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## Psychomotor Vigilance Testing of Professional Drivers in the Occupational Health Clinic: a Potential Objective Screen for Daytime Sleepiness

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### Abstract

**Objective**—Psychomotor vigilance testing (PVT) rapidly assesses attention, reaction time (RT) and abnormal vigilance. Thus, PVT may be an adjunct to screening drivers for high risk obstructive sleep apnea (OSA)/excess daytime sleepiness (EDS).

**Methods**—Commercial drivers and emergency responders undergoing occupational examinations took a 10-minute PVT and were instructed to achieve their fastest possible RTs. Participants with maximum RT >5 seconds or 2 “super lapses” (RT >1000ms) were categorized as “microsleepers”.

**Results**—Among 193 male participants, the 15 microsleepers (8%) were significantly more obese, but not different on age or Epworth Sleepiness Score. Time of day had no effect on RT.

**Conclusion**—PVT is suitable to occupational clinics and can identify otherwise unrecognized, impaired vigilance. Further studies must validate the PVT abnormalities most predictive of OSA/EDS and vehicular crashes, compared to adiposity measures alone.

### Introduction

Obstructive Sleep Apnea (OSA), a sleep disorder characterized by repeated collapse of the upper airway during sleep, results in nocturnal hypoxemia and fragmented sleep and is the most common medical cause of excessive daytime sleepiness (EDS)(1). OSA-associated

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#### Disclosures

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neurocognitive dysfunction may also manifest as fatigue, lack of concentration/attention and difficulty remaining alert (1–2). Moreover, such dysfunction can potentially cause accidents resulting from delayed or absent reactions during safety-sensitive tasks (3). For example, untreated OSA is associated with a 2–7 fold increase in motor vehicle crashes, posing a major public health concern with respect to road safety (4–6). Each year in the United States, crashes involving large trucks and buses kill more than 5300 persons and cause over 104,000 additional injuries(7–8). With as many as 30% of these accidents attributable to fatigue (9–11), OSA-related EDS is a major concern in commercial motor vehicle (CMV) drivers and other safety-sensitive professions (12–13).

The prevalence of OSA among CMV drivers is considerably higher than in the general population and ranges from 12–28% (13–16). However, a number of challenges exist with regard to screening and diagnosing CMV drivers or other safety-sensitive professionals for OSA. These include the lack of a federal mandate for medical examiners and trucking companies to perform OSA screening, the ability of drivers to “doctor-shop” for less stringent examiners and substantial wait times and cost issues for obtaining sleep studies (14, 17). Additionally, unlike patients in the community seeking treatment for a sleep disorder, in the setting of commercial driver medical examinations (CDME), CMV drivers have been documented to under-report or deny daytime sleepiness, nighttime symptoms of OSA and OSA diagnoses, (14) (16, 18–19) which forces examiners to rely almost exclusively on objective anthropometric examination measures, such as body mass index (BMI) and neck circumference.

While anthropometric screening criteria have been shown to have reasonable sensitivity and high specificity, industry programs and potential federal regulations have been slowed by several concerns. Specifically, the very high prevalence of obesity among CMV drivers (up to 50%) (18, 20), raises practical issues regarding the inconvenience, cost and availability of in-laboratory polysomnography (PSG) for large numbers of drivers. Additionally, in the opinion of some drivers, utilizing obesity as a major determinant of which drivers receive PSGs may be viewed as discriminatory. Finally, there is not agreement among experts or studies in the literature that all drivers with OSA have EDS or are at higher risk for vehicular crashes (2, 21).

Therefore, there is strong interest in developing efficient and low cost, point of care strategies that can be applied at CMV medical certification examinations in order to identify the sleepiest drivers who should receive prioritized sleep laboratory testing in an expeditious manner. In this context, we investigated the psychomotor vigilance test (PVT) (22–23), a 10-minute test of attention, vigilance and reaction time, as a possible adjunct to current occupational OSA screening methods. The PVT is a validated test in the context of sleep deprivation-related performance deficits (23–25) and can be accomplished within a short office visit. Research has shown that longer lapses in reaction time (RT) on the PVT are associated with eye closure and “microsleep” (26). We hypothesized that adiposity, as measured by the Body Mass Index (BMI) and body composition (body fat percentage), is independently associated with worse (delayed) reaction time patterns which are a potential surrogate measure of OSA and EDS (27–28). Our ultimate goal is to develop objective screening methods to be used in safety-sensitive workers, recognizing that subjective reports of EDS are notoriously unreliable in this population.

## Materials and Methods

### Participants

Eligible participants were potentially engaged in safety-sensitive occupations, expected to drive a non-personal vehicle as part of their essential job duties, and over the age of 18

years. They included CMV drivers undergoing a CDME and all emergency responders (policemen, firefighters, emergency medical technicians/paramedics) undergoing pre-placement or annual occupational health examinations who presented to the occupational clinic from July, 1, 2009 to November, 5, 2010.

Provided there was no evidence of overt neuropsychological disturbance as judged by historical and physical examination screening, subjects were consecutively recruited on days that research personnel were available in clinic. Consented subjects performed a PVT in addition to their employment-mandated examination. No monetary incentives were given for the recruitment. Participants were assured as part of the human subjects' protocol that the PVT results would only be used for research, would not be part of their medical record and would not be used to judge their fitness for their respective occupations. The research protocol was approved by the Institutional Review Board of the Cambridge Health Alliance. On most days that testing was conducted, over 80% of eligible participants agreed to participate.

