

# Psychomotor Vigilance Testing of Professional Drivers in the Occupational Health Clinic

## *A Potential Objective Screen for Daytime Sleepiness*

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**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  $\geq 2$  "super lapses" (RT  $\geq 1000$  ms) 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.

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

The prevalence of OSA among CMV drivers is considerably higher than in the general population and ranges from 12% to 28%.<sup>13-16</sup> 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.<sup>14,17</sup> In addition, 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,<sup>14,16,18-19</sup> which forces examiners to rely almost exclusively on objective anthropometric examination measures, such as body mass index (BMI) and neck circumference.

Although 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%)<sup>18,20</sup> raises practical issues regarding the inconvenience, cost, and availability of in-laboratory polysomnography (PSG) for large numbers of drivers. In addition, 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.<sup>2,21</sup>

Therefore, there is strong interest in developing efficient and low cost, point of care strategies that can be applied at CMV medical certification examinations to identify the sleepest drivers who should receive prioritized sleep laboratory testing in an expeditious manner. In this context, we investigated the psychomotor vigilance test (PVT),<sup>22-23</sup> a 10-minute test of attention, vigilance, and reaction time (RT), 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<sup>23-25</sup> and can be accomplished within a short office visit. Research has shown that longer lapses in RT on the PVT are associated with eye closure and "microsleep."<sup>26</sup> We hypothesized that adiposity, as measured by the BMI and body composition (body fat percentage), is independently associated with worse (delayed) RT patterns which are a potential surrogate measure of OSA and EDS.<sup>27-28</sup> 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 nonpersonal 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 preplacement 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

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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

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.<sup>29</sup> 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 and 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 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 seconds. Each administration of the PVT lasted 10 minutes. Because there are no appreciable practice effects, PVT is an ideal test to compare performance across subjects. From each PVT trial, 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).<sup>30-31</sup> 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).<sup>32</sup> In addition, we extracted information from all physical exams regarding resting blood pressures, antihypertensive 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 RT > 500 ms. We further defined "Super lapses" as RT  $\geq$  1000 ms. Participants with a maximum RT > 5 seconds and/or  $\geq$  2 super lapses were categorized as probable "microsleepers." 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  $\geq$  95% 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 analysis of variance (continuous) or chi-square and Fisher's exact tests (nominal), as appropriate. Based on a priori hypotheses, covariates

(eg, 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  $\leq 0.05$  for all analyses.

### RESULTS

Valid PVT results were generated by 208 subjects, including 15 women (7%) and 193 men (93%). Figure 1 shows characteristic histogrammatic representations of 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 five super lapses (RT  $\geq$  1000 ms). Panel C shows the results of a commercial driver with admitted EDS (ESS of 15 of 24) and a subsequently established diagnosis of severe OSA who likely fell asleep during the test.

