studies using driving simulators, that there are higher rates of off-road incidents and lane deviations following sleep deprivation.[158,181-183] It is safe to assume that a sleep disorder such as OSA, which restricts or disrupts sleep and causes some level of sleep loss, would result in substantial daytime sleepiness.[1848,9] For the driving simulator task in this study, Figure 2 in appendix shows that there was no significant difference between the OSA and Control groups for the first 2 sections. In the third section, there was a non-significant decrease in lane position variability in the driving simulator task for control participants; participants with OSA steadily increased lane position variability throughout the task (p=.063). Overall these data indicate that the OSA and Control groups did not differ significantly on either the registered driving violations and accidents nor on any self-reported driving measure, contrary to what would be expected. However, on the driving simulator, there was some suggestion that at least one aspect of performance for participants with OSA deteriorated in the third section of the task (i.e. after driving 40 minutes). It is important to note that the sample sizes in this section are small; a

study with a larger sample size would be required to confirm these preliminary results. Nonetheless, it would be appropriate that drivers with OSA should be alerted to their particular sensitivity toward long distance driving.

Objective clinical measures of daytime sleepiness such as the MSLT have been shown to be useful at discriminating between sleepy vs alert drivers with OSA.[53] More specifically, a study found that simulated-driving performance (i.e. road lateral position and crash occurrence) was correlated with sleep latency on the MSLT, demonstrating discriminability between sleepy versus alert drivers with OSA.[185] However, such associations are not represented in real driving performances.[53] An earlier study found that age, AHI and MSLT were not significant predictors of riskier driving.[156] Though the MSLT is also a less accessible measure due to its costly and timely nature, it may have provided this study with more discriminatory power for identifying riskier drivers with OSA within the driving simulation task. Limitations of the present study described in the above chapters could benefit from including MSLT as a measure for sleepiness/alertness.

By the same token, sleepiness is a known symptom of psychiatric illnesses. Psychiatric illnesses can affect sleep and wakefulness and psychotropic medications may affect normal patterns of sleep.[186] Sleep disorders such as OSA and psychiatric conditions often coexist.[186] A poor understanding of the relationship between these comorbidities may result in misdiagnosis and undertreatment.[187-189] More importantly, this may be a concern for personal and public safety, particularly for drivers. Although individuals with acute psychiatric illnesses were excluded from this study, data on psychotropic drug use were not collected or accounted for. Such data could contribute to the better understanding of treatment trajectory and, again, driving behavior.

Conclusions

The purpose for this project was to review current guidelines on driving and OSA, attempt to identify a distinct behavioral profile associated with poor driving performance in drivers with OSA, and address the need for an accurate metric quantifying severity of driving

risk associated with OSA. Specifically, the preceding chapters addressed these issues by 1) assessing whether levels of fatigue and sleepiness differ in individuals with OSA from those without OSA and how they relate to driver performance, 2) assessing the effect of CPAP treatment on driving performance, and 3) exploring whether self-reported driving violations can be used as an accurate assessment of actual driving risk.

The first chapter makes clear that there is a lack of uniformity in existing consensus and guidelines as to how to deal with the issue of driving with OSA. Because conclusions from numerous studies have been inconsistent, it is, in fact, difficult to have clear guidelines for this population. Individual differences and variability are important aspects to consider, especially for clinicians assessing fitness-to-drive.

In the second chapter, it was demonstrated that drivers with OSA did not commit more documented driving violations than control participants, however, a correlation showed that sleepiness was related to a higher number of actual driving violations for drivers with OSA, Factor analysis revealed a strong association between fatigue and official driving violations for both groups of drivers - with and without OSA .Notably, there was considerable variability among individuals with OSA, and we were unable to identify a risk profile in our sample. Somewhat surprisingly, no differences were found on symptoms of fatigue, sleepiness or number of violations reported in drivers with OSA before and after treatment.

The third chapter demonstrated that the DVI successfully identified drivers with OSA who deviate from the road lateral position in the driving simulator—a commonly used measure of dangerous driving, indicating this measure may be useful as a more accessible tool than the much more complex assessment using the driving simulation task or actual road driving performance.

Bibliographie

1. Peppard PE, Young T, Barnet JH, Palta M, Hagen EW, Hla KM. Increased prevalence of sleep-disordered breathing in adults. *American journal of epidemiology* 2013; **177**(9): 1006-14.
2. Punjabi NM. The epidemiology of adult obstructive sleep apnea. *Proceedings of the American Thoracic Society* 2008; **5**(2): 136-43.
3. Bailes S, Libman E, Baltzan M, et al. Fatigue: the forgotten symptom of sleep apnea. *Journal of psychosomatic research* 2011; **70**(4): 346-54.
4. Bucks RS, Olaithe M, Eastwood P. Neurocognitive function in obstructive sleep apnoea: A meta-review. *Respirology* 2013; **18**(1): 61-70.
5. Gagnon K, Baril AA, Gagnon JF, et al. Cognitive impairment in obstructive sleep apnea. *Pathologie Biologie* 2014; **62**(5): 233-40.
6. Nishino S, Riehl J, Hong J, Kwan M, Reid M, Mignot E. Is narcolepsy a REM sleep disorder? Analysis of sleep abnormalities in narcoleptic Dobermans. *Neuroscience research* 2000; **38**(4): 437-46.
7. Ford ES, Cunningham TJ, Croft JB. Trends in self-reported sleep duration among US adults from 1985 to 2012. *Sleep* 2015; **38**(5): 829-32.
8. Rodenstein D. Driving in Europe: the need of a common policy for drivers with obstructive sleep apnoea syndrome. *Journal of sleep research* 2008; **17**(3): 281-4.
9. Weaver TE, Maislin G, Dinges DF, et al. Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep* 2007; **30**(6): 711-9.
10. Lyznicki JM, Doege TC, Davis RM, Williams MA. Sleepiness, driving, and motor vehicle crashes. *Jama* 1998; **279**(23): 1908-13.
11. Franklin KA, Lindberg E. Obstructive sleep apnea is a common disorder in the population—a review on the epidemiology of sleep apnea. *Journal of thoracic disease* 2015; **7**(8): 1311.
12. Patterson KC, Huang F, Oldham JM, Bhardwaj N, Hogarth DK, Mokhlesi B. Excessive daytime sleepiness and obstructive sleep apnea in patients with sarcoidosis. *Chest* 2013; **143**(6): 1562-8.
13. Sforza E. Sleep apnea syndrome and cognition. *Frontiers in neurology* 2012; **3**: 87.
14. Day R, Gerhardstein R, Lumley A, Roth T, Rosenthal L. The behavioral morbidity of obstructive sleep apnea. *Progress in cardiovascular diseases* 1999; **41**(5): 341-54.
15. Eckert DJ, Malhotra A, Lo YL, White DP, Jordan AS. The influence of obstructive sleep apnea and gender on genioglossus activity during rapid eye movement sleep. *Chest* 2009; **135**(4): 957-64.
16. Eckert DJ, Butler JE. Respiratory physiology: Understanding the control of ventilation. Principles and practice of sleep medicine. Philadelphia, PA: Elsevier; 2016: 167-73.
17. Dewan NA, Nieto FJ, Somers VK. Intermittent hypoxemia and OSA: implications for comorbidities. *Chest* 2015; **147**(1): 266-74.
18. Chasens ER, Sereika SM, Weaver TE, Umlauf MG. Daytime sleepiness, exercise, and physical function in older adults. *Journal of sleep research* 2007; **16**(1): 60-5.