### Study design

This was a cross-sectional study at an occupational health clinic which examined vigilance and attention parameters, as measured by PVT, in association with anthropometric and other clinical examination characteristics.

**Psychomotor Vigilance Test (PVT)**—A portable PVT device (Model PVT-192, Ambulatory Monitoring, Inc., Ardsley, NY, CWE, Inc, Ardmore, PA) based on the original test described in 1985 by Dinges and Powel was used (29). Participants sat in a quiet environment without auditory or visual disturbances. A 1-minute mock PVT demonstration was done prior to each test. The PVT visual display was between 14–22 inches from the subjects' eyes. The subject was asked to either use the index finger or thumb of their dominant hand to respond to the PVT signals. Participants were instructed to maintain the fastest possible reaction times (RTs) to a simple visual stimulus. Anticipatory responses before the appearance of the target starts were discouraged. The inter-stimulus interval involves a high signal rate, randomly varying between 2 and 10 s. Each administration of the PVT lasted 10 min. Because there are no appreciable practice effects, PVT is an ideal test to compare performance across subjects. From each PVT trial, reaction time (RTs) parameters were collected and standard performance variables were automatically extracted from the device's software program.

**Anthropometric and other clinical characteristics**—Participants' heights were measured (to the nearest 0.25 inch) by nursing staff using a standard clinic stadiometer with the subjects' shoes removed. A Body Composition Analyzer (TANITA BC-418) was then used to weigh the subjects, calculate their BMI and estimate their body fat content using its built-in scale, bioelectrical impedance and pre-established algorithms based on height, gender, age and activity patterns (TANITA BC-418) (30–31). Per standard clinical protocol for all the commercial drivers who presented for their CMDE, we also measured neck circumference (to the nearest 0.25 inch) and the Epworth Sleepiness Scale (ESS) (32). Additionally, we extracted information from all physical exams regarding resting blood pressures, anti-hypertensive medications and established OSA diagnoses.

### Statistical Analysis

BMI and body fat content were used as primary exposure variables and PVT parameters as outcome variables. "Lapses" were defined according to the PVT manufacturer as reaction time (RT) > 500 ms. We further defined "Super lapses" as RT > 1000 ms. Participants with a maximum RT > 5 seconds and/or > 2 super lapses were categorized as probable

“microsleepers”. Reaction time (RT) parameters were summarized by the mean RT, median RT, mean slowest 10% of RTs and maximum RT, as well as lapses and super lapses for each individual. Parameters were analyzed categorically as falling below or  $\geq$ 95th percentile of the study population (higher percentiles indicate worse RTs). Covariates included BMI, body fat, neck circumference, blood pressure, ESS, age and time of day. Univariate analysis was performed on individual variables (outcome and covariates) by comparing groups using ANOVA (continuous) or chi-square and Fisher’s exact tests (nominal), as appropriate. Based on a priori hypotheses, covariates (e.g. age, gender and time of day the PVT was taken) were also used in regression models (logistic regression) to adjust for their potential effects on the outcomes. Data analyses were performed with Stata version 11.1/SE (Stata Corp., College Station, TX) and SPSS 17. The level of statistical significance was set at 0.05 for all analyses.

## Results

Valid PVT results were generated by 208 subjects, including 15 women (7%) and 193 men (93%). Figure 1 shows characteristic histographic representations of reaction times (RT) from three selected participants in response to the stimuli-challenges throughout the 10-minute PVT. **Panel A** shows the results of a participant with a normal response pattern and no lapses (RT  $>500$  ms). **Panel B** illustrates the characteristics of a typical “microsleeper” in this case, a participant with 5 super lapses (RT  $\geq 1000$  ms). **Panel C** shows the results of a commercial driver with admitted EDS (ESS of 15/24) and a subsequently established diagnosis of severe OSA who likely fell asleep during the test.

No women were categorized as “microsleepers”, and because of their small number, females were excluded from further analyses. The demographic and anthropometric characteristics, as well as the PVT test measurements of the 193 male participants are summarized in Table 1. The mean age of the participants was 35.6 ( $\pm 10$ ) years. Most were CMV drivers undergoing CDME (69%), with the remainder being examined for public safety positions. The subjects’ mean BMI was 29 ( $\pm 5$ ) kg/m<sup>2</sup>, and 42% were obese by the BMI criterion (BMI  $\geq 30$  kg/m<sup>2</sup>). The mean body fat percentage for the male participants was 22.4 ( $\pm 6.7$ ) %, with 32% considered obese by this measure (body fat  $\geq 25$ %). Subjective reports of excessive sleepiness were quite rare among the drivers who completed an ESS; with over 97% of drivers reporting an ESS less than 10 and the mean ESS being less than 3/24.

Table 2 summarizes the participants stratified by reaction time categories ( $<$  or  $\geq$  95th percentile of observations) and BMI categories (normal, overweight and obese). Obese participants were significantly more likely to be at or above the 95th percentile for super lapses and mean slowest 10% of RT’s than normal weight and overweight subjects. A very similar distribution of results was found when the participants were stratified by body fat categories results as shown in Table 3.

