

# Obstructive Sleep Apnea in North American Commercial Drivers

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*Received November 3, 2013 and accepted December 3, 2013*

*Published online in J-STAGE December 9, 2013*

**Abstract:** The most common medical cause of excessive daytime sleepiness (EDS) is obstructive sleep apnea (OSA). Specifically, among an estimated 14 million US commercial drivers, 17–28% or 2.4 to 3.9 million are expected to have OSA. Based on existing epidemiologic evidence, most of these drivers are undiagnosed and not adequately treated. Untreated OSA increases the risk of vehicular crashes as documented in multiple independent studies and by meta-analysis. Therefore, identifying commercial drivers with OSA and having them effectively treated should decrease crash-related fatalities and injuries. Several strategies are available for screening and identifying drivers with OSA. The simplest and most effective objective strategies use body mass index (BMI) cutoffs for obesity. Functional screens are promising adjuncts to other objective tests. The most effective approach will likely be a combination of a good questionnaire; BMI measures; and a careful physician-obtained history complemented by a functional screen.

**Key words:** Obstructive sleep apnea, Commercial drivers, Crashes, Screening, Body mass index

## Introduction

Obstructive Sleep Apnea, or OSA, is a critical occupational health concern in the transportation industry. It affects a substantial percentage of today's transportation operators, particularly in the trucking sector. OSA is a syndrome characterized by sleep-disordered breathing due to recurrent upper airway obstruction, which in turn results in arousals from sleep and impaired sleep quantity and quality. Accordingly, OSA produces diurnal and nocturnal symptoms. These include excessive daytime sleepiness (EDS), sleep attacks, psychomotor deficits, and disrupted

nighttime sleep due to frequent arousals.

Probably the most important consequence of OSA in the context of occupational health is EDS. OSA is the most common medical cause of EDS, which is a significant public safety concern for any safety-sensitive occupation, especially commercial driving<sup>1</sup>. Indeed, somewhere between 10 and 30 percent of all vehicle crashes are estimated to have sleepy drivers as a root cause<sup>2-4</sup>. Not surprisingly, drivers with OSA have an increased crash risk estimated across various studies to be in the range of 2–11 fold<sup>5</sup>.

Moreover, OSA is common among commercial drivers. Howard et al. analyzed a population of Australian truck drivers, found 60% to have disordered breathing during sleep, and diagnosed 16% with OSA<sup>6</sup>. The number one risk factor for OSA is obesity, and 45 to 50 percent of truck drivers in the United States are obese<sup>7-9</sup>. As a result, about 15 to 30 percent of North American commercial

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Presented at the 86th Annual Meeting of Japan Society for Occupational Health, May 17, 2013, Matsuyama, Japan

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drivers are estimated to have OSA. It is widely underdiagnosed in at-risk populations and under-treated among those who have been diagnosed<sup>6, 10–12</sup>. All of these facts, taken together, demand an active public health response from occupational medicine physicians, transportation industry leaders, and government regulatory agencies to effectively screen drivers for OSA and to ensure treatment compliance among those diagnosed with OSA<sup>13, 14</sup>.

## Risk Factors

The major risk factors for OSA in transportation workers and in the general population include obesity, age, and male gender. Alterations in craniofacial structure are also associated with OSA, and may account in part for observed ethnic variations in OSA prevalence along with ethnic differences in sensitivity to the metabolic consequences of increasing adiposity.

### *Obesity*

Obesity is the most important risk factor for OSA, both in the general population and among commercial drivers<sup>13–16</sup>. A study of Japanese commercial vehicle operators found that a weight gain of 10 kg or more or an increase in body mass index (BMI) of 5 kg/m<sup>2</sup> or more were associated with increased sleepiness and sleep disordered breathing<sup>17</sup>. North American research has identified a strong relationship between the risk of OSA and a BMI greater than 26 kg/m<sup>2</sup><sup>18</sup>. In non-Asian populations, the relative risk of OSA is greater than 10-fold in persons with a BMI >29 kg/m<sup>2</sup><sup>19, 20</sup>. A study in Israel found that over 75% of commercial drivers with a BMI greater than 32 kg/m<sup>2</sup> had OSA, and most of these drivers demonstrated objective evidence of EDS, although none of them voluntarily reported any symptoms<sup>21</sup>. Given the strong relationship between obesity and OSA, and the reluctance of most professional drivers to report sleepiness, BMI criteria are important screening metrics in conjunction with other tools to identify drivers with OSA.

### *Age*

Age is a risk factor, but also a likely disease modifier for OSA. Bixler *et al.* conducted a large-scale study of men in the United States to assess the relationship between age and OSA<sup>22</sup>. After controlling for BMI, they found that OSA prevalence increases with age, while on the other hand OSA severity decreases with age. Spanish researchers, also found a direct relationship between increasing age and the prevalence of OSA<sup>23</sup>.

### *Male sex*

In addition to obesity and age, male gender has been linked with an increased likelihood of OSA<sup>24–26</sup>. In particular, pre-menopausal women appear to be hormonally protected from OSA<sup>27</sup>. The predominantly male industry of transportation operators, particularly sedentary truck drivers, together with the aging population and increasing US obesity epidemic have created a perfect storm of high OSA prevalence among commercial drivers in North America<sup>28</sup>.

### *Ethnicity and OSA risk*

The majority of studies on OSA have been conducted with participants in the United States, Europe and Australia who have been primarily Caucasian or of European descent. Thus, less data is available on other ethnic populations. Villaneuva *et al.* reviewed the existing literature, finding that Asian populations have a higher risk of OSA at lower levels of obesity than Caucasian populations. The review also suggests that African-American ethnicity may be an OSA risk factor<sup>29</sup>. In a study comparing Hispanic, White, and Japanese test subjects, OSA prevalence overall was positively correlated with increasing BMI in each group, although the distribution of BMI is different in each group<sup>30</sup>.

A unique concern for the Asian population is the occurrence of OSA, metabolic syndrome and other consequences of increasing adiposity at lower BMI ranges than among European populations<sup>31</sup>. Thus, the main difference in risk factors between the United States and Japan is that most drivers with OSA in Japan are not obese by international criteria (BMI  $\geq 30$  kg/m<sup>2</sup>)<sup>17, 30, 32</sup>. Some have suggested that this may be due to differences in facial structure, as well as differences in the distribution and the amount of body fat per body weight<sup>27, 31</sup>. Therefore, despite a lower prevalence of obesity in Japan as compared to the United States, up to 25% of the commercial driver population in both countries have been found to have sleep-disordered breathing<sup>32</sup>.