19. Marshall NS, Wong KKH, Liu PY, Cullen SRJ, Knuiman MW, Grunstein RR. Sleep apnea as an independent risk factor for all-cause mortality: the Busselton Health Study. *Sleep* 2008; **31**(8): 1079-85.
20. Cowie MR, Woehrle H, Wegscheider K, et al. Adaptive servo-ventilation for central sleep apnea in systolic heart failure. *New England Journal of Medicine* 2015; **373**(12): 1095-105.
21. Eckert DJ, Malhotra A, Jordan AS. Mechanisms of apnea. *Progress in cardiovascular diseases* 2009; **51**(4): 313-23.
22. Abdominal fat and what to do about it. 2015. https://www.health.harvard.edu/staying-healthy/abdominal-fat-and-what-to-do-about-it (accessed May 4 2016.
23. Korcarz CE, Stein JH, Peppard PE, Young TB, Barnet JH, Nieto FJ. Combined effects of sleep disordered breathing and metabolic syndrome on endothelial function: the Wisconsin Sleep Cohort study. *Sleep* 2014; **37**(10): 1707-13.
24. Reutrakul S, Van Cauter E. Interactions between sleep, circadian function, and glucose metabolism: implications for risk and severity of diabetes. *Annals of the New York Academy of Sciences* 2014; **1311**(1): 151-73.
25. Chiu HK, Tsai EC, Juneja R, et al. Equivalent insulin resistance in latent autoimmune diabetes in adults (LADA) and type 2 diabetic patients. *Diabetes research and clinical practice* 2007; **77**(2): 237-44.
26. Louis M, Punjabi NM. Effects of acute intermittent hypoxia on glucose metabolism in awake healthy volunteers. *Journal of applied physiology* 2009; **106**(5): 1538-44.
27. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. *Sleep* 2010; **33**(5): 585-92.
28. Broussard JL, Ehrmann DA, Van Cauter E, Tasali E, Brady MJ. Impaired insulin signaling in human adipocytes after experimental sleep restriction: a randomized, crossover study. *Annals of internal medicine* 2012; **157**(8): 549-57.
29. Balkau B, Loko S, Andriamboavonjy T, et al. High baseline insulin levels associated with 6-year incident observed sleep apnea. *Diabetes Care* 2010; **33**(5): 1044-9.
30. Vgontzas AN, Bixler EO, Chrousos GP. Sleep apnea is a manifestation of the metabolic syndrome. *Sleep medicine reviews* 2005; **9**(3): 211-24.
31. Coughlin SR, Mawdsley L, Mugarza JA, Calverley PMA, Wilding JPH. Obstructive sleep apnoea is independently associated with an increased prevalence of metabolic syndrome. *European heart journal* 2004; **25**(9): 735-41.
32. Badran M, Ayas N, Laher I. Cardiovascular complications of sleep apnea: role of oxidative stress. *Oxidative medicine and cellular longevity* 2014; **2014**.
33. O'Donoghue FJ, Wellard RM, Rochford PD, et al. Magnetic resonance spectroscopy and neurocognitive dysfunction in obstructive sleep apnea before and after CPAP treatment. *Sleep* 2012; **35**(1): 41-8.
34. Flemons WW, Remmers JE, Whitelaw WA. The correlation of a computer simulated driving program with polysomnographic indices and neuropsychological tests in consecutively referred patients for assessment of sleep apnea. *Sleep: Journal of Sleep Research & Sleep Medicine* 1993.

35. McKay A, Liew C, Schönberger M, Ross P, Ponsford J. Predictors of the on-road driving assessment after traumatic brain injury: comparing cognitive tests, injury factors, and demographics. *The Journal of head trauma rehabilitation* 2016; **31**(6): E44-E52.
36. Kim HC, Young T, Matthews CG, Weber SM, Woodard AR, Palta M. Sleep-disordered breathing and neuropsychological deficits: a population-based study. *American journal of respiratory and critical care medicine* 1997; **156**(6): 1813-9.
37. Ayalon L, Ancoli-Israel S, Aka AA, McKenna BS, Drummond SPA. Relationship between obstructive sleep apnea severity and brain activation during a sustained attention task. *Sleep* 2009; **32**(3): 373-81.
38. May JF, Porter BE, Ware JC. The deterioration of driving performance over time in drivers with untreated sleep apnea. *Accident Analysis & Prevention* 2016; **89**: 95-102.
39. Vakulin A, D'Rozario A, Kim J-W, et al. Quantitative sleep EEG and polysomnographic predictors of driving simulator performance in obstructive sleep apnea. *Clinical Neurophysiology* 2016; **127**(2): 1428-35.
40. Vakulin A, Dorrian J, Duggan TR, et al. Behavioural Observation as a Means of Assessing Sleepiness Related Driving Impairment in Obstructive Sleep Apnea. *Eat, Sleep, Work* 2016; **1**(1).
41. Aksan N, Dawson J, Tippin J, Lee JD, Rizzo M. Effects of fatigue on real-world driving in diseased and control participants. 2015: NIH Public Access. p. 268.
42. Vakulin A, D'Rozario AL, Grunstein RR. Driving Impairment and Accident Risk in Sleep Apnea: We Need Better Assessment Tools. J Sleep Disor: Treat Care 1: 1. *of* 2012; **2**: 2.
43. Rizzo D, Lavigne, G., Creti, L., Bergeron, J., Baltzan, M., Tran, D.-L., Bailes, S., Fichten, C., Libman, E. Are drivers with OSA getting bad press? *Sleep Medicine* 2015; **16**: S246.
44. Ayas NT, Hirsch AAJ, Laher I, et al. New frontiers in obstructive sleep apnoea. *Clinical Science* 2014; **127**(4): 209-16.
45. Strohl KP, Saunders NA, Feldman NT, Hallett M. Obstructive sleep apnea in family members. *New England Journal of Medicine* 1978; **299**(18): 969-73.
46. Ayas N, Skomro R, Blackman A, et al. Obstructive sleep apnea and driving: A Canadian Thoracic Society and Canadian Sleep Society position paper. *Canadian respiratory journal* 2014; **21**(2): 114-23.
47. Strohl KP, Brown DB, Collop N, et al. An official American Thoracic Society Clinical Practice Guideline: sleep apnea, sleepiness, and driving risk in noncommercial drivers. An update of a 1994 Statement. *American journal of respiratory and critical care medicine* 2013; **187**(11): 1259-66.
48. McNicholas WT. New Standards and guidelines for drivers with obstructive sleep Apnoea syndrome-report of the obstructive sleep Apnoea working group: European Commission. Directorate-General for Energy and Transport, 2013.
49. Ruskin KJ, Caldwell JA, Caldwell JL, Boudreau EA. Screening for sleep apnea in morbidly obese pilots. *Aerospace medicine and human performance* 2015; **86**(9): 835-41.
50. Gonçalves M, Amici R, Lucas R, et al. Sleepiness at the wheel across Europe: a survey of 19 countries. *Journal of sleep research* 2015; **24**(3): 242-53.
51. National Highway Traffic Safety A. Fatality analysisi reporting system encyclopedia. *http://www-fars nhtsa dot gov/Main/index aspx* 2009.