Among the 193 males, we identified 15 probable “microsleepers”, representing 8% of the male study population. As shown in Figure 2, the microsleepers were highly likely to be obese: 13/15 (87%) were obese by at least one criterion (BMI  $\geq 30$  kg/m<sup>2</sup> or Body Fat  $\geq 25$ %) ( $p=0.003$ ). Furthermore, when compared to subjects who were not obese by any criterion, the odds (95%, CI) of being a microsleeper increased to 5.5 (0.96–31.3) and 10.4 (2.1–50.0) for those obese by one or both adiposity criteria, respectively.

Table 4 summarizes clinical parameters and PVT response profiles for microsleepers compared to non-microsleepers. Probable microsleepers had significantly greater adiposity than non-microsleepers by all BMI and body fat criteria, and consistently worse PVT results, but on average had ESS scores identical to non-microsleepers.

From the 135 participants presenting for a Department of Transportation (DOT) exam, a total of 23 (17%) screened positive according to the Joint Task Force (JTF) consensus criteria for OSA screening (33), seven had subsequent polysomnograms and were all confirmed as having OSA. We compared these 23 drivers (confirmed OSA or at high risk of OSA) with 47 drivers categorized as at very low risk (BMI<27, neck circumference <17 in., ESS<10 and normal blood pressure without prescribed medications for blood pressure) on PVT parameters: namely mean, median, maximum, mean slowest 10% reaction times, total errors lapses and super lapses (< or ≥95%ile of observations), as well as for the probability of being a micro sleeper. The results (data not shown) demonstrated that the OSA drivers were significantly more likely to have a mean RT ≥95%ile ( $p$ -value = 0.03, Fischer's exact test) and more likely to be micro sleepers ( $p$ -value=0.04, Fischer's exact test).

We examined logistic regression models with the probability of being a micro sleeper as the dependent variable (outcome) and adiposity (BMI or body fat %), age and time of the day as predictors (data not shown). Only BMI and body fat % yielded significant and similar results as predictors. For example, for every 1 unit increase in the BMI, the odds of being a micro sleeper increased by 13% ( $p$ =0.012). Adjusting for age and time of the day did not change these results. Likewise, similar regression results found significantly increased likelihood for being in the worst 5% for several RT parameters (maximum RT, slowest 10% of RTs and super lapses) based on obesity, with no effect exerted by age or time of day.

## Discussion

The present study demonstrated that the PVT is a practical and feasible point of care test, easily accomplished during routine occupational medicine examinations. Additionally, our investigation found the PVT was capable of identifying a subset of safety-sensitive workers with impaired vigilance who may require more immediate testing with polysomnography (PSG). To our knowledge, this is the first time that the PVT has been used for these purposes, “real-time” in an occupational clinic.

The frequency of the “micro sleeper” response profile among male participants was 2% in non-obese subjects, 8% in the entire study population and 17% among subjects obese by both BMI ( $>30\text{kg/m}^2$ ) and body fat ( $>25\text{kg/m}^2$ ). Thus, the micro sleepers detected by PVT are predominantly a subset of obese males whose anthropometrics put them at high risk for OSA. Among CMV drivers who met the JTF consensus criteria for OSA screening, again, 17% were classified as micro sleepers. Similar results were found for other RT parameters with obese participants having higher risks of their other RT parameters falling in the worst 5% of the study population.

Given a prevalence of obesity as high as 50% among commercial drivers and a prevalence of OSA as high as 12–28%, the PVT may be a promising adjunct which would allow the rapid identification of a smaller driver subset. Moreover, it is of interest that most of the participants identified as having worse vigilance by PVT, while at risk for OSA on the basis of clinical and epidemiologic grounds, did not meet the JTF consensus screening criteria which are known to have limited sensitivity due to excluding obese drivers with BMI from 30 to  $<35\text{kg/m}^2$ . In this light, we do not see the PVT as replacing traditional, anthropometric OSA screening, but serving as an important added functional screen. Particularly, our results demonstrated significantly worse PVT performance outcomes, evident by increased RTs, in a subset of obese participants rather than in all obese subjects or all subjects with OSA. Thus, although our findings are in general agreement with *Vgontzas et al.* who demonstrated that obesity can be independently associated with EDS, without the presence of OSA (27–28, 34–35), the PVT is not simply capturing elevated BMI which is likely an inadequate screening method in isolation for EDS. In other words, if the

PVT is actually testing EDS, it would add additional value by identifying at risk drivers who might otherwise not be sent for a sleep study via the most common occupational screening criteria, as well as drivers selected by screening criteria, but who should have expedited sleep studies.

A case-control study published in 2004 by Verstraeten et al., showed that patients with OSA had visual vigilance decrements characterized by lapses of attention, slowed information processing and decreased short-term memory span (36). Likewise, in a recent study with a driving simulation test, Tippin et al. found that drivers with OSA have significantly impaired visual vigilance compared to drivers without neurological or sleep disorders (37). The degraded vigilance in OSA drivers may suggest a means for identifying those with a higher crash risk. A recent study using PVT and video monitoring in young healthy participants subjected to sleep restriction, demonstrated that while shorter lapses (500–1000 ms) with the eyes open are more common, the vast majority of longer lapses (>1000 ms) occur with the eyes closed and are most consistent with microsleeping (26). Moreover, this investigation found the risk of eye closure increased further with additional lags in RT. Therefore, the participants in our study found to be “microsleepers”, as defined by a maximum RT >5 seconds and/or 2 super lapses (RT 1 second), were highly likely to experience eye closure during the PVT. Accordingly, there is strong biologic plausibility that such a profile indicates sleepiness during the test.