## Consequences of OSA for Transportation Workers

Transportation workers with OSA may suffer from Excessive Daytime Sleepiness (EDS) as well as impaired vigilance, which in turn puts them at an increased risk for motor vehicle crashes.

### *Excessive daytime sleepiness (EDS) and increased crash risk*

OSA is the most frequently diagnosed cause of Excessive Daytime Sleepiness, or EDS<sup>21, 33, 34</sup>. EDS can impair a person's judgment and abilities, resulting in serious consequences for drivers, given that prolonged wakefulness has been shown to produce impairment similar to that of alcohol consumption<sup>35</sup>. Indeed, sleepiness has been shown to contribute directly to highway crashes<sup>36</sup>. Given this information, EDS is an especially dangerous condition for commercial vehicle operators who drive professionally. Indeed, the proportion of commercial vehicle crashes due to the driver's sleepiness has been estimated at up to 30% of these accidents<sup>2-4</sup>.

### *OSA and increased crash risk*

Accordingly, OSA has also been repeatedly associated with an increased crash risk among non-professional drivers; however, there are limitations to the studies<sup>37-42</sup>. These studies may be biased due to underreporting in the occupational setting, where a crash may have negative job consequences for the driver. Conversely, over-reporting is possible from selection bias when cases are drawn from sleep clinics where patients may have been referred due to sleep-related motor vehicle crashes<sup>43</sup>. Several other studies, however, eliminated reporting biases through the use of government or insurance company-based records of crashes, rather than self-reports. These investigations also support an increased risk of crashes associated with OSA<sup>38, 42-47</sup>. Moreover, a recent review and meta-analysis by Tregear and colleagues examined seven different literature databases and identified 18 unique studies of crash risk, two involving commercial drivers and the remainder examining persons with non-commercial licenses<sup>45</sup>. Their meta-analysis based on the 10 studies that provided adequate information to calculate a crash relative risk and 95% CI found that drivers with OSA had more than a two-fold increase in the risk of motor vehicle crashes (crash Relative Risk = 2.43, 95% CI: 1.21-4.89) when compared to drivers without OSA.

Recently published data support this assertion as well. Because of the close relationship of OSA and obesity in drivers, Anderson et al prospectively looked at obesity among newly recruited commercial drivers and subsequent crash risk<sup>48</sup>. They used two different multivariate statistical models, which both demonstrated an over 50% increase in subsequent crash risk for drivers reporting a BMI of  $\geq 35$  kg/m<sup>2</sup> at the time of trucking firm hire.

Experimental data also support that untreated OSA is

detrimental to driving, and additionally that persons with OSA are more sensitive to sleep deprivation and alcohol consumption<sup>49</sup>. Australian researchers conducted simulated driving assessments and found that OSA patients had more steering deviation (less ability to maintain their lane of traffic) than the control subjects. OSA patients also demonstrated increased steering deviation even when the control subjects had a restricted time in bed or were given alcohol and the OSA patients were allowed to sleep as normal. When OSA patients were sleep restricted or given alcohol, they suffered additional marked increases in steering deviation on the driving simulator<sup>49</sup>.

Given the strong associations between OSA and both driving impairment and motor vehicle accidents; it is clear that OSA in professional drivers should be identified and treated aggressively, as well as subject to adequate regulation.

## **Management of OSA Risk in the Transportation Industry**

Programs to identify and treat commercial drivers with OSA through screening, diagnosis and compliance monitoring programs are promising risk management/mitigation strategies for the transportation industry. Ideally, these medical programs should also be accompanied by administrative controls related to hours of service, shift work and other factors to minimize driver fatigue.

### *Screening for OSA*

In this review, "screening" refers to the use of questionnaires, anthropometric measures, and other subjective and objective criteria applied to all drivers to determine which drivers should then undergo a "diagnostic" procedure for confirming or excluding the presence of OSA. "Diagnosis" and "diagnostic" procedures for OSA refer to sleep studies that measure or estimate the presence of sleep apnea (see below). In North America, OSA screening modalities include subjective/self-reported items regarding sleep disorders, daytime sleepiness and sleep-related symptoms; objective measures such as BMI and neck circumference cutoffs and blood pressure guidelines; guidelines that combine subjective and objective criteria; as well as functional performance screens designed to detect impairment related to fatigue or sleepiness. Table 1 summarizes a number of these screening methods in terms of several characteristics of performance and effectiveness in detecting OSA.

**Table 1. Comparison of various OSA screening strategies in a typical population of commercial drivers in North America**

Screening Criterion	Estimated Performance during an Occupational Examination*				Mean AHI of Cases Detected	Study, Year
	Prevalence of Positive Screens	OSA Case Yield <sup>1</sup>	Sensitivity <sup>2</sup>	Positive Predictive Value <sup>3</sup>		
US Federal CDL Exam Driver Sleep Question	0–3%	0–2%	0–7%	–	–	Talmage <i>et al.</i> , 2008 <sup>10)</sup> Parks <i>et al.</i> , 2009 <sup>12)</sup>
ESS>10	3.4%	1.4%	4%	–	37+/-28	Berger <i>et al.</i> , 2012 <sup>53)</sup>
SomniSage Questionnaire	30%	21%	75%	68%	40+/-28	Berger <i>et al.</i> , 2012 <sup>53)</sup>
BMI>/=30 kg/m <sup>2</sup>	50%	19%	68–70%	38%	41+/-29	Berger <i>et al.</i> , 2012 <sup>53)</sup> Gurubhagavatula <i>et al.</i> , 2004 <sup>8)</sup>
Joint Task Force	12–13%	10–12%	36–46%	79 – >/=95%	42–49	Talmage <i>et al.</i> , 2008 <sup>10)</sup> Parks <i>et al.</i> , 2009 <sup>12)</sup> Xie <i>et al.</i> , 2011 <sup>7)</sup>
BMI>/=40 kg/m <sup>2</sup>	6–7%	6–7%	23%	>95%	51+/-32	Berger <i>et al.</i> , 2012 <sup>53)</sup>

\*Based on available data and below assumptions. <sup>1</sup>Percent of Commercial Drivers who will screen positive and then be diagnosed with OSA (defined as AHI>10) via Polysomnography (PSG). <sup>2</sup>Assumes that 28% of North American Drivers have Sleep Disordered Breathing (AHI>5) based on the study by Gurubhagavatula *et al.* (2004)<sup>8)</sup>. <sup>3</sup>Calculated as: (Number of Drivers with a Positive Screen and Positive OSA on PSG ÷ Number of Drivers with a Positive Screen) × 100%.