52. Siskind V, Steinhardt D, Sheehan M, O'Connor T, Hanks H. Risk factors for fatal crashes in rural Australia. *Accident Analysis & Prevention* 2011; **43**(3): 1082-8.
53. Vakulin A, Catcheside PG, Baulk SD, et al. Individual variability and predictors of driving simulator impairment in patients with obstructive sleep apnea. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2014; **10**(6): 647.
54. Ward KL, Hillman DR, James A, et al. Excessive daytime sleepiness increases the risk of motor vehicle crash in obstructive sleep apnea. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2013; **9**(10): 1013.
55. Daltro C, Gregorio PB, Alves E, et al. Prevalence and severity of sleep apnea in a group of morbidly obese patients. *Obesity surgery* 2007; **17**(6): 809-14.
56. Teran-Santos J, Jimenez-Gomez A, Cordero-Guevara J, Cooperative Group BS. The association between sleep apnea and the risk of traffic accidents. *New England Journal of Medicine* 1999; **340**(11): 847-51.
57. Kay GG, McLaughlin D. Relationship between obesity and driving. *Current obesity reports* 2014; **3**(3): 336-40.
58. Basoglu OK, Tasbakan MS. Elevated risk of sleepiness-related motor vehicle accidents in patients with obstructive sleep apnea syndrome: a case-control study. *Traffic injury prevention* 2014; **15**(5): 470-6.
59. Katz SL, Vaccani J-P, Barrowman N, Momoli F, Bradbury CL, Murto K. Does neck-to-waist ratio predict obstructive sleep apnea in children? *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2014; **10**(12): 1303.
60. Peromaa-Haavisto P, Tuomilehto H, Kössi J, et al. Prevalence of obstructive sleep apnoea among patients admitted for bariatric surgery. A prospective multicentre trial. *Obesity surgery* 2016; **26**(7): 1384-90.
61. Ho AW, Moul DE, Krishna J. Neck circumference-height ratio as a predictor of sleep related breathing disorder in children and adults. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2016; **12**(3): 311.
62. Gunstad J, Strain G, Devlin MJ, et al. Improved memory function 12 weeks after bariatric surgery. *Surgery for obesity and related diseases* 2011; **7**(4): 465-72.
63. Sarkhosh K, Switzer NJ, El-Hadi M, Birch DW, Shi X, Karmali S. The impact of bariatric surgery on obstructive sleep apnea: a systematic review. *Obesity surgery* 2013; **23**(3): 414-23.
64. Redenius R, Murphy C, O'Neill E, Al-Hamwi M, Zallek SN. Does CPAP lead to change in BMI? *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2008; **4**(3): 205.
65. Pack AI, Maislin G, Staley B, et al. Impaired performance in commercial drivers: role of sleep apnea and short sleep duration. *American journal of respiratory and critical care medicine* 2006; **174**(4): 446-54.
66. Czeisler CA, Wickwire EM, Barger LK, et al. Sleep-deprived motor vehicle operators are unfit to drive: a multidisciplinary expert consensus statement on drowsy driving. *Sleep Health: Journal of the National Sleep Foundation* 2016; **2**(2): 94-9.
67. Hossain JL, Shapiro CM. The prevalence, cost implications, and management of sleep disorders: an overview. *Sleep and Breathing* 2002; **6**(2): 85-102.

68. Bailes S, Baltzan M, Rizzo D, Fichten CS, Amsel R, Libman E. A diagnostic symptom profile for sleep disorder in primary care patients. *Journal of Psychosomatic Research* 2008; **64**(4): 427-33.
69. Pack AI, Pack AM, Rodgman E, Cucchiara A, Dinges DF, Schwab CW. Characteristics of crashes attributed to the driver having fallen asleep. *Accident Analysis & Prevention* 1995; **27**(6): 769-75.
70. Smiley A. Fatigue management: lessons from research. INTERNATIONAL CONFERENCE ON FATIGUE AND TRANSPORTATION, 3RD, 1998, FREMANTLE, WESTERN AUSTRALIA; 1998; 1998.
71. Thiffault P, Bergeron J. Fatigue and individual differences in monotonous simulated driving. *Personality and individual differences* 2003; **34**(1): 159-76.
72. Bioulac S, Tailard J, Quera-Salva M-A, Sagaspe P, Philip P. Attention deficit hyperactivity symptoms, sleepiness and near-misses driving accidents among a population of French highway drivers. *Journal of sleep research* 2014; **23**: 233.
73. Sagaspe P, Taillard J, Bayon V, et al. Sleepiness, near-misses and driving accidents among a representative population of French drivers. *Journal of sleep research* 2010; **19**(4): 578-84.
74. Sánchez AI, Martínez P, Miró E, Bardwell WA, Buela-Casal G. CPAP and behavioral therapies in patients with obstructive sleep apnea: effects on daytime sleepiness, mood, and cognitive function. *Sleep medicine reviews* 2009; **13**(3): 223-33.
75. Elgar NJ, Esterman AJ, Antic NA, Smith BJ. Self-reporting by unsafe drivers is, with education, more effective than mandatory reporting by doctors. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2016; **12**(3): 293.
76. Tregear S, Reston J, Schoelles K, Phillips B. Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2009; **5**(6): 573.
77. Burks SV, Anderson JE, Bombyk M, et al. Nonadherence with employer-mandated sleep apnea treatment and increased risk of serious truck crashes. *Sleep* 2016; **39**(5): 967-75.
78. Elliott MW. How to predict the risk of traffic accidents in sleepy patients. Sleep and Breathing. Berlin, Germany; 2013.
79. Karimi M, Hedner J, Zou D, Eskandari D, Lundquist A-C, Grote L. Attention deficits detected in cognitive tests differentiate between sleep apnea patients with or without a motor vehicle accident. *Sleep medicine* 2015; **16**(4): 528-33.
80. Turkington P, Sircar M, Allgar V, Elliott M. Relationship between obstructive sleep apnoea, driving simulator performance, and risk of road traffic accidents. *Thorax* 2001; **56**(10): 800-5.
81. Ghosh D, Jamson SL, Baxter PD, Elliott MW. Continuous measures of driving performance on an advanced office-based driving simulator can be used to predict simulator task failure in patients with obstructive sleep apnoea syndrome. *Thorax* 2012: thoraxjnl-2011-200699.