As expected from previous studies of drivers in the occupational setting (14, 16) in our current study population the mean Epworth Sleepiness Scale score was only 3/24 which is considered in the low normal range. Accordingly, most participants with established OSA diagnoses and those found to be microsleepers reported an ESS score of 3 or less. Thus, it appears that the PVT can be a more accurate and more objective discriminator, especially when faced with drivers who seek to minimize their symptoms. For example, a recent study by Parks et al.(14) reported that 85% of drivers with likely OSA answered negatively the federally mandated question: “*Do you have sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring*”. From the same study, a number of drivers initially denied the presence of their previously diagnosed OSA until they were told that based on screening criteria they were required to obtain a sleep study. These findings make objective tests such as the PVT even more important for point of care decisions.

Our study does have some limitations. First, the design was cross-sectional and limited to a single observation in each subject. Thus, at this time we cannot be sure that PVT would identify the same drivers consistently over time as having abnormal vigilance or whether it detects drivers who were more sleepy or fatigued on the day they happened to report for the medical examination. However, day-to-day fluctuations in PVT may also reflect real variations in accident risk, emphasizing the need for further research in this area. Second and related, because it was implemented with the time constraints of a busy clinic, rather than a research setting, we were unable to collect additional information on recent sleep hygiene, and stimulant or sedative use. This information would have been difficult to obtain accurately even if time were not limited because we believe that participants undergoing medical clearance for safety-sensitive work would not have been forthcoming. However, we believe our data reflect the real world clinical environment and may be more relevant and generalizable to the context of CDME’s than experimental data from a research laboratory. Finally, because of human subjects’ considerations and cost limitations, we could not order confirmatory further sleep laboratory testing (e.g overnight polysomnography, multiple sleep latency test (MSLT) or maintenance of wakefulness test (MWT)) on all participants. Therefore, the present study was exploratory and addressed feasibility, but requires validation by additional objective testing. However, because neither MSLT nor MWT are known to be reliably predictive of motor vehicle crashes (2), large scale studies will likely

be required to predict accidents which are relatively rare events. Further studies are also needed to validate which patterns of functional impairment observed on PVT are most predictive of OSA/EDS, as well as a greater risk of vehicular crashes when compared to simple measures of adiposity alone.

Nevertheless, for an exploratory study, our investigation had several strengths. Our results demonstrated the feasibility of the PVT as a potentially promising point of care screening instrument administered within a CDME at an occupational clinic. Second, as seen in Figure 1, PVT output can be easily interpreted by a clinician. Further, we believe once standard criteria are established, the appropriate performance thresholds could be detected by the PVT software and scored automatically. Finally, based on the distribution of demographic and anthropometric data for the current study population, our data are generalizable to large segments of the US CMV population.

## Conclusion

The PVT is a practical and promising in-clinic or point of care objective method for identifying safety-sensitive workers with impaired vigilance. The abnormal vigilance patterns detected by PVT are found almost exclusively in a subset of obese males whose anthropometrics put them at high risk for OSA; some of whom would escape detection by the JTF screening criteria employed alone. In particular, the micro sleeper pattern is highly likely to identify drivers experiencing eye closure. Further studies in representative clinical and occupational populations are necessary to validate whether the PVT is adequately sensitive and specific to predict EDS related to OSA and most importantly, crash risk.