### Subjective screening modalities

Unfortunately, most self-reports of information related to OSA by commercial drivers have a low yield. Diverse data show that commercial drivers generally do not report their symptoms and diagnoses accurately because of the economic and occupational implications of an OSA diagnosis<sup>10, 12–14, 21, 28)</sup>. These concerns range from the inconvenience of an having to go through a diagnostic work-up after positive screening; being pulled out of service during a medical evaluation; and potentially losing one's job and/or medical certification for professional driving. Given this reluctance to self-report symptoms of OSA, it is especially important that occupational physicians take the time to also employ objective measures (see below) as well as ask supplementary questions of higher risk drivers.

### United states commercial driver's medical examination form

In the United States, commercial vehicle drivers are required to complete a federal medical form that currently includes only one question regarding sleep disorders. It asks the yes or no question, "Do you have sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring?" Among the drivers who are at high risk for OSA, 85% self-reported the answer to this question as "No."<sup>12)</sup> Obviously, this status quo approach is inadequate and ineffective by itself.

### Epworth sleepiness scale (ESS)

The Epworth sleepiness scale, or ESS, is a questionnaire designed to identify persons with EDS either due to lifestyle circumstances (e.g. chronic sleep deprivation based on work or social schedules) or a sleep disorder (e.g. OSA, idiopathic hypersomnia and narcolepsy)<sup>50)</sup>. The ESS questionnaire asks an individual to rate his/her average likelihood of falling asleep (self-rated from 0 [no chance of dozing] to 3 [high chance of dozing]) during eight different common situations (e.g. watching television or sitting and talking to someone). A score greater than 10 indicates probable EDS. Most occupational guidelines encourage physicians to recommend further testing for OSA when the ESS exceeds 10<sup>13, 14)</sup>. An accurate ESS assessment can provide valuable screening information, and high ESS scores have been associated with an increased accident risk in a study of North Carolina drivers<sup>51)</sup>. Unfortunately, among commercial drivers, the ESS has been found to have a low yield and to produce results, which are often likely to be inaccurate. Most OSA-affected commercial drivers report very low ESS scores at driver certification exams (range 2–4)<sup>10, 12)</sup>, which are lower than ESS scores from the general community<sup>50)</sup>. For example, Parks *et al.* found a mean ESS score of 3.4 among commercial drivers who ultimately were diagnosed with OSA as part of a multi-modal OSA screening program during commercial driver medical certifications<sup>12)</sup>. Another OSA screening study during commercial driver medical examinations by Talmage *et al.* found an inverse relationship between

reported ESS scores and OSA diagnosis, which they attributed to “potential denial or deception” on the part of the drivers<sup>10</sup>). In contrast, an anonymous, population-based survey of transportation operators conducted by the National Science Foundation found a mean ESS score of 5.2 for all professional truck drivers assessed— a population that included drivers with and without OSA<sup>52</sup>). Moreover, in another anonymous survey of US truck drivers, over 20% reported falling asleep at traffic lights<sup>9</sup>), casting further doubt on the validity of ESS reported at certification exams.

#### Somni-Sage<sup>®</sup> questionnaire

Precision Pulmonary Diagnostics, LLC (PPD), has developed a self-report, online screening questionnaire for OSA<sup>53</sup>). PPD conducted an unpublished pilot study of 100 commercial drivers, which analyzed the drivers’ complete medical records and their polysomnogram (PSG) results. The survey instrument, known as Somni-Sage<sup>®</sup>, was then constructed based on the pilot study results and a medical literature review. The goal was to provide trucking companies with a simple, cost-effective tool for identifying drivers with an increased likelihood of having OSA. Drivers suggested as high-risk based on the questionnaire are then ideally referred for PSG for diagnostic confirmation. This OSA screening instrument is trademarked as Somni-Sage<sup>®</sup>, and it has been awarded a US Patent (US 7,720,696B1)<sup>53</sup>).

In addition to questions about subjective symptoms, Somni-Sage<sup>®</sup> also has incorporated items designed to obtain reliable surrogate measures of objective data (self-reports of height and weight and medical conditions)<sup>53</sup>). Thus, Somni-Sage<sup>®</sup> incorporates weighted values for BMI, neck circumference, hypertension and other medical co-morbidities, as well as heavy snoring, witnessed apneas, other symptoms and, as well as EDS. EDS is elicited in two ways. The first is the ESS questionnaire described above, which is embedded within Somni-Sage<sup>®</sup>. The second is the simple question: “Do you become drowsy while driving?” Additionally, some of the symptoms elicited by Somni-Sage<sup>®</sup> assess OSA risk in ways that are unfamiliar to drivers as being related to OSA (e.g. nocturia).

Berger et al retrospectively assessed the Somni-Sage<sup>®</sup> Questionnaire effectiveness using data from three large US trucking firms who used the instrument in employer-mandated OSA screening programs of their commercial drivers<sup>53</sup>). The investigators were able to assess both the diagnostic yield of sending drivers determined as high-risk for a PSG and the positive predictive value of a high-risk

designation on Somni-Sage<sup>®</sup>. In this population of over 19,000 drivers who completed the questionnaire, almost 6,000 drivers (30%) were found to be at higher risk for OSA<sup>53</sup>). The employer-based programs utilized overnight, in-lab, PSG for diagnostic confirmation. Despite the limitation that all higher-risk drivers were not sent for testing by their employers, among over 2,000 higher-risk drivers who underwent PSG, 68% were diagnosed with definite OSA (an apnea–hypopnea index (AHI) greater than 10) and 80% had at least probable OSA (an AHI of 5 or more). A conservative prevalence estimate for definite OSA (AHI >10) was 21% among the commercial driver population studied<sup>53</sup>).

Another interesting finding regarding Somni-Sage<sup>®</sup> is that the patented statistical algorithm used to identify higher risk drivers appears to be robust and effective despite drivers’ efforts to change their behavior to avoid a sleep apnea diagnosis. In 2006, the first year that the Schneider National trucking firm began using this questionnaire, almost 30% of drivers admitted that they had EDS. However, the Berger et al study documented that the proportion of drivers willing to admit EDS went down every year afterwards reaching a nadir of 6% in 2010<sup>53</sup>). The commercial driver population’s characteristics were the same during this study period, therefore, the likely reason behind this drop was that drivers talked to each other, learned that the company was trying to identify sleepy drivers, and changed their answers to avoid being diagnosed with a sleep disorder. Nevertheless, the Somni-Sage questionnaire and program maintained a positive predictive value of roughly 70% throughout the period 2006–2010. Given that the estimated prevalence (case yield) of OSA remained at about 20%, the questionnaire’s performance did not seem to suffer even after drivers changed their behavior.