82. Richer I, Bergeron J. Driving under the influence of cannabis: Links with dangerous driving, psychological predictors, and accident involvement. *Accident Analysis & Prevention* 2009; **41**(2): 299-307.
83. Philip P, Micoulaud-Franchi J-A, Lagarde E, et al. Attention deficit hyperactivity disorder symptoms, sleepiness and accidental risk in 36140 regularly registered highway drivers. *PLoS one* 2015; **10**(9): e0138004.
84. Bioulac S, Chaufton C, Taillard J, et al. Excessive daytime sleepiness in adult patients with ADHD as measured by the Maintenance of Wakefulness Test, an electrophysiologic measure. *The Journal of clinical psychiatry* 2015; **76**(7): 943-8.
85. Orriols L, Avalos-Fernandez M, Moore N, et al. Long-term chronic diseases and crash responsibility: a record linkage study. *Accident Analysis & Prevention* 2014; **71**: 137-43.
86. Moták L, Bayssac L, Taillard J, et al. Naturalistic conversation improves daytime motorway driving performance under a benzodiazepine: A randomised, crossover, double-blind, placebo-controlled study. *Accident Analysis & Prevention* 2014; **67**: 61-6.
87. Philip P, Chaufton C, Taillard J, et al. Modafinil improves real driving performance in patients with hypersomnia: a randomized double-blind placebo-controlled crossover clinical trial. *Sleep* 2014; **37**(3): 483-7.
88. George CF. Sleep apnea, alertness, and motor vehicle crashes. *American journal of respiratory and critical care medicine* 2007; **176**(10): 954-6.
89. Publications Online A. Assessing Fitness to Drive for Commercial and Private Vehicle Drivers. In: Commission NT, editor. Australia; 2014.
90. véhicules Cpléàlcelad. Arrêté royal relatif au permis de conduire. In: Routière IBplS, editor. Normes minimales et attestations concernant l'aptitude physique et psychique à la conduite d'un véhicule à moteur. Brussels, Belgium; 1998.
91. l'intérieur Md. Journal officiel de la République Française. In: Française R, editor. Décrets, arrêtés, circulaires. Paris, France; 2015.
92. Dobbs BM. Medical Conditions and Driving: A Review of the Literature (1960 – 2000): U.S. Department of Transportation, National Highway Traffic Safety Administration, 2005.
93. Administration FMCS. Driving When You Have Sleep Apnea. 2016. https://www.fmcsa.dot.gov/driver-safety/sleep-apnea/driving-when-you-have-sleep-apnea (accessed May 4, 2016.
94. Hossain JL, Ahmad P, Reinish LW, Kayumov L, Hossain NK, Shapiro CM. Subjective fatigue and subjective sleepiness: two independent consequences of sleep disorders? *Journal of sleep research* 2005; **14**(3): 245-53.
95. Chotinaiwattarakul W, O'Brien LM, Fan L, Chervin RD. Fatigue, tiredness, and lack of energy improve with treatment for OSA. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2009; **5**(3): 222.
96. Lee I-S, Bardwell WA, Ancoli-Israel S, Dimsdale JE. Number of lapses during the psychomotor vigilance task as an objective measure of fatigue. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2010; **6**(2): 163.
97. Aksan N, Dawson J, Tippin J, Lee JD, Rizzo M. Effects of fatigue on real-world driving in diseased and control participants. Proceedings of the International Driving Symposium on

Human Factors in Driver Assessment, Training, and Vehicle Design; 2015: NIH Public Access; 2015. p. 268.
98. Bener A, Yildirim E, Özkan T, Lajunen T. Driver sleepiness, fatigue, careless behavior and risk of motor vehicle crash and injury: Population based case and control study. *Journal of Traffic and Transportation Engineering (English Edition)* 2017; **4**(5): 496-502.
99. Aguillard RN, Riedel BW, Lichstein KL, Grieve FG, Johnson CT, Noe SL. Daytime functioning in obstructive sleep apnea patients: exercise tolerance, subjective fatigue, and sleepiness. *Applied psychophysiology and biofeedback* 1998; **23**(4): 207-17.
100. Moradi A, Nazari SSH, Rahmani K. Sleepiness and the risk of road traffic accidents: A systematic review and meta-analysis of previous studies. *Transportation Research Part F: Traffic Psychology and Behaviour* 2018.
101. McCormick F, Kadzielski J, Landrigan CP, Evans B, Herndon JH, Rubash HE. Surgeon fatigue: a prospective analysis of the incidence, risk, and intervals of predicted fatigue-related impairment in residents. *Archives of Surgery* 2012; **147**(5): 430-5.
102. Van JC, Marcora S, De KP, Bailey S, Meeusen R, Roelands B. The Effects of Mental Fatigue on Physical Performance: A Systematic Review. *Sports medicine (Auckland, NZ)* 2017; **47**(8): 1569-88.
103. Lal SK, Craig A. A critical review of the psychophysiology of driver fatigue. *Biological psychology* 2001; **55**(3): 173-94.
104. Van Cutsem J, Marcora S, De Pauw K, Bailey S, Meeusen R, Roelands B. The effects of mental fatigue on physical performance: a systematic review. *Sports Medicine* 2017; **47**(8): 1569-88.
105. Bardwell WA, Ancoli-Israel S, Dimsdale JE. Comparison of the effects of depressive symptoms and apnea severity on fatigue in patients with obstructive sleep apnea: a replication study. *Journal of affective disorders* 2007; **97**(1-3): 181-6.
106. Philip P, Sagaspe P, Moore N, et al. Fatigue, sleep restriction and driving performance. *Accident Analysis & Prevention* 2005; **37**(3): 473-8.
107. Carskadon MA, Brown ED, Dement WC. Sleep fragmentation in the elderly: relationship to daytime sleep tendency. *Neurobiology of aging* 1982; **3**(4): 321-7.
108. Baiardi S, La Morgia C, Sciamanna L, Gerosa A, Cirignotta F, Mondini S. Is the Epworth Sleepiness Scale a useful tool for screening excessive daytime sleepiness in commercial drivers? *Accident Analysis & Prevention* 2018; **110**: 187-9.
109. Garbarino S, Scoditti E, Lanteri P, Conte L, Magnavita N, Toraldo DM. Obstructive sleep apnea with or without excessive daytime sleepiness: clinical and experimental data-driven phenotyping. *Frontiers in neurology* 2018; **9**: 505.
110. Gharagozlou F, Saraji GN, Mazloumi A, et al. Detecting driver mental fatigue based on EEG alpha power changes during simulated driving. *Iranian journal of public health* 2015; **44**(12): 1693.
111. Sawyer AM, Gooneratne NS, Marcus CL, Ofer D, Richards KC, Weaver TE. A systematic review of CPAP adherence across age groups: clinical and empiric insights for developing CPAP adherence interventions. *Sleep medicine reviews* 2011; **15**(6): 343-56.

112. Libman E. Sociocultural and cognitive factors in aging and sexual expression: Conceptual and research issues. *Canadian Psychology/Psychologie canadienne* 1989; **30**(3): 560.
113. Berry RB, Brooks R, Gamaldo CE, Harding SM, Marcus CL, Vaughn BV. The AASM manual for the scoring of sleep and associated events. *Rules, Terminology and Technical Specifications, Darien, Illinois, American Academy of Sleep Medicine* 2012.
114. Mashita M, Nonoue S, Kato T, et al. Spontaneous arousal related expiratory mouth leak during CPAP titration predict non-adherence in OSAS patients. *Sleep Medicine* 2017; **40**: e211.
115. Batool-Anwar S, Baldwin CM, Fass S, Quan SF. Role of spousal involvement in continuous positive airway pressure (CPAP) adherence in patients with obstructive sleep apnea (OSA). *Southwest journal of pulmonary & critical care* 2017; **14**(5): 213.
116. McEvoy RD, Antic NA, Heeley E, et al. CPAP for prevention of cardiovascular events in obstructive sleep apnea. *New England Journal of Medicine* 2016; **375**(10): 919-31.
117. Fichten CS, Creti L, Amsel R, Brender W, Weinstein N, Libman E. Poor sleepers who do not complain of insomnia: myths and realities about psychological and lifestyle characteristics of older good and poor sleepers. *Journal of Behavioral Medicine* 1995; **18**(2): 189-223.
118. Alapin I, Fichten CS, Libman E, Creti L, Bailes S, Wright J. How is good and poor sleep in older adults and college students related to daytime sleepiness, fatigue, and ability to concentrate? *Journal of psychosomatic research* 2000; **49**(5): 381-90.
119. Libman E, Fichten CS, Bailes S, Amsel R. Sleep questionnaire versus sleep diary: which measure is better? *International Journal of Rehabilitation and Health* 2000; **5**(3): 205-9.
120. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *sleep* 1991; **14**(6): 540-5.
121. Krupp LB, LaRocca NG, Muir-Nash J, Steinberg AD. The fatigue severity scale: application to patients with multiple sclerosis and systemic lupus erythematosus. *Archives of neurology* 1989; **46**(10): 1121-3.
122. Chalder T, Berelowitz G, Pawlikowska T, et al. Development of a fatigue scale. *Journal of psychosomatic research* 1993; **37**(2): 147-53.
123. Ware Jr JE. SF-36 health survey update. *Spine* 2000; **25**(24): 3130-9.
124. Beck AT, Steer RA, Brown GK. BDI-II: Beck Depression Inventory: manual, svensk version: Psykologiförlaget; 2006.
125. Beck A, Croudace T, Singh S, Harrison G. The Nottingham Acute Bed Study: alternatives to acute psychiatric care. *The British Journal of Psychiatry* 1997; **170**(3): 247-52.
126. Québec Sdlaa. Infractions et points d'inaptitude. 2018. https://saaq.gouv.qc.ca/permis-de-conduire/points-inaptitude/infractions-points-inaptitude/2018).
127. Lawton R, Parker D, Manstead ASR, Stradling SG. The role of affect in predicting social behaviors: The case of road traffic violations. *Journal of applied social psychology* 1997; **27**(14): 1258-76.
128. Sullman MJM, Meadows ML, Pajo KB. Aberrant driving behaviours amongst New Zealand truck drivers. *Transportation Research Part F: Traffic Psychology and Behaviour* 2002; **5**(3): 217-32.