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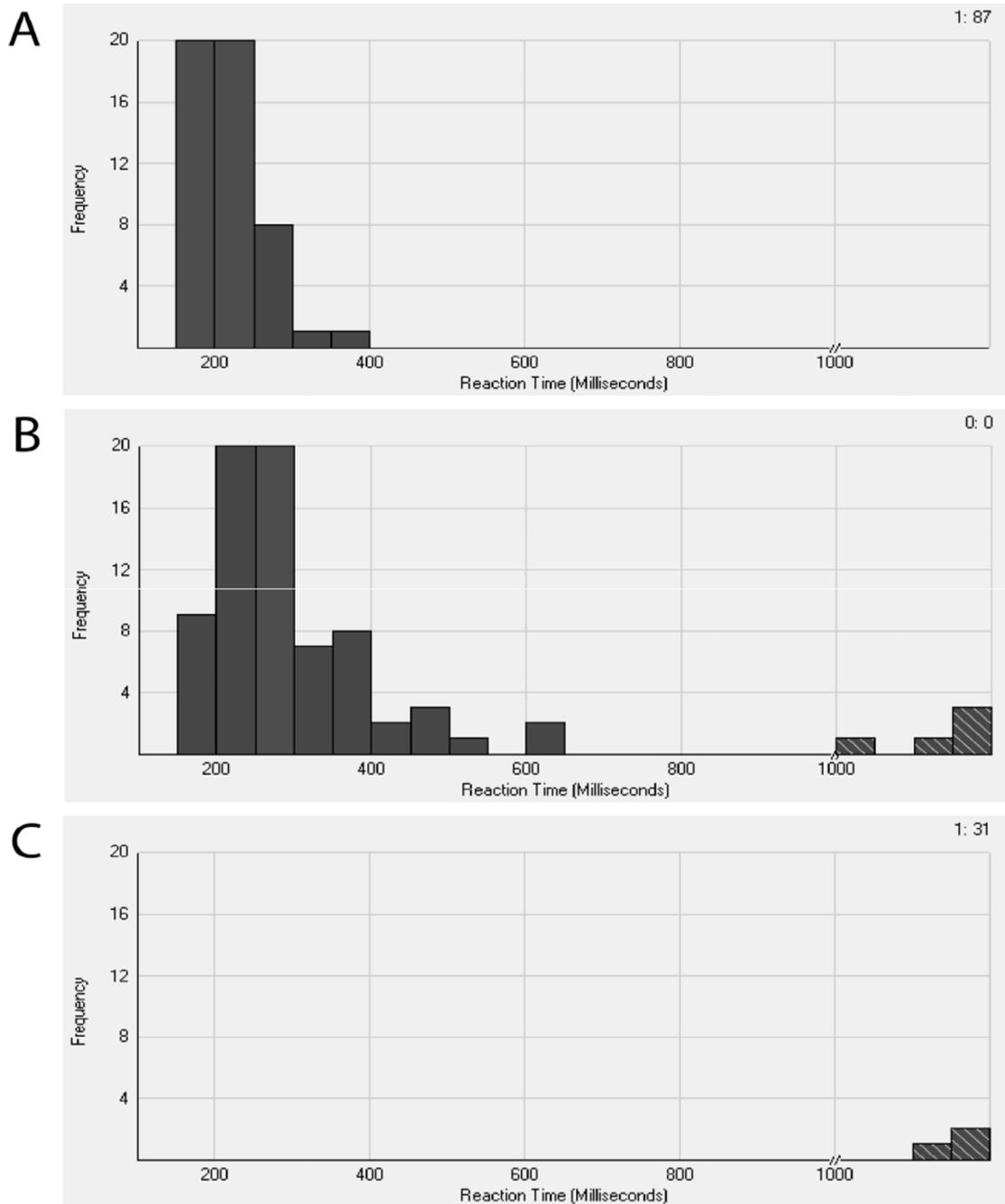
Dr. Kales reports serving as paid expert witness and independent medical examiner including cases involving commercial drivers. Dr. Kales has consulted with Circadies. Dr. Malhotra reports having received consulting and/or research grant income from Philips, SGS, SHC, Pfizer, Merck, Ethnicon, Medtronic, Apnex, Apnicure, Cephalon and Sepracor. Dr. Vela is the principal director of Circadies.

## References

1. Malhotra A, White DP. Obstructive sleep apnoea. *Lancet*. 2002; 360:237–245. [PubMed: 12133673]
2. Hartenbaum N, Collop N, Rosen IM, et al. 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*. 2006; 48:S4–S37. [PubMed: 16985410]
3. Findley L, Unverzagt M, Guchu R, Fabrizio M, Buckner J, Suratt P. Vigilance and automobile accidents in patients with sleep apnea or narcolepsy. *Chest*. 1995; 108:619–624. [PubMed: 7656606]
4. Teran-Santos J, Jimenez-Gomez A, Cordero-Guevara J. The association between sleep apnea and the risk of traffic accidents. Cooperative Group Burgos-Santander. *N Engl J Med*. 1999; 340:847–851. [PubMed: 10080847]
5. Tregear S, Reston J, Schoelles K, Phillips B. Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis. *J Clin Sleep Med*. 2009; 5:573–581. [PubMed: 20465027]