#### Diagnostic interviews by the commercial driver medical examiner

Although evidence-based data are lacking to directly support a more probing interview of higher risk commercial drivers by the commercial driver medical examiner, common sense and the clinical experience of the senior author (SNK) and his colleagues is that such an approach can have a fairly high supplemental yield to other measures. Drivers who deny symptoms and diagnoses on questionnaires and self-report forms will often divulge much more information when skilled physicians take the time to ask repetitive and additional questions in creative ways. For example, many obese male drivers check off a

no answer to “snoring,” yet when they are asked in joking way whether their bed partners complain about their snoring, their answers may change<sup>54</sup>). Recently, a professional male driver at high risk for OSA (obesity, hypertension, increased neck circumference and atrial fibrillation) was seen and reported an ESS of only 4, but on direct questioning, he admitted dozing off at stops while waiting for his passengers. Likewise, when they are asked about past diagnostic procedures or told that they are at high risk for OSA, drivers may volunteer that they have undergone a PSG in the past or even that they have a continuous positive airway pressure (CPAP) machine at home<sup>12</sup>).

#### *Objective screening modalities*

Objective screening tools have the advantage that they are directly measured and are not subject or at least less subject to manipulation, deception and under-reporting by drivers. These metrics may relate directly to OSA risk: BMI, neck circumference and blood pressure guidelines. Also included in this section are consensus occupational health guidelines that combine both subjective and objective criteria, but rely more heavily on the latter objective measures.

#### Body mass index (BMI)

As discussed earlier in the review, the presence of obesity in any given driver or patient markedly increases that individual's likelihood of having OSA, even without considering any other factors. This is especially true of middle-aged men who comprise the majority of American commercial drivers. This makes BMI a very important and valuable first line tool for OSA risk assessment. A number of occupational health studies of commercial driver populations directly support BMI as an effective OSA screening tool.

In Israel, Dagan *et al.* recommend the use of Body Mass Index, or BMI, to identify and diagnose EDS in commercial motor vehicle operators<sup>21</sup>). Drivers with a BMI of 32 or greater were referred to the Institute for Fatigue and Sleep Medicine for PSG and multiple sleep latency tests (MSLT) to rule out sleep apnea and EDS, respectively. This testing was done at the behest of the Traffic Safety Department of the Israeli Ministry of Health as part of the drivers' license renewal process. A respiratory disturbance index (RDI) of  $\geq 5$  was used to classify drivers as having sleep-disordered breathing (SDB). In sleep laboratory testing, 78% of the drivers in Dagan's series had SDB according to the study criteria. Supporting the lack of effectiveness of subjective reports in occupational driver testing, 100%

of the drivers in this study denied symptoms of OSA and EDS. Yet, on MSLT almost half of these drivers had abnormal results consistent with objectively measured EDS<sup>21</sup>).

At the University of Pennsylvania, Gurubhagavatula *et al.* conducted a study of Pennsylvania commercial driver's license holders who were recruited using population-based methods<sup>55</sup>). Drivers voluntarily consented to the research study, which was done outside of any occupational medical certification. This study used a two-step risk stratification procedure, beginning with a basic questionnaire for all commercial drivers, followed by oximetry conducted with a subset of drivers<sup>55</sup>). Groups of both high and lower risk drivers were tested using PSG, which allowed the investigators to estimate the overall population prevalence of varying levels of SDB/OSA, as well as screening criteria performance characteristics. The best BMI cutoff for identifying any level of OSA (AHI $\geq 5$ ) was 30 kg/m<sup>2</sup>, which had an estimated sensitivity of 70%. For severe OSA (AHI $>30$ ), a BMI of 33 kg/m<sup>2</sup>, performed best with a 77% sensitivity and 70% specificity<sup>8</sup>). Based on these findings, the United States Medical Expert Panel recommended a BMI screening cutoff of 33 kg/m<sup>2</sup> in 2008<sup>56</sup>).

#### Joint task force guidelines

In 2006, the Joint Task Force (JTF) of three important groups representing a variety of expertise: the American College of Chest Physicians, the American College of Occupational and Environmental Medicine, and the National Sleep Foundation published consensus guidelines in the *Journal of Occupational and Environmental Medicine* and *Chest* for identifying and diagnosing OSA in commercial vehicle operators (Table 2)<sup>13, 14</sup>). Subsequent to the publication of the JTF recommendations, two independent studies published in 2008 and 2009 provided support for the validity and high positive predictive value of the JTF guidelines. Talmage *et al.* reported a series of 1,443 consecutive drivers screened using the JTF criteria, resulting in 190 (13%) drivers being recommended for PSG<sup>10</sup>). Of the drivers who underwent PSG, 95% were diagnosed with OSA, supporting an estimated positive predictive value of 95%. In another independent study of 456 commercial drivers screened with the same criteria, Parks *et al.* referred 53 drivers (12%) for PSG. All 20 drivers who underwent subsequent PSG or provided information about prior PSG were found to have OSA<sup>12</sup>). In the absence of US Federal regulations specifying other required methods to screen for OSA, the JTF guidelines have become a *de facto* community standard in the US occupational medicine community.

**Table 2. Summary of the joint task force consensus recommendations for screening commercial drivers for OSA**

Criteria for (+) OSA Screen	
Drivers meeting one or more of the six criteria are considered to have OSA or probable OSA	
Subjective Criteria (1–4)	
-Historical Findings (1–3)	1. Any of the following symptoms: snoring, excessive daytime sleepiness, witnessed apneas 2. History of MVC likely related to sleep disturbance (run off road, at-fault, rear-end collision) 3. Previous OSA diagnosis; prior PSG with AHI>5; reported CPAP prescription and/or use
-Epworth Sleepiness Scale	4. ESS score>10
Objective Criteria (5, 6)	5. Sleeping in examination or waiting room 6. Two or more of the following* a. BMI $\geq$ 35 kg/m <sup>2</sup> b. NC>17 inches in men, 16 inches in women c. Hypertension (new, uncontrolled, or requiring $\geq$ 2 medications for control)

\* Most Drivers are identified through Criterion 6. Adapted from *J Occup Environ Med.* 2006; 48 (9 Suppl): S4–S37<sup>13</sup>) and *Chest* 2006; 130: 902–905<sup>14</sup>). Abbreviations: OSA, obstructive sleep apnea; MVC, motor vehicle collision; PSG, polysomnography; AHI, apnea-hypopnea index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness scale; BMI, body mass index; kg/m<sup>2</sup>, kilograms per meter squared; NC, neck circumference.