129. Rizzo D, Lavigne G, Libman E, et al. Self-reported driving violations as a putative mirror measure of real-world driving quality in individuals with and without Obstructive Sleep Apnea. *Transportation Research Part F: Traffic Psychology and Behaviour* 2019; **62**: 78-85.
130. Tansey CM, Matté AL, Needham D, Herridge MS. Review of retention strategies in longitudinal studies and application to follow-up of ICU survivors. *Intensive care medicine* 2007; **33**(12): 2051-7.
131. Bailes S, Libman E, Baltzan M, Amsel R, Schondorf R, Fichten CS. Brief and distinct empirical sleepiness and fatigue scales. *Journal of Psychosomatic Research* 2006; **60**(6): 605-13.
132. Pagel J. Excessive daytime sleepiness. *Am Fam Physician* 2009; **79**(5): 391-6.
133. Pierce RJ. Driver sleepiness: occupational screening and the physician's role. *Australian and New Zealand journal of medicine* 1999; **29**(5): 658-61.
134. Chervin RD, Aldrich MS. The Epworth Sleepiness Scale may not reflect objective measures of sleepiness or sleep apnea. *Neurology* 1999; **52**(1): 125-.
135. Lindberg E. Epidemiology of OSA. 2010.
136. Chung KF. Insomnia subtypes and their relationships to daytime sleepiness in patients with obstructive sleep apnea. *Respiration* 2005; **72**(5): 460-5.
137. Roure N, Gomez S, Mediano O, et al. Daytime sleepiness and polysomnography in obstructive sleep apnea patients. *Sleep medicine* 2008; **9**(7): 727-31.
138. Zhou J, Camacho M, Tang X, Kushida CA. A review of neurocognitive function and obstructive sleep apnea with or without daytime sleepiness. *Sleep medicine* 2016; **23**: 99-108.
139. Rizzo D, Libman E, Creti L, et al. Determinants of policy decisions for non-commercial drivers with OSA: an integrative review. *Sleep medicine reviews* 2018; **37**: 130-7.
140. Kaye S-A, Lewis I, Freeman J. Comparison of self-report and objective measures of driving behavior and road safety: A systematic review. *Journal of safety research* 2018; **65**: 141-51.
141. Rizzo D L, G., Bergeron, J., Baltzan, M., Champagne, K., Creti, L., Bailes, S., Fichten, C., Libman, E. Descriptive Sleep Profile and Self-reported Driving Offenses Between Participants with OSA vs Controls: A Preliminary Analysis. Colloque annuel du Réseau de recherche en sécurité routière; 2014; Québec, Canada; 2014.
142. McNicholas WT. Diagnosis of obstructive sleep apnea in adults. *Proceedings of the American thoracic society* 2008; **5**(2): 154-60.
143. Simpson L, Hillman DR, Cooper MN, et al. High prevalence of undiagnosed obstructive sleep apnoea in the general population and methods for screening for representative controls. *Sleep and Breathing* 2013; **17**(3): 967-73.
144. Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. *The Lancet Respiratory Medicine* 2015; **3**(4): 310-8.
145. Peppard PE, Hagen EW. The Last 25 Years of Obstructive Sleep Apnea Epidemiology—and the Next 25? *American journal of respiratory and critical care medicine* 2017; (ja).
146. Tefft BC. Prevalence of motor vehicle crashes involving drowsy drivers, United States, 1999–2008. *Accident Analysis & Prevention* 2012; **45**: 180-6.

147. Bioulac S, Micoulaud Franchi J-A, Arnaud M, et al. Risk of motor vehicle accidents related to sleepiness at the wheel: a systematic review and meta-analysis. *Sleep* 2017.
148. Ellen R, Marshall SC, Palayew M, Molnar FJ, Wilson K, Man-Son-Hing M. Systematic review of motor vehicle crash risk in persons with sleep apnea. *J Clin Sleep Med* 2006; **2**(2): 193-200.
149. Karimi M, Hedner J, Lombardi C, et al. Driving habits and risk factors for traffic accidents among sleep apnea patients–a European multi-centre cohort study. *Journal of sleep research* 2014; **23**(6): 689-99.
150. Mulgrew A, Nasvadi G, Butt A, et al. Risk and severity of motor vehicle crashes in patients with obstructive sleep apnoea/hypopnoea. *Thorax* 2008; **63**(6): 536-41.
151. Di Milia L, Smolensky MH, Costa G, Howarth HD, Ohayon MM, Philip P. Demographic factors, fatigue, and driving accidents: An examination of the published literature. *Accident Analysis & Prevention* 2011; **43**(2): 516-32.
152. Philip P, Chaufton C, Orriols L, et al. Complaints of poor sleep and risk of traffic accidents: a population-based case-control study. *PloS one* 2014; **9**(12): e114102.
153. Stevenson MR, Elkington J, Sharwood L, et al. The role of sleepiness, sleep disorders, and the work environment on heavy-vehicle crashes in 2 Australian states. *American journal of epidemiology* 2013: kwt305.
154. Van Dongen H, Kerkhof G. Cognition and daytime functioning in sleep-related breathing disorders. *Hum Sleep Cognit Part II: Clin Appl Res* 2011; **2**: 53.
155. George C, Boudreau A, Smiley A. Effects of nasal CPAP on simulated driving performance in patients with obstructive sleep apnoea. *Thorax* 1997; **52**(7): 648-53.
156. George C, Boudreau A, Smiley A. Simulated driving performance in patients with obstructive sleep apnea. *American journal of respiratory and critical care medicine* 1996; **154**(1): 175-81.
157. Hack M, Choi S, Vijayapalan P, Davies R, Stradling J. Comparison of the effects of sleep deprivation, alcohol and obstructive sleep apnoea (OSA) on simulated steering performance. *Respiratory medicine* 2001; **95**(7): 594-601.
158. Otmani S, Pebayle T, Roge J, Muzet A. Effect of driving duration and partial sleep deprivation on subsequent alertness and performance of car drivers. *Physiology & behavior* 2005; **84**(5): 715-24.
159. Verster JC, Roth T. Standard operation procedures for conducting the on-the-road driving test, and measurement of the standard deviation of lateral position (SDLP). *International journal of general medicine* 2011; **4**: 359.
160. Vakulin A, Catcheside PG, Van Den Heuvel CJ, Antic NA, McEvoy RD, Baulk SD. Increased rate of traffic law infringements during on-road metropolitan driving in obstructive sleep apnea patients. *Sleep and Biological Rhythms* 2011; **9**(3): 144-9.
161. Aksan N, Schall M, Anderson S, Dawson J, Tippin J, Rizzo M. Can intermittent video sampling capture individual differences in naturalistic driving? Proceedings of the International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design; 2013: NIH Public Access; 2013. p. 135.