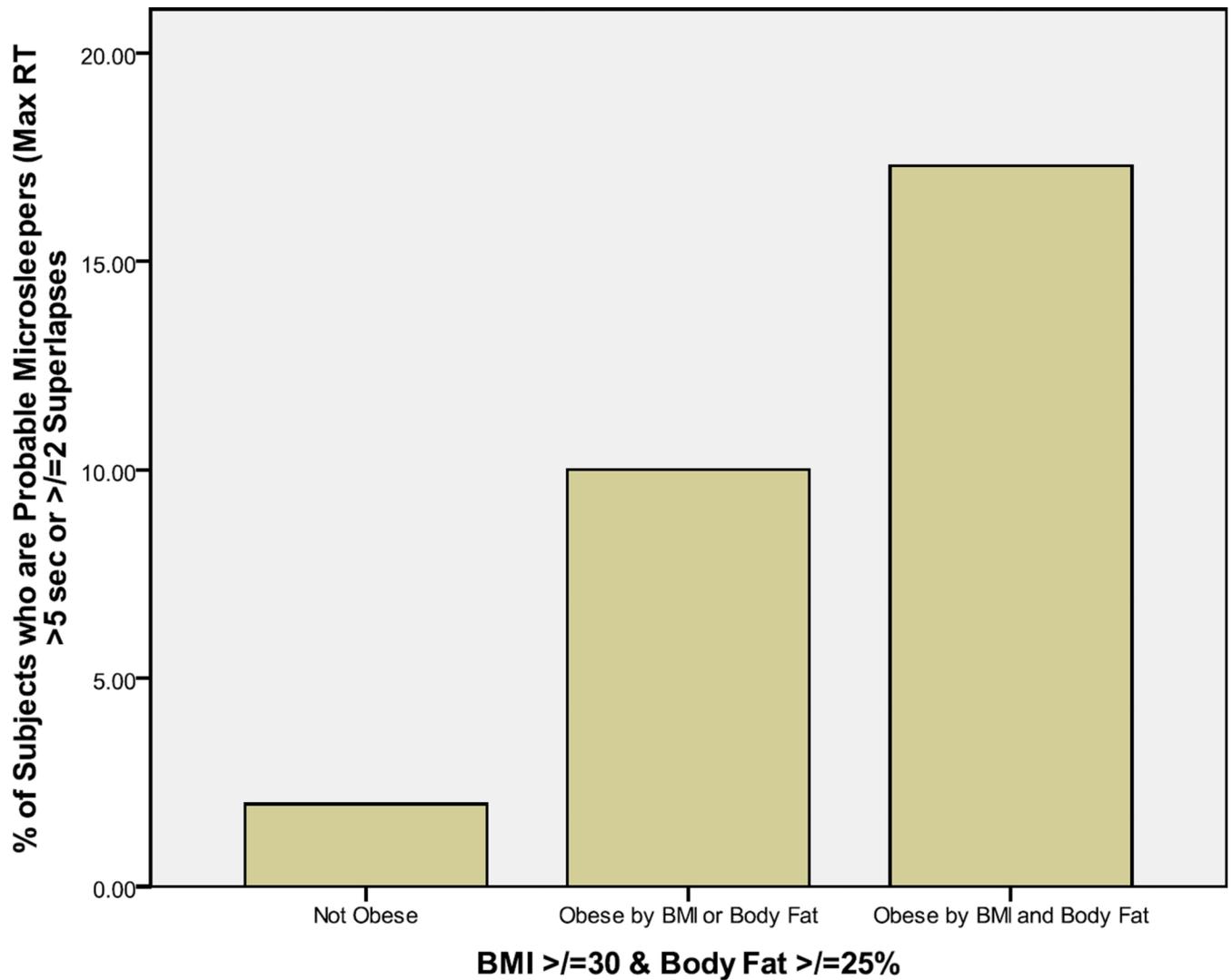
6. George CF. Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. *Thorax*. 2001; 56:508–512. [PubMed: 11413347]
7. National Summary of Large Truck and Passenger Carriers Crashes. US Department of Transportation; 2010.
8. Certification Process for Drivers with Serious Medical Conditions. United States Government Accountability Office; 2008.
9. Philip P. Sleepiness of occupational drivers. *Ind Health*. 2005; 43:30–33. [PubMed: 15732301]
10. Radun I, Summala H. Sleep-related fatal vehicle accidents: characteristics of decisions made by multidisciplinary investigation teams. *Sleep*. 2004; 27:224–227. [PubMed: 15124714]
11. Akerstedt T. Consensus statement: fatigue and accidents in transport operations. *J Sleep Res*. 2000; 9:395. [PubMed: 11123524]
12. Pack AI, Maislin G, Staley B, et al. Impaired performance in commercial drivers: role of sleep apnea and short sleep duration. *Am J Respir Crit Care Med*. 2006; 174:446–454. [PubMed: 16690976]
13. Howard ME, Desai AV, Grunstein RR, et al. Sleepiness, sleep-disordered breathing, and accident risk factors in commercial vehicle drivers. *Am J Respir Crit Care Med*. 2004; 170:1014–1021. [PubMed: 15317672]
14. Parks P, Durand G, Tsismenakis AJ, Vela-Bueno A, Kales S. Screening for obstructive sleep apnea during commercial driver medical examinations. *J Occup Environ Med*. 2009; 51:275–282. [PubMed: 19280762]
15. Pack A, Dinges D, Maislin G. A Study of Prevalence of Sleep Apnea Among Commercial Truck Drivers. FMCSA, Publication No DOT-RT-02-030. :2002.
16. Talmage JB, Hudson TB, Hegmann KT, Thiese MS. Consensus criteria for screening commercial drivers for obstructive sleep apnea: evidence of efficacy. *J Occup Environ Med*. 2008; 50:324–329. [PubMed: 18332782]
17. Durand G, Kales SN. Obstructive sleep apnea screening during commercial driver medical examinations: a survey of ACOEM members. *J Occup Environ Med*. 2009; 51:1220–1226. [PubMed: 19786899]
18. Xie W, Chakrabarty S, Levine R, Johnson R, Talmage JB. Factors associated with obstructive sleep apnea among commercial motor vehicle drivers. *J Occup Environ Med*. 2011; 53:169–173. [PubMed: 21270659]
19. Dagan Y, Doljansky JT, Green A, Weiner A. Body Mass Index (BMI) as a first-line screening criterion for detection of excessive daytime sleepiness among professional drivers. *Traffic Inj Prev*. 2006; 7:44–48. [PubMed: 16484032]
20. Gurubhagavatula I, Maislin G, Nkwuo JE, Pack AI. Occupational screening for obstructive sleep apnea in commercial drivers. *Am J Respir Crit Care Med*. 2004; 170:371–376. [PubMed: 15142866]
21. George CF. Sleep. 5: Driving and automobile crashes in patients with obstructive sleep apnoea/hypopnoea syndrome. *Thorax*. 2004; 59:804–807. [PubMed: 15333860]
22. Drummond SP, Bischoff-Grethe A, Dinges DF, Ayalon L, Mednick SC, Meloy MJ. The neural basis of the psychomotor vigilance task. *Sleep*. 2005; 28:1059–1068. [PubMed: 16268374]
23. Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. *Sleep*. 1997; 20:267–277. [PubMed: 9231952]
24. Van Dongen HP, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*. 2003; 26:117–126. [PubMed: 12683469]
25. Cohen DA, Wang W, Wyatt JK, et al. Uncovering residual effects of chronic sleep loss on human performance. *Sci Transl Med*. 2010; 2:14ra13.
26. Anderson C, Wales AW, Horne JA. PVT lapses differ according to eyes open, closed, or looking away. *Sleep*. 2010; 33:197–204. [PubMed: 20175403]