### Functional performance screens

Functional performance screens are modalities that can identify otherwise unrecognized, impaired vigilance possibly related to fatigue or sleepiness. These tests can potentially identify the sleepiest drivers who should receive prioritized, more urgent sleep laboratory testing in an expeditious manner; as well as drivers who are functionally impaired, but fall outside the sensitivity ranges of the screening criteria described above<sup>57</sup>.

### Psychomotor vigilance test

The Psychomotor Vigilance Test (PVT) has been used in multiple studies to detect decrements in performance due to sleep deprivation<sup>58, 59</sup>. The PVT measures a person's reaction time to a visual cue that occurs rapidly and at random intervals of two to ten seconds<sup>60</sup>. When administered to a group of emergency responders that may be called on to drive professionally and commercial truck/bus drivers at medical certification examinations, the PVT was found to be a practical and promising in-clinic or point of care objective method for identifying safety-sensitive workers with impaired vigilance<sup>57</sup>. The abnormal vigilance patterns (response times of more than five seconds or two or more "super lapses" of equal to or greater than one second) detected by the PVT were found almost exclusively in a subset of obese males whose anthropometrics put them at high risk for OSA. Notably, some of these subjects would have escaped detection by the JTF screening criteria as described above.

### Driving simulators

Driving simulators are another type of functional testing that may become another potential adjunct to OSA screening. As their name implies, driving simulators simulate the environment and performance of driving in a laboratory or clinic environment devoid of actual safety risks. Simulators vary in their sophistication from simple video-game type tasks to so-called high-fidelity driving simulators that attempt to mimic driving an actual vehicle<sup>13, 14</sup>. The primary measure on most of these tests is steering deviation or tracking—how closely a driver follows their designated lane of travel as opposed to deviating right and left in the lane<sup>49, 61, 62</sup>. Secondary measures often include a reaction time component, often associated with simulated braking times, as well as crashes. Crashes tend to indicate even more serious sleepiness<sup>49</sup>.

For the most part, various driving simulators consistently demonstrate decrements in performance among subjects with OSA and other sleep disorders, as well as subjects who have been sleep deprived. However, there is not yet robust evidence associating simulator performance with on-road driving performance<sup>13, 14</sup>. Moreover, the National Highway Traffic Safety Administration (NHTSA) determined as part of a literature review that "the results reveal that measures commonly used to measure disease severity in sleep apnea are not very useful in discriminating between individuals who are likely to perform poorly on laboratory based measures putatively related to driving performance or who are at risk for crashes"<sup>63</sup>.

A simulator that has attracted attention recently, the Aus-Ed Driving Simulator, was developed by collaborat-

ing teams of researchers based in Australia and Edinburgh, Scotland deriving its name from those two locations. A major study using the Aus-Ed on a group of drivers with OSA and a control group that did not have OSA is summarized above in the section: OSA and Increased Crash Risk<sup>49</sup>).

Further research is necessary to determine whether simulators can distinguish drivers at high-risk for OSA and occupational sleepiness from their colleagues and whether they can predict on-road crash risk.

#### *Diagnosis of OSA*

“Diagnosis” and “diagnostic” procedures for OSA refer to sleep studies that confirm or exclude the presence of sleep disordered breathing by measuring or estimating the RDI or AHI. In most cases, diagnostic procedures are reserved for subjects who report OSA symptoms, demonstrate impairment consistent with possible OSA or who have screened as higher risk for OSA as described above.

#### Polysomnography (PSG)

Polysomnography, or PSG, remains the gold standard for diagnosing and assessing OSA, and when conducted in the laboratory, it produces the most reliable results<sup>64</sup>. “Type I” PSGs are overnight, technician-attended, in-laboratory sleep studies with physiologic monitoring via 14–16 channels and serve as the reference standard among PSGs. A “type II” PSG records the same information as a type I PSG, but lacks technician attendance and may be done in the laboratory or outside of a lab setting<sup>28</sup>).

Although it is the current gold standard, errors can still occur and these include data loss, artifacts, and intra- and inter-rater variability in scoring events. Additionally, different sleep laboratories use different types of monitoring equipment, which may change the sensitivity of event recognition. Nonetheless, most sleep laboratories use very similar montages for baseline PSG. These include electroencephalogram (EEG) leads; electrooculographic (EOG) leads; electromyography (EMG) leads; a modified electrocardiogram lead; an airflow signal (a nasal thermistor and/or a nasal cannula pressure transducer); a measure of respiratory effort of the chest and abdomen (either respiratory inductance plethysmography or impedance pneumography); and a pulse oximeter to monitor oxygen saturation. All other diagnostic tools are, therefore, compared to PSG for quality standards<sup>28</sup>).

#### Portable monitors (PMs)

Although PSG is the gold standard for OSA diagnosis,

given the large number of professional drivers at high-risk for OSA, sleep clinic availability is limited, costs are high, and the process itself is time-consuming. Therefore, portable monitors (PM’s), also known as limited channel testing (e.g. pulse oximetry alone or in conjunction with one to several other channels), have been proposed as an alternative method of OSA diagnosis in North America. While a full discussion of in-lab PSG versus PM testing is beyond the scope of the present article, this subject has recently been reviewed in depth in the context of testing commercial drivers for OSA<sup>28</sup>). Generally, the best use of PM’s in North America is for confirming the presence of OSA in a patient seeking diagnosis who has already been deemed at high-risk based on symptoms and or screening. When OSA is confirmed in such a case with high pre-test probability, treatment can be recommended and implemented without further testing. On the other hand, a negative or indeterminate result from a PM is not considered sufficient to exclude OSA in such a high-risk person<sup>28</sup>).

The major concern in North America regarding the use of PM’s is the unique behavior of commercial drivers. Unlike the typical patient at a sleep clinic who is actively seeking diagnosis and treatment for a presumed sleep disorder, as discussed above in the section on screening, American commercial motor vehicle drivers actively avoid an OSA diagnosis because of its economic and occupational implications. Therefore, among commercial drivers motivated to gain/maintain employment, human factors that may alter test accuracy are a major potential obstacle to using PM’s in this population. We are aware of several scenarios whereby drivers could sabotage PM’s. They may attempt to stay awake all night to avoid sleep-disordered breathing events when the PM does not measure or estimate sleep stages. In a second scenario for data fudging, drivers may place the device on a healthier family member to avoid an accurate diagnosis. For this reason, the most experts advocate using PM devices with “chain of custody” (a bracelet or other identifier placed on the driver by a professional technician), which deactivates the PM if the subject removes it<sup>28</sup>).