162. Tregear S, Reston J, Schoelles K, Phillips B. Continuous positive airway pressure reduces risk of motor vehicle crash among drivers with obstructive sleep apnea: systematic review and meta-analysis. *Sleep* 2010; **33**(10): 1373-80.
163. Barger LK, Rajaratnam SM, Wang W, et al. Common sleep disorders increase risk of motor vehicle crashes and adverse health outcomes in firefighters. *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine* 2015; **11**(3): 233.
164. Rizzo D, Libman E, Creti L, et al. Determinants of Policy Decisions for Non-Commercial Drivers with OSA: An Integrative Review. *Sleep Medicine Reviews* 2017.
165. Libman E, Rizzo D, Creti L, Bergeron J, Bailes S, Fichten C. Devrait-on cibler tous les individus souffrant d'apnée du sommeil comme étant des conducteurs à risque élevé : Un profil de risque comportemental et psychologique. Québec QC Canada, 2016.
166. Driver HS, Pereira EJ, Bjerring K, et al. Validation of the MediByte® type 3 portable monitor compared with polysomnography for screening of obstructive sleep apnea. *Canadian respiratory journal* 2011; **18**(3): 137-43.
167. Libman E. Sociocultural and Cognitive-Factors in Aging and Sexual Expression - Conceptual and Research Issues. *Can Psychol* 1989; **30**(3): 560-7.
168. Libman E, Fichten CS. Prostatectomy and Sexual Function. *Urology* 1987; **29**(5): 467-78.
169. Libman E, Creti L, Fichten CS. Determining What Patients Should Know About Transurethral Prostatectomy. *Patient Educ Couns* 1987; **9**(2): 145-53.
170. Québec Sdlaa. Infractions et points d'inaptitudes. 2018. https://saaq.gouv.qc.ca/permis-de-conduire/points-inaptitude/infractions-points-inaptitude/ (accessed June 1, 2014 2014).
171. Thiffault P, Bergeron J. Monotony of road environment and driver fatigue: a simulator study. *Accident Analysis & Prevention* 2003; **35**(3): 381-91.
172. Libman E, Bergeron, J., Creti, L. . Devrait-on cibler tous les individus souffrant de l'apnée du sommeil comme étant des conducteurs à risque élevé : Rapport scientifique intégral, 2016.
173. Deol R, Lee KA, Kandula NR, Kanaya AM. Risk of obstructive sleep apnoea is associated with glycaemia status in South Asian men and women in the United States. *Obesity Medicine* 2018; **9**: 1-6.
174. Bailes S, Fichten CS, Rizzo D, et al. The challenge of identifying family medicine patients with obstructive sleep apnea: addressing the question of gender inequality. *Family practice* 2017; **34**(4): 467-72.
175. Harrison L. The validity of self-reported drug use in survey research: an overview and critique of research methods. *NIDA Res Monogr* 1997; **167**: 17-36.
176. van Loon RJ, Brouwer RF, Martens MH. Drowsy drivers' under-performance in lateral control: How much is too much? Using an integrated measure of lateral control to quantify safe lateral driving. *Accident analysis & prevention* 2015; **84**: 134-43.
177. Kim H, Yun C-H, Thomas RJ, et al. Obstructive sleep apnea as a risk factor for cerebral white matter change in a middle-aged and older general population. *Sleep* 2013; **36**(5): 709-15.

178. Karimi M, Eder DN, Eskandari D, Zou D, Hedner JA, Grote L. Impaired vigilance and increased accident rate in public transport operators is associated with sleep disorders. *Accident Analysis & Prevention* 2013; **51**: 208-14.
179. Chai R, Naik GR, Nguyen TN, et al. Driver fatigue classification with independent component by entropy rate bound minimization analysis in an EEG-based system. *IEEE journal of biomedical and health informatics* 2017; **21**(3): 715-24.
180. Craig A, Tran Y, Wijesuriya N, Nguyen H. Regional brain wave activity changes associated with fatigue. *Psychophysiology* 2012; **49**(4): 574-82.
181. Arnedt JT, Wilde GJ, Munt PW, MacLean AW. How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis & Prevention* 2001; **33**(3): 337-44.
182. Åkerstedt T, Peters B, Anund A, Kecklund G. Impaired alertness and performance driving home from the night shift: a driving simulator study. *Journal of sleep research* 2005; **14**(1): 17-20.
183. Ingre M, Åkerstedt T, Peters B, Anund A, Kecklund G. Subjective sleepiness, simulated driving performance and blink duration: examining individual differences. *Journal of sleep research* 2006; **15**(1): 47-53.
184. Drake C, Roehrs T, Breslau N, et al. The 10-year risk of verifed motor vehicle crashes in relation to physiologic sleepiness. *Sleep* 2010; **33**(6): 745-52.
185. Pizza F, Contardi S, Mondini S, Trentin L, Cirignotta F. Daytime sleepiness and driving performance in patients with obstructive sleep apnea: comparison of the MSLT, the MWT, and a simulated driving task. *Sleep* 2009; **32**(3): 382-91.
186. Obermeyer WH, Benca RM. Effects of drugs on sleep. *Otolaryngologic Clinics of North America* 1999; **32**(2): 289-302.
187. Benca RM, Obermeyer WH, Thisted RA, Gillin JC. Sleep and psychiatric disorders: a meta-analysis. *Archives of general psychiatry* 1992; **49**(8): 651-68.
188. Plante DT, Birn RM, Walsh EC, Hoks RM, Cornejo MD, Abercrombie HC. Reduced resting-state thalamostriatal functional connectivity is associated with excessive daytime sleepiness in persons with and without depressive disorders. *Journal of affective disorders* 2018; **227**: 517-20.
189. Ruoff CM, Reaven NL, Funk SE, et al. High rates of psychiatric comorbidity in narcolepsy: findings from the Burden of Narcolepsy Disease (BOND) study of 9,312 patients in the United States. *J Clin Psychiatry* 2017; **78**(2): 171e6.

Discussion figure and tables

Tableau XI.Correlations between driving variables and driving simulator variables, OSA group.