27. Bixler EO, Vgontzas AN, Lin HM, Calhoun SL, Vela-Bueno A, Kales A. Excessive daytime sleepiness in a general population sample: the role of sleep apnea, age, obesity, diabetes, and depression. *J Clin Endocrinol Metab.* 2005; 90:4510–4515. [PubMed: 15941867]
28. Basta M, Vgontzas AN. Metabolic abnormalities in obesity and sleep apnea are in a continuum. *Sleep Med.* 2007; 8:5–7. [PubMed: 17157061]
29. Dinges DF, Powell JW. Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behavior Research Methods, Instruments, & Computer.* 1985; 17:652–655.
30. Fogelholm M, van Marken Lichtenbelt W. Comparison of body composition methods: a literature analysis. *Eur J Clin Nutr.* 1997; 51:495–503. [PubMed: 11248873]
31. Lukaski HC, Bolonchuk WW, Hall CB, Siders WA. Validation of tetrapolar bioelectrical impedance method to assess human body composition. *J Appl Physiol.* 1986; 60:1327–1332. [PubMed: 3700310]
32. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep.* 1991; 14:540–545. [PubMed: 1798888]
33. Hartenbaum N, Collop N, Rosen IM, et al. 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.* 2006; 130:902–905. [PubMed: 16963693]
34. Vgontzas AN. Does obesity play a major role in the pathogenesis of sleep apnoea and its associated manifestations via inflammation, visceral adiposity, and insulin resistance? *Arch Physiol Biochem.* 2008; 114:211–223. [PubMed: 18946782]
35. Vgontzas AN. Excessive daytime sleepiness in sleep apnea: it is not just apnea hypopnea index. *Sleep Med.* 2008; 9:712–714. [PubMed: 18640872]
36. Verstraeten E, Cluydts R, Pevernagie D, Hoffmann G. Executive function in sleep apnea: controlling for attentional capacity in assessing executive attention. *Sleep.* 2004; 27:685–693. [PubMed: 15283003]
37. Tippin J, Sparks J, Rizzo M. Visual vigilance in drivers with obstructive sleep apnea. *J Psychosom Res.* 2009; 67:143–151. [PubMed: 19616141]



**Figure 1.**

**Panel A** shows a normal PVT graph, **Panel B**= typical "micro-sleeper", **Panel C**= a morbidly obese driver with an ESS of 15 and subsequently-proven severe OSA on polysomnographic testing who demonstrated grossly impaired vigilance on the PVT, likely explained by sleep during the testing period.



**Figure 2.**

Prevalence of “microsleeper” PVT results according to obesity categories (not obese- BMI < 30 and Body Fat <25%; obese by one criterion (BMI ≥ 30 or Body Fat ≥ 25%); obese by both BMI and Body Fat criteria. The difference between categories was statistically significant, *p*-value for Chi-square= 0.003

**Table 1**

Demographic, anthropometric characteristics and PVT test measurements for 193 male study participants

	Mean ( $\pm$ SD)	Median (90% Range)	Minimum	Maximum
Age (yrs)	35.6 ( $\pm$ 10)	34.0 (22–55)	19.0	67.0
BMI	29.0 ( $\pm$ 5)	28.7 (21.4–37)	17.6	51.6
Body Fat (%)	22.4 ( $\pm$ 7)	22.4 (10.5–32.5)	3.0	41.5
Neck size (in) (n=129)	16.4 ( $\pm$ 1.3)	16.3 (14.5–18)	14.0	21.0
Systolic (mmHg)	123.0 ( $\pm$ 13)	122.0 (104–145)	94.0	180.0
Diastolic (mmHg)	78.0 ( $\pm$ 10)	80.0 (60–90)	52.0	106.0
ESS (n=133)	2.7 ( $\pm$ 2.7)	2.0 (0–8)	0.0	15.0
Mean RT (ms)	325.0 ( $\pm$ 830)	246.7 (209–370)	5.0	11635.0
Maximum RT (ms)	1050.0 ( $\pm$ 2510)	522.0 (348–2741)	263.0	25416.0
Median RT (ms)	278.0 ( $\pm$ 463)	234.0 (198–295)	189.0	6445.0
Total Errors	4.0 ( $\pm$ 8)	1.0 (0–15)	0.0	70.0
Super Lapses (RT 1000ms)	0.6 ( $\pm$ 3.3)	0.0 (0–2)	0.0	44.0
Lapses (RT>500ms)	2.0 ( $\pm$ 5)	1.0 (0–9)	0.0	62.0

BMI=Body Mass Index; ESS = Epworth Sleepiness Scale; in = inches; ms=milliseconds; RT = reaction time; SD = standard deviation; yrs = years

**Table 2**

Number and percentage of participants stratified by maximum reaction time categories, super lapses categories, lapses categories and mean slowest 10% reaction time categories (<or 95%ile of observations) according to BMI categories.