Other potential issues with PM programs being marketed to US trucking firms include testing and results interpretation protocols that may have no sleep specialist oversight, and sometimes minimal physician involvement. In addition, most PM’s cannot determine the total sleep time and therefore, cannot calculate a true AHI<sup>28</sup>). Additional studies comparing unattended and unmonitored PMs directly against full in-laboratory PSG are needed to provide evidence for their efficacy among American com-

mercial motor vehicle operators.

#### *Management and risk reduction of OSA among commercial drivers*

Once diagnosed, Continuous Positive Airway Pressure (CPAP) is the first-line and best treatment for OSA among commercial drivers. Although other treatments are available, CPAP is the only non-operative therapy for which compliance can be objectively monitored<sup>13, 14</sup>). Additional risk reduction methods include fitness and wellness programs, education and administrative controls, pre-employment and regular OSA driver screening, and driver monitoring systems. Some of these measures have been recently reviewed<sup>1</sup>).

#### Continuous positive airway pressure (CPAP)

Although published data are largely limited to non-commercial drivers, evidence supports that CPAP treatment of OSA reduces motor vehicle accident risk. Several investigations have reported reductions in crash risk<sup>47, 65</sup>). Those OSA patients who were compliant with CPAP had fewer crashes, while OSA patients who did not use CPAP saw no change in crash rate<sup>47</sup>). George and colleagues also found that CPAP treatment improved driver performance in those with previously untreated OSA and reduced the crash risk to levels comparable to that of the control group<sup>66</sup>).

Although much of the literature indicates a positive result of CPAP therapy for individuals diagnosed with OSA, some literature suggests that residual consequences of OSA may persist even with CPAP treatment. Using driving simulator data, Vakulin et al. found that even after individuals with severe OSA followed their CPAP prescription closely for three months, their driving performance was still worse than the healthy control group<sup>67</sup>). The authors suggested that neurobehavioral deficits may cause some long-term driving impairment in individuals with severe OSA despite a high adherence to CPAP treatment.

#### Shift work

Factors that heighten the risk of a driver becoming involved in an accident are not limited to sleep disorders. Fatigue is also related to the number of hours a driver has slept or rested, the time of day, whether they have taken drugs or medication, whether they have been drinking alcohol, and how long they have been driving without a break. Shift work is associated with disruption of circadian rhythms, a lower likelihood of getting adequate sleep and other factors that may increase fatigue at work<sup>68</sup>). In addition, research has documented that the highest number and

relative risks of motor vehicle accidents occur between the hours of midnight and six am<sup>36</sup>). Moreover, shift work is likely to produce synergistic impairment with OSA. Therefore, we do not recommend rotating shifts or night shift driving for professional drivers with OSA even when they are compliant with CPAP treatment.

#### Fitness and wellness programs

Because obesity is a primary risk factor for OSA, an investment in employee fitness and wellness programs could have a potential return for the transportation industry. Such programs exist within the realm of productivity and health management, where employee health and employer costs are viewed from a holistic perspective with the ultimate goal of reducing costs and improving health.

#### *Cost benefit*

Limited data from the economic perspective support that industry-based programs to screen and diagnose OSA among drivers could save money. A cost-benefit analysis of OSA screening based on estimated vehicle crash costs concluded that commercial driver OSA screening should be cost-effective within the transportation industry<sup>69</sup>). Another study of professional drivers supports cost-benefits based on medical costs<sup>70</sup>). OSA is associated with higher risks of hypertension, incident diabetes mellitus, and incident cardiovascular events; therefore, we would expect that CPAP treatment ultimately decreases co-morbid medical costs.

## Conclusion

Untreated OSA is associated with an increased risk of motor vehicle accidents. OSA is common among North American commercial drivers, underdiagnosed, and undertreated. A number of effective screening strategies are available. Moreover, data support that treatment of OSA reduces the risk of motor vehicle accidents. Therefore, identifying commercial drivers with OSA and having them effectively treated should decrease crash-related fatalities and injuries.

## References

- 1) Kales SN (2013) Preventing Accidents in North American Commercial Drivers with Obstructive Sleep Apnea. International Association of Traffic and Safety Sciences [http://www.iatss.or.jp/common/pdf/en/publication/booklet/06-Summary\\_of\\_Remarks.pdf](http://www.iatss.or.jp/common/pdf/en/publication/booklet/06-Summary_of_Remarks.pdf).