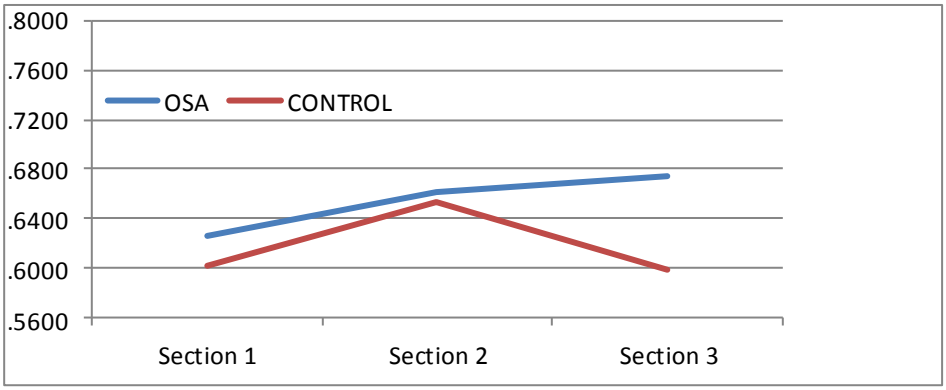
	TST	WASO	Sleep efficiency	Fatigue (ESFS)	Sleepiness (ESFS)	Psychological adjustment (SSC Subscale)	Mental Health (SF-36)
Driving Simulator Variables (n=13):							
Mean speed	-.468	.169	-.366	-.263	-.389	-.337	.266
Mean lateral position	.050	.192	.108	.140	-.291	-.349	.281
Mean orientation of steering wheel	-.188	.066	-.097	-.066	-.193	.100	-.214

Tableau XII.Correlations between driving variables and driving simulator variables, Control group.

	TST	WASO	Sleep efficiency	Fatigue (ESFS)	Sleepiness (ESFS)	Psychological adjustment (SSC Subscale)	Mental Health (SF-36)
Driving Simulator Variables (n=11):							
Mean speed	-.500	.053	-.385	-.518	.136	.364	-.673*
Mean lateral position	-.357	.248	-.337	.361	.075	.343	.376
Mean orientation of steering wheel	.169	-.343	.294	-.031	.058	.155	-.273

*Note. *p<.05.*

Figure 2. Mean lateral position scores for OSA and Control groups.



Other analyses

High/ low fatigue; high/ low sleepiness and driving behaviour.

We predicted that high scores on sleepiness and fatigue measures, regardless of group – OSA or Control – would be related to poorer driving. Since our previous research showed that not all individuals with OSA reported significant sleepiness or fatigue, we explored the role of high and low sleepiness and fatigue in participants with and without OSA in driving characteristics and behaviour. We calculated median splits, for fatigue and sleepiness scores, for the entire sample of 58 participants, and then re-allocated them into their respective OSA or Control group. On the sleepiness variable, the median split yielded the following 4 groups: High Sleepy OSA (n=20), Low Sleepy OSA (n=9), High Sleepy Control (n=11), Low Sleepy Control (n=18). For the fatigue variable, the median split yielded the following groups: High Fatigue OSA (n=21), Low Fatigue OSA (n=8), High Fatigue Control (n=8), Low Fatigue Control (n=21).

Table XIII presents mean scores and standard deviations on Sleepiness for the 4 High/Low OSA and Control groups. A series of 2-way ANOVA's (OSA, Control groups x high/low sleepiness) were carried out separately for the following 9 driving variables: number of actual driving violations, number of self-reported driving violations, DBQ subscales and DBQ total score (Table 6). There was a significant main effect for high vs. low sleepiness only for the documented violations variable; there was no significant effect for group (OSA/Control) or interaction. ANOVAs conducted on the other driving variables were not significant.

Tableau XIII.Differences in number of infractions and driving behaviors for high- and low-sleepiness, OSA and Control group

	OSA group (n=29)		Control group (n=29)		ANOVA results			*Bonferroni Comparisons*
	Mean	SD	Mean	SD	Effect	*df*	*F*	
Number of official infractions								
High sleepiness	0.85	1.23	1.00	1.30	Group	1, 57	4.95	**Low sleepiness > high sleepiness*
Low sleepiness	1.89	1.45	0.00	0.00	Sleepiness	1, 57	7.15*	
					Group * Sleepiness	1, 57	0.19	
Self-reported infractions								
High sleepiness	16.93	15.74	13.90	17.78	Group	1, 57	0.01	
Low sleepiness	10.33	8.73	11.11	9.84	Sleepiness	1, 57	1.26	
					Group * Sleepiness	1, 57	0.23	
Aggressive driving (DBQ subscale)								
High sleepiness	14.65	4.11	15.15	6.15	Group	1, 57	0.81	
Low sleepiness	14.33	3.16	17.89	7.98	Sleepiness	1, 57	0.17	
					Group * Sleepiness	1, 57	0.38	
Ordinary infractions (DBQ subscale)								
High sleepiness	27.85	8.88	24.75	9.63	Group	1, 57	0.20	
Low sleepiness	25.00	6.14	26.44	8.35	Sleepiness	1, 57	0.58	
					Group * Sleepiness	1, 57	0.18	
Driving errors (DBQ subscale)								
High sleepiness	25.90	6.21	24.85	8.63	Group	1, 57	0.41	
Low sleepiness	26.78	5.09	25.56	5.00	Sleepiness	1, 57	0.00	
					Group * Sleepiness	1, 57	0.18	
Lapses while driving (DBQ subscale)								
High sleepiness	20.10	5.77	19.15	6.04	Group	1, 57	1.08	
Low sleepiness	22.78	6.63	21.06	3.88	Sleepiness	1, 57	0.49	
					Group * Sleepiness	1, 57	0.95	
Total DBQ score								
High sleepiness	95.43	27.99	91.30	24.11	Group	1, 57	0.01	
Low sleepiness	78.78	14.77	79.11	12.84	Sleepiness	1, 57	2.03	
					Group * Sleepiness	1, 57	1.31	

*Notes. *p<.05. High sleepiness OSA group (n=20), Low sleepiness OSA group (n=9), High sleepiness Control group (n=20), and Low sleepiness Control group n=9).*

Table XIV presents mean scores and standard deviations on Fatigue for the 4 High/low, OSA/Control groups, as well as the results of 2-way ANOVAs conducted on the 7 driving variables. In this series of analyses, a significant main effect for Fatigue was found on the Total DBQ score; the high Fatigue category had worse scores than the low Fatigue category regardless of OSA diagnosis. There was no main effect for group (OSA vs. Control) and no significant interaction. No significant differences were found on any other driving variable.

Tableau XIV.Differences in number of infractions and in driving for high- and low-fatigue, OSA and Control group

	OSA group (n=29)		Control group (n=29)		ANOVA results			*Bonferroni Comparisons*
	Mean	SD	Mean	SD	Effect	*df*	*F*	
Official infractions								
High fatigue	1.14	1.32	0.50	0.76	Group	1, 57	2.23	
Low fatigue	1.25	1.58	0.76	1.30	Fatigue	1, 57	0.24	
					Group * Fatigue	1, 57	0.04	
Self-reported infractions								
High fatigue	16.98	3.43	10.63	2.51	Group	1, 57	0.04	
Low fatigue	9.38	2.34	13.95	3.91	Fatigue	1, 57	0.24	
					Group * Fatigue	1, 57	1.55	
Aggressive driving (DBQ subscale)								
High fatigue	14.67	1.08	14.75	6.88	Group	1, 57	0.50	
Low fatigue	14.25	2.43	16.48	6.80	Fatigue	1, 57	0.16	
					Group * Fatigue	1, 57	0.43	
Ordinary infractions (DBQ subscale)								
High fatigue	27.38	8.53	26.75	13.31	Group	1, 57	0.12	
Low fatigue	25.88	7.38	24.71	7.33	Fatigue	1, 57	0.47	
					Group * Fatigue	1, 57	0.01	
Driving errors (DBQ subscale)								
High fatigue	26.81	5.75	23.88	8.34	Group	1, 57	0.23	
Low fatigue	24.50	6.00	25.52	7.47	Fatigue	1, 57	0.03	
					Group * Fatigue	1, 57	0.97	
Lapses while driving (DBQ subscale)								
High fatigue	21.24	5.78	19.38	7.73	Group	1, 57	0.37	
Low fatigue	20.13	7.10	19.88	4.56	Fatigue	1, 57	0.03	
					Group * Fatigue	1, 57	0.22	
Total DBQ score								
High fatigue	96.60	27.05	95.00	21.97	Group	1, 57	0.50	
Low fatigue	73.63	9.74	84.67	21.55	Fatigue	1, 57	6.20*	**High fatigue > Low fatigue*
					Group * Fatigue	1, 57	0.89	