<b>BMI Categories</b>				
	<b>&lt;25 (normal) n=41 (21%)</b>	<b>25- 30 (overweight) n=71 (37%)</b>	<b>30 (obese) n=81(42%)</b>	<b>p-value</b>
<b>Maximum reaction time categories</b>				
Maximum RT (<95%ile) <sup>I</sup>	41 (100%)	69 (97%)	74 (91%)	0.066
Maximum RT ( 95%ile) <sup>I</sup>	0 (0%)	2 (3%)	7 (9%)	
<b>Super Lapses categories</b>				
Super Lapses (<95%ile) <sup>I</sup>	41 (100%)	70 (98%)	73 (90%)	<b>0.013</b>
Super Lapses ( 95%ile) <sup>I</sup>	0 (0%)	1 (2%)	8 (10%)	
<b>Lapses categories</b>				
Lapses (<95%ile) <sup>I</sup>	40 (98%)	69 (97%)	74 (31%)	0.182
Lapses ( 95%ile) <sup>I</sup>	1 (2%)	2 (3%)	7 (9%)	
<b>Mean slowest 10% Reaction Time categories</b>				
Mean slowest 10% Reaction Time (<95%ile) <sup>I</sup>	41 (100%)	70 (98%)	73 (90%)	<b>0.013</b>
Mean slowest 10% Reaction Time ( 95%ile) <sup>I</sup>	0 (0%)	1 (2%)	8 (10%)	

<sup>I</sup> n of cases (%); BMI=Body Mass Index. Percentages have been rounded to the nearest integer.

**Table 3**

Number and percentage of participants stratified by maximum reaction time categories, super lapses categories, lapses categories and mean slowest 10% reaction time categories (< 95% of observations) according to Body Fat categories.

<b>Body Fat Categories</b>				
	<b>&lt; 15%</b> <b>N=43 (22%)</b>	<b>15- 25%</b> <b>N=86 (45%)</b>	<b>25%</b> <b>N=61 (32%)</b>	<b>p-value</b>
<b>Maximum reaction time categories</b>				
Maximum RT (<95%ile) <sup>I</sup>	42 (98%)	84 (98%)	55 (92%)	0.16
Maximum RT ( 95%ile) <sup>I</sup>	1 (2%)	2 (2%)	5 (8%)	
<b>Super Lapses categories</b>				
Super Lapses (<95%ile) <sup>I</sup>	42 (98%)	87 (99%)	55 (89%)	<b>0.01</b>
Super Lapses ( 95%ile) <sup>I</sup>	1 (2%)	1 (1%)	7 (11%)	
<b>Lapses categories</b>				
Lapses (<95%ile) <sup>I</sup>	41 (95%)	85 (98%)	57 (92%)	0.44
Lapses 95%ile) <sup>I</sup>	2 (5%)	3 (2%)	5 (8%)	
<b>Mean slowest 10% Reaction Time categories</b>				
Mean slowest 10% Reaction Time (<95%ile) <sup>I</sup>	42 (98%)	87 (99%)	55 (89%)	<b>0.01</b>
Mean slowest 10% Reaction Time ( 95%ile) <sup>I</sup>	1 (2%)	1 (1%)	7 (11%)	

<sup>I</sup>n of cases (%); BMI=Body Mass Index. Percentages have been rounded to the nearest integer.

**Table 4**

Comparison of microsleepers and non-microsleepers.

	Microsleepers (n=15)	Non-Microsleepers (n=178)	p-value
Age (years) <sup>1</sup>	34.5 (±10)	35.7 (±10.3)	0.65
BMI <sup>1</sup>	32.3 (±4.6)	28.7 (±5)	<b>0.01</b>
Body Fat % <sup>1</sup>	27.0 (±4.8)	22.0 (±6.7)	<b>0.002</b>
Systolic BP (mmHg) <sup>1</sup>	122.4 (±8.3)	122.7 (±13.2)	0.91
Diastolic BP (mmHg) <sup>1</sup>	79.0 (±6.5)	78.0 (±9.8)	0.48
Neck circumference (in) <sup>1</sup>	17.0 (±1.2)	16.3 (±1.2)	0.11
Epworth Sleepiness Scale score <sup>1</sup>	2.8 (±4.2)	2.7 (±2.5)	0.92
Obesity (Body Fat ≥25% and/or BMI>30) <sup>2</sup>	11 (73%)	70 (39%)	<b>0.01</b>
<b>Lapses categories</b>			
Lapses (<95%ile) <sup>2</sup>	8 (53%)	175 (98%)	<b>&lt;0.001</b>
Lapses (≥95%ile) <sup>2</sup>	7 (47%)	3 (2%)	
<b>Mean slowest 10% Reaction Time categories</b>			
Mean slowest 10% Reaction Time (<95%ile) <sup>2</sup>	6 (40%)	178 (100%)	<b>&lt;0.001</b>
Mean slowest 10% Reaction Time (≥95%ile) <sup>2</sup>	9 (60%)	0 (0%)	
<b>Total Errors Categories</b>			
Total errors (<95%ile) <sup>2</sup>	12 (80%)	172 (97%)	<b>0.003</b>
Total errors (≥95%ile) <sup>2</sup>	3 (20%)	6 (3%)	

<sup>1</sup> Mean (±SD)<sup>2</sup> n of cases (%); BMI= Body Mass Index; BP= Blood pressure