- 2) Philip P (2005) Sleepiness of occupational drivers. *Ind Health* **43**, 30–3.
- 3) Radun I, Summala H (2004) Sleep-related fatal vehicle accidents: characteristics of decisions made by multidisciplinary investigation teams. *Sleep* **27**, 224–7.
- 4) Akerstedt T (2000) Consensus statement: fatigue and accidents in transport operations. *J Sleep Res* **9**, 395.
- 5) George CF (2004) Sleep. 5: driving and automobile crashes in patients with obstructive sleep apnoea/hypopnoea syndrome. *Thorax* **59**, 804–7.
- 6) Howard ME, Desai AV, Grunstein RR, Hukins C, Armstrong JG, Joffe D, Swann P, Campbell DA, Pierce RJ (2004) Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *Am J Respir Crit Care Med* **170**, 1014–21.
- 7) Xie W, Chakrabarty S, Levine R, Johnson R, Talmage JB (2011) Factors associated with obstructive sleep apnea among commercial motor vehicle drivers. *J Occup Environ Med* **53**, 169–73.
- 8) Gurubhagavatula I, Maislin G, Nkwuo JE, Pack AI (2004) Occupational screening for obstructive sleep apnea in commercial drivers. *Am J Respir Crit Care Med* **170**, 371–6.
- 9) Smith B, Phillips BA (2011) Truckers drive their own assessment for obstructive sleep apnea: a collaborative approach to online self-assessment for obstructive sleep apnea. *J Clin Sleep Med* **7**, 241–5.
- 10) Talmage JB, Hudson TB, Hegmann KT, Thiese MS (2008) Consensus criteria for screening commercial drivers for obstructive sleep apnea: evidence of efficacy. *J Occup Environ Med* **50**, 324–9.
- 11) Pack A, Dinges D, Maislin G (2002) A Study of Prevalence of Sleep Apnea among Commercial Truck Drivers. Publication no. DOT-RT-02–030. Federal Motor Carrier Safety Administration, Washington, DC.
- 12) Parks P, Durand G, Tsismenakis AJ, Vela-Bueno A, Kales S (2009) Screening for obstructive sleep apnea during commercial driver medical examinations. *J Occup Environ Med* **51**, 275–82.
- 13) Hartenbaum N, Collop N, Rosen IM, Phillips B, George CF, Rowley JA, Freedman N, Weaver TE, Gurubhagavatula I, Strohl K, Leaman HM, Moffitt GL, Rosekind MR (2006) Sleep apnea and commercial motor vehicle operators: statement from the joint Task Force of the American College of Chest Physicians, American College of Occupational and Environmental Medicine, and the National Sleep Foundation. *J Occup Environ Med* **48** (9 Suppl), S4–37.
- 14) Hartenbaum N, Collop N, Rosen IM, Phillips B, George CF, Rowley JA, Freedman N, Weaver TE, Gurubhagavatula I, Strohl K, Leaman HM, Moffitt GL; American College of Chest Physicians; American College of Occupational and Environmental Medicine; National Sleep Foundation (2006) Sleep apnea and commercial motor vehicle operators: statement from the joint task force of the American College of Chest Physicians, the American College of Occupational and Environmental Medicine, and the National Sleep Foundation. *Chest* **130**, 902–5.
- 15) Strohl KP, Redline S (1996) Recognition of obstructive sleep apnea. *Am J Respir Crit Care Med* **154**, 279–89.
- 16) Phillips B, Cook Y, Schmitt F, Berry D (1989) Sleep apnea: prevalence of risk factors in a general population. *South Med J* **82**, 1090–2.
- 17) Cui R, Tanigawa T, Nakano H, Sakurai S, Yamagishi K, Ohira T, Iso H (2009) Associations between weight change since 20 years of age and sleep-disordered breathing among male truck drivers. *Int J Obes Lond* **33**, 1396–401.
- 18) Young T, Peppard PE, Gottlieb DJ (2002) Epidemiology of obstructive sleep apnea: a population health perspective. *Am J Respir Crit Care Med* **165**, 1217–39.
- 19) Schäfer H, Pauleit D, Sudhop T, Gouni-Berthold I, Ewig S, Berthold HK (2002) Body fat distribution, serum leptin, and cardiovascular risk factors in men with obstructive sleep apnea. *Chest* **122**, 829–39.
- 20) Gami AS, Caples SM, Somers VK (2003) Obesity and obstructive sleep apnea. *Endocrinol Metab Clin North Am* **32**, 869–94.
- 21) Dagan Y, Doljansky JT, Green A, Weiner A (2006) Body Mass Index (BMI) as a first-line screening criterion for detection of excessive daytime sleepiness among professional drivers. *Traffic Inj Prev* **7**, 44–8.
- 22) Bixler EO, Vgontzas AN, Ten Have T, Tyson K, Kales A (1998) Effects of age on sleep apnea in men: I. Prevalence and severity. *Am J Respir Crit Care Med* **157**, 144–8.
- 23) Durán J, Esnaola S, Rubio R, Iztueta A (2001) Obstructive sleep apnea-hypopnea and related clinical features in a population-based sample of subjects aged 30 to 70 year. *Am J Respir Crit Care Med* **163**, 685–9.
- 24) Ferguson KA, Ono T, Lowe AA, Ryan CF, Fleetham JA (1995) The relationship between obesity and craniofacial structure in obstructive sleep apnea. *Chest* **108**, 375–81.
- 25) Gopal M, Duntley S, Uhles M, Attarian H (2002) The role of obesity in the increased prevalence of obstructive sleep apnea syndrome in patients with polycystic ovarian syndrome. *Sleep Med* **3**, 401–4.
- 26) Nishimura Y, Nishimura T, Hattori H, Hattori C, Yonekura A, Suzuki K (2003) Obesity and obstructive sleep apnea syndrome. *Acta Otolaryngol Suppl* **550**, 22–4.
- 27) Pack AI (2006) Advances in Sleep-disordered Breathing. *Am J Respir Crit Care Med* **173**, 7–15.
- 28) Zhang C, Berger M, Malhotra A, Kales SN (2012) Portable diagnostic devices for identifying obstructive sleep apnea among commercial motor vehicle drivers: considerations and unanswered questions. *Sleep* **35**, 1481–9.
- 29) Villaneuva AT, Buchanan PR, Yee BJ, Grunstein RR (2005) Ethnicity and obstructive sleep apnoea. *Sleep Med Rev* **9**, 419–36.
- 30) Yamagishi K, Ohira T, Nakano H, Bielinski SJ, Sakurai S, Imano H, Kiyama M, Kitamura A, Sato S, Konishi M, Shahar E, Folsom AR, Iso H, Tanigawa T (2010) Cross-