*Notes. *p<.05. High fatigue OSA group (n=21), Low fatigue OSA group (n=8), High fatigue Control group (n=8), and Low fatigue Control group (n=20).*

Violation track record: A chi-square test of independence was performed on the entire sample to examine the relation between High/Low fatigue and the presence of actual violations (SAAQ). The relation between these variables was not significant, X2 (2, N = 58) = .43, p=.596; i.e. high-fatigue individuals were not more likely to have at least 1 driving violation in their SAAQ records than the low-fatigue individuals. Another chi-square test of independence was performed to examine the relation between High/Low sleepiness and the presence of actual violations. The relation between these variables was also not significant,

X2 (2, N = 58) = .83, p=1.00; i.e. high-sleepiness participants were not more likely to have at least 1 driving violation in their SAAQ records than the low-sleepiness individuals.

Driving simulator: It is important to note that the sample sizes in this section are small; a study with a larger sample size would be required to confirm these preliminary results. The comparison of data on the 3 driving simulator tests using a multivariate analysis of variance (MANOVA) did not show differences between participants with OSA and controls according to high/low Fatigue or Sleepiness categories. However, a repeated measures analyses on driving simulator data by time interval (section 1, section 2, section 3) identified a general effect of the fatigue variable that was apparent only after 35-40 minutes of driving (see Figure 4). A significant increase in lane position variability was evident as the drive progressed for the majority of participants who had high scores on the Fatigue Scale. After 40 to 45 minutes, only the performance of participants with OSA who also had high scores on the fatigue scale, deteriorated significantly on the standard deviation of the lateral position (see figure 3). The latter measure is the traditional and most reliable indicator of decreased alertness in driving. In summary, Fatigue had an important effect on simulator driving; participants both with and without apnea deteriorated on driving aspects. This effect was more pronounced in individuals with OSA but only after having driven for an extended period while driving a monotonous route in the "afternoon dip" time period. No general effect was found for sleepiness (see Figure 5).

Figure 3. Mean lateral position scores for high/low fatigue in OSA, Control groups.

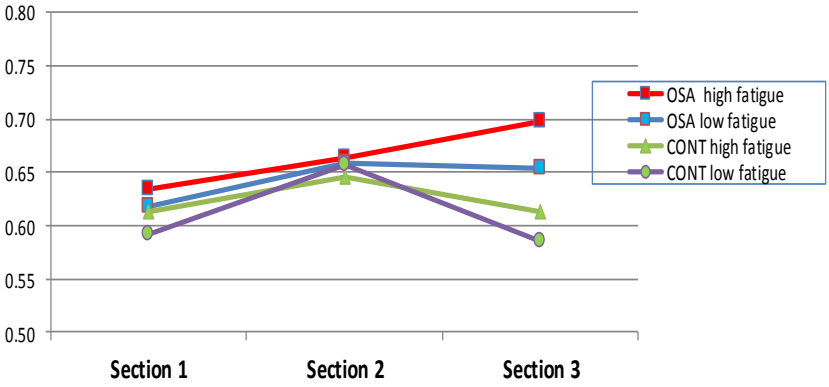


Figure 4. Mean lateral position scores for high/low fatigue (N=58).

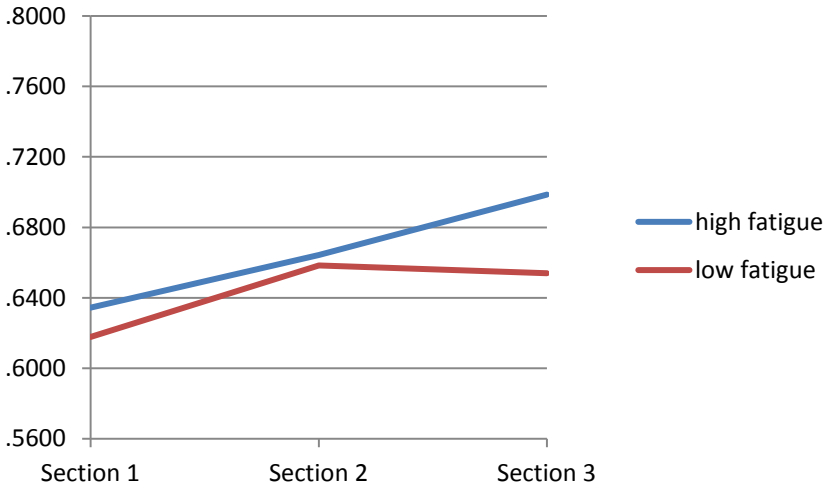
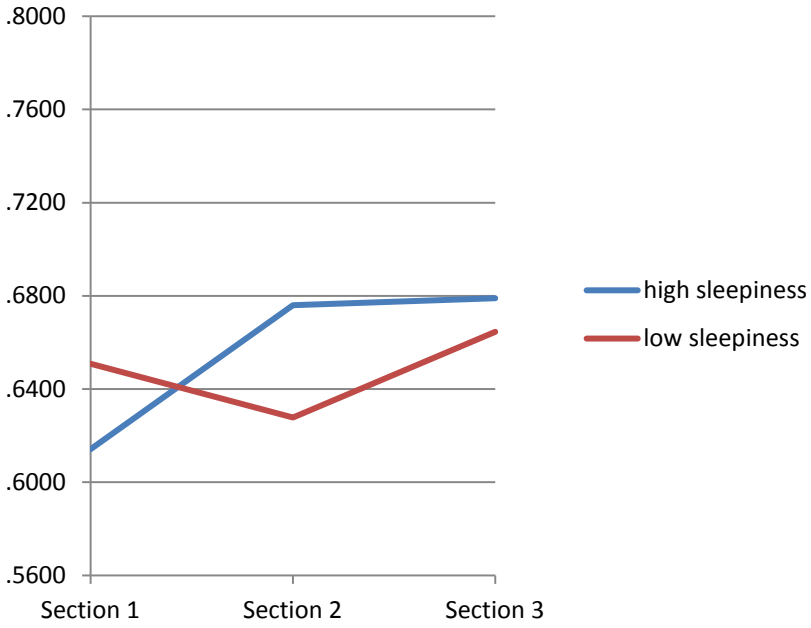


Figure 5. Mean lateral position scores for high/low sleepiness (N=58).



We also examined whether individuals with OSA who have low daytime fatigue and sleepiness scores would resemble their Control Group counterparts on driving performance. Data are available for 32 individuals (18 with OSA, 14 Controls). Participants with OSA who were in the low-Fatigue (n=8), and low-Sleepiness (n=6) categories were selected and compared with an age and gender-matched Control sample (n=14). When comparing participants with OSA in the low Sleepiness category with Controls, there were no significant differences on any variable (variations in lateral position, speed variations, variations in orientation) throughout the whole course of the simulation task. When looking at Fatigue, a single difference appeared in the final 20 minutes of the task; variations of lateral position were statistically different between participants with OSA low-fatigued individuals (M=.244, SD=.141), and Controls (M=.544, SD=.268) and, $t(10.855)=-2.627$, $p = .024$.