- cultural comparison of the sleep-disordered breathing prevalence among Americans and Japanese. *Eur Respir J* **36**, 379–84.
- 31) Pan WH, Yeh WT, Weng LC (2008) Epidemiology of metabolic syndrome in Asia. *Asia Pac J Clin Nutr* **17** (Suppl 1), 37–42.
  - 32) Sakurai S, Cui R, Tanigawa T, Yamagishi K, Iso H (2007) Alcohol consumption before sleep is associated with severity of sleep-disordered breathing among professional Japanese truck drivers. *Alcohol Clin Exp Res* **31**, 2053–8.
  - 33) Malhotra A, White DP (2002) Obstructive sleep apnoea. *Lancet* **360**, 237–45.
  - 34) Seneviratne U, Puvanendran K (2004) Excessive daytime sleepiness in obstructive sleep apnea: prevalence, severity, and predictors. *Sleep Med* **5**, 339–43.
  - 35) Arnedt JT, Wilde GJ, Munt PW, MacLean AW (2001) How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accid Anal Prev* **33**, 337–44.
  - 36) Garbarino S, Nobili L, Beelke M, De Carli F, Ferrillo F (2001) The contributing role of sleepiness in highway vehicle accidents. *Sleep* **24**, 203–6.
  - 37) George CF, Smiley A (1999) Sleep apnea and automobile crashes. *Sleep* **22**, 790–5.
  - 38) Findley LJ, Unverzadt M, Suratt P (1988) Automobile accidents in patients with obstructive sleep apnea. *Am Rev Respir Dis* **138**, 337–40.
  - 39) Terán-Santos J, Jimenez-Gomez A, Cordero-Guevara J (1999) The association between sleep apnea and the risk of traffic accidents. *N Engl J Med* **340**, 847–51.
  - 40) Horstmann S, Hess CW, Bassetti C, Gugger M, Mathis J (2000) Sleepiness-related accidents in sleep apnea patients. *Sleep* **23**, 383–9.
  - 41) Shiomi T, Arita AT, Sasanabe R, Banno K, Yamakawa H, Hasegawa R, Ozeki K, Okada M, Ito A (2002) Falling asleep while driving and automobile accidents among patients with obstructive sleep apnea-hypopnea syndrome. *Psychiatry Clin Neurosci* **56**, 333–4.
  - 42) Barbé F, Pericás J, Muñoz A, Findley L, Antó JM, Agustí AG (1998) Automobile accidents in patients with sleep apnoea syndrome. *Am J Respir Crit Care Med* **158**, 18–22.
  - 43) George CF (2007) Sleep apnea, alertness, and motor vehicle crashes. *Am J Respir Crit Care Med* **176**, 954–6.
  - 44) Young T, Blustein J, Finn L, Palta M (1997) Sleep-disordered breathing and motor vehicle accidents in a population-based sample of employed adults. *Sleep* **20**, 608–13.
  - 45) Tregear S, Reston J, Schoelles K, Phillips B (2009) Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis. *J Clin Sleep Med* **5**, 573–81.
  - 46) Mulgrew AT, Nasvadi G, Butt A, Cheema R, Fox N, Fleetham JA, Ryan CF, Cooper P, Ayas NT (2008) Risk and severity of motor vehicle crashes in patients with obstructive sleep apnoea/hypopnoea. *Thorax* **63**, 536–41.
  - 47) Findley L, Smith C, Hooper J, Dineen M, Suratt PM (2000) Treatment with nasal CPAP decreases automobile accidents in patients with sleep apnea. *Am J Respir Crit Care Med* **161**, 857–9.
  - 48) Anderson JE, Govada M, Steffen TK, Thorne CP, Varvarigou V, Kales SN, Burks SV (2012) Obesity is associated with the future risk of heavy truck crashes among newly recruited commercial drivers. *Accid Anal Prev* **49**, 378–84.
  - 49) Vakulin A, Baulk SD, Catcheside PG, Antic NA, van den Heuvel CJ, Dorrian J, McEvoy RD (2009) Effects of alcohol and sleep restriction on simulated driving performance in untreated patients with obstructive sleep apnea. *Ann Intern Med* **151**, 447–55.
  - 50) Johns MW (1991) A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* **14**, 540–5.
  - 51) Stutts JC, Wilkins JW, Scott Osberg J, Vaughn BV (2003) Driver risk factors for sleep-related crashes. *Accid Anal Prev* **35**, 321–31.
  - 52) National Sleep Foundation (2012) 2012 Sleep in America Poll: Planes, Trains, Automobiles and Sleep. Washington (DC): The Foundation. <http://www.sleepfoundation.org/2012poll>.
  - 53) Berger M, Varvarigou V, Rielly A, Czeisler CA, Malhotra A, Kales SN (2012) Employer-mandated sleep apnea screening and diagnosis in commercial drivers. *J Occup Environ Med* **54**, 1017–25.
  - 54) Durand G, Parks PD, Kales SN (2008) Occupational medicine forum: alleged daytime somnolence in a professional driver: approaching the fitness for duty determination. *J Occup Environ Med* **50**, 1086–8.
  - 55) Gurubhagavatula I, Maislin G, Pack AI (2001) An algorithm to stratify sleep apnea risk in a sleep disorders clinic population. *Am J Respir Crit Care Med* **164**, 1904–9.
  - 56) Federal Motor Carrier Safety Administration (2008) Medical Expert Panel Recommendations. Obstructive sleep apnea and commercial motor vehicle driver safety Federal Motor Carrier Safety Administration, Washington DC.
  - 57) Zhang C, Varvarigou V, Parks PD, Gautam S, Vela Bueno A, Malhotra A, Kales SN (2012) Psychomotor vigilance testing of professional drivers in the occupational health clinic: a potential objective screen for daytime sleepiness. *J Occup Environ Med* **54**, 296–302.
  - 58) Van Dongen HP, Maislin G, Mullington JM, Dinges DF (2003) The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep* **26**, 117–26.
  - 59) Cohen DA, Wang W, Wyatt JK, Kronauer RE, Dijk DJ, Czeisler CA, Klerman EB (2010) Uncovering residual effects of chronic sleep loss on human performance. *Sci Transl Med* **2**, ra13.
  - 60) Dinges DF, Pack F, Williams K, Gillen KA, Powell JW, Ott GE, Aptowicz C, Pack AI (1997) Cumulative sleepiness,

- mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. *Sleep* **20**, 267–77.
- 61) Hack M, Davies RJ, Mullins R, Choi SJ, Ramdassing-Dow S, Jenkinson C, Stradling JR (2000) Randomised prospective parallel trial of therapeutic versus subtherapeutic nasal continuous positive airway pressure on simulated steering performance in patients with obstructive sleep apnoea. *Thorax* **55**, 224–31.
- 62) Juniper M, Hack MA, George CF, Davies RJ, Stradling JR (2000) Steering simulation performance in patients with obstructive sleep apnoea and matched control subjects. *Eur Respir J* **15**, 590–5.
- 63) Dobbs BM (2005) Medical Conditions and Driving; A Review of the Literature (1960–2000). NHTSA Report No. DOT HS 809–690. [www.nhtsa.dot.gov/people/injury/research/MedicalConditions\\_Driving.pdf](http://www.nhtsa.dot.gov/people/injury/research/MedicalConditions_Driving.pdf).
- 64) Collop NA, Tracy SL, Kapur V, Mehra R, Kuhlmann D, Fleishman SA, Ojile JM (2011) Obstructive sleep apnea devices for out-of-center (OOC) testing: technology evaluation. *J Clin Sleep Med* **7**, 531–48.
- 65) Cassel W, Ploch T, Becker C, Dugnus D, Peter JH, von Wichert P (1996) Risk of traffic accidents in patients with sleep-disordered breathing: reduction with nasal CPAP. *Eur Respir J* **9**, 2606–11.
- 66) George CF (2001) Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. *Thorax* **56**, 508–12.
- 67) Vakulin A, Baulk SD, Catchside PG, Antic NA, van den Heuvel CJ, Dorrian J, McEvoy RD (2011) Driving simulator performance remains impaired in patients with severe OSA after CPAP treatment. *J Clin Sleep Med* **7**, 246–53.
- 68) Smith MR, Eastman CI (2012) Shift work: health, performance and safety problems, traditional countermeasures, and innovative management strategies to reduce circadian misalignment. *Nat Sci Sleep* **4**, 111–32.
- 69) Gurubhagavatula I, Nkwuo JE, Maislin G, Pack AI (2008) Estimated cost of crashes in commercial drivers supports screening and treatment of obstructive sleep apnea. *Accid Anal Prev* **40**, 104–15.
- 70) Hoffman B, Wingenbach DD, Kagey AN, Schaneman JL, Kasper D (2010) The long-term health plan and disability cost benefit of obstructive sleep apnea treatment in a commercial motor vehicle driver population. *J Occup Environ Med* **52**, 473–7.