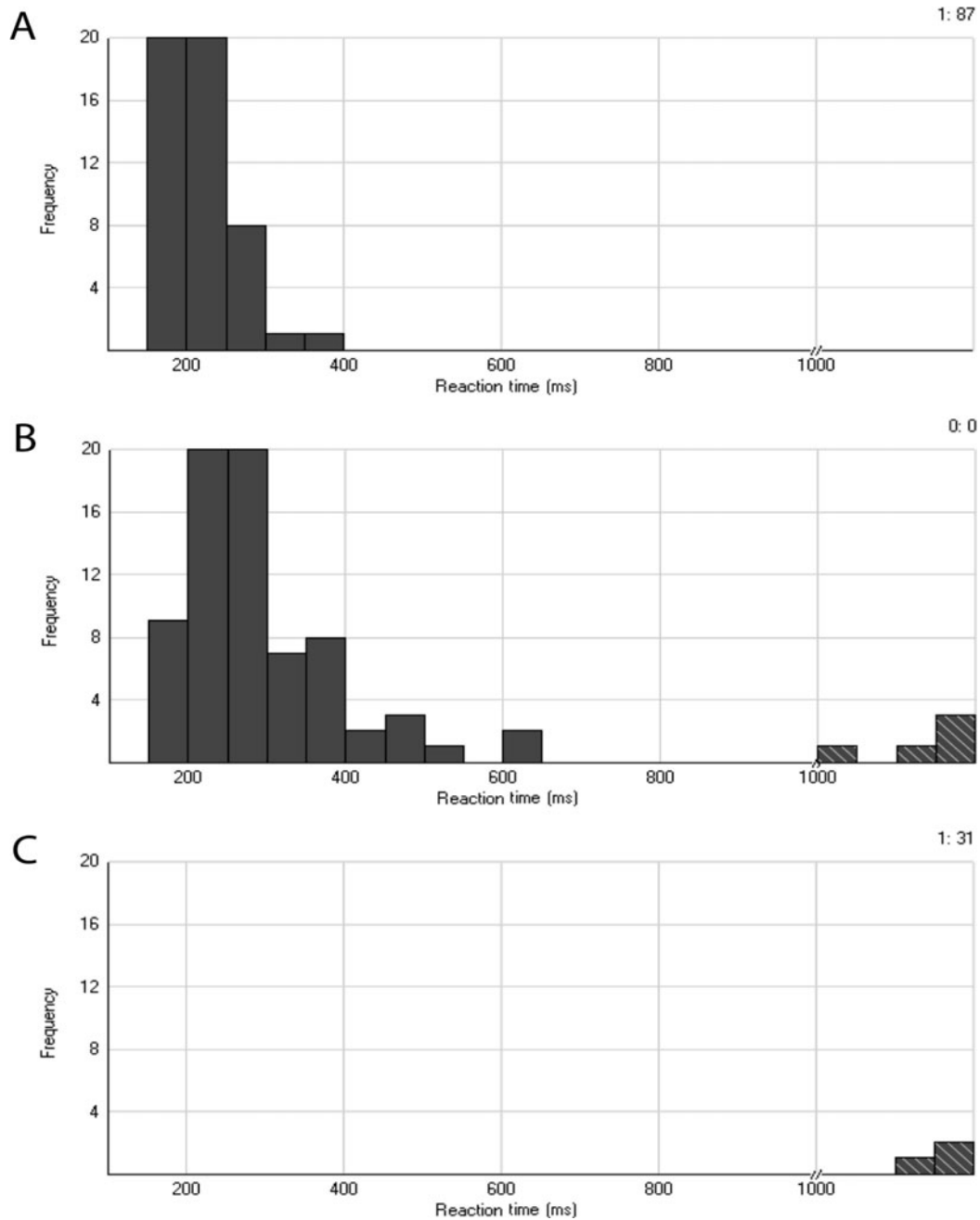
No women were categorized as "microsleepers," and because of their small number, females were excluded from further analyses. The demographic and anthropometric characteristics, as well as the PVT test measurements of the 193 male participants are summarized in Table 1. The mean age of the participants 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 of 24.

Table 2 summarizes the participants stratified by RT 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 RTs 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 Fig. 2, the microsleepers were highly likely to be obese: 13 of 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% confidence interval [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 exam, a total of 23 (17%) screened positive according to the Joint Task Force (JTF) consensus criteria for OSA screening,<sup>33</sup> 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 inches, ESS < 10, and normal blood pressure without prescribed medications for blood pressure) on PVT parameters: namely mean, median, maximum, mean slowest 10% RTs, total errors lapses, and super lapses (< or  $\geq$  95th percentile of observations), as well as for the probability of being a microsleeper. The results (data not shown) demonstrated



**FIGURE 1.** Panel A shows a normal PVT graph. Panel B shows typical “micro-sleeper.” Panel C shows 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.

that the OSA drivers were significantly more likely to have a mean RT  $\geq$  95% ( $P = 0.03$ , Fischer’s exact test) and more likely to be microsleepers ( $P = 0.04$ , 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. Similarly, similar regression results found significantly

increased likelihood for being in the worst 5% for several RT parameters (maximum RT, slowest 10% of RTs, and superlapses) based on obesity, with no effect exerted by age or time of day.

**DISCUSSION**

This study demonstrated that the PVT is a practical and feasible point of care test, easily accomplished during routine occupational medicine examinations. In addition, 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 PSG. To our knowledge, this is the first time that the

**TABLE 1.** Demographic, Anthropometric Characteristics and PVT Test Measurements for 193 Male Study Participants

	Mean ( $\pm$ SD)	Median (90% Range)	Minimum	Maximum
Age (yr)	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 (mm Hg)	123.0 ( $\pm$ 13)	122.0 (104–145)	94.0	180.0
Diastolic (mm Hg)	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 $\geq$ 1000 ms)	0.6 ( $\pm$ 3.3)	0.0 (0–2)	0.0	44.0
Lapses (RT > 500 ms)	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; yr, 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  $\geq$ 95th percentile of Observations) According to BMI Categories

	BMI Categories			<i>P</i>
	<25 (Normal) <i>n</i> = 41 (21%)	25 to $\leq$ 30 (Overweight) <i>n</i> = 71 (37%)	$\geq$ 30 (Obese) <i>n</i> = 81 (42%)	
Maximum reaction time categories				
Maximum RT (<95th percentile)	41 (100%)	69 (97%)	74 (91%)	0.066
Maximum RT ( $\geq$ 95th percentile)	0 (0%)	2 (3%)	7 (9%)	
Super lapses categories				
Super lapses (<95th percentile)*	41 (100%)	70 (98%)	73 (90%)	0.013
Super lapses ( $\geq$ 95th percentile)*	0 (0%)	1 (2%)	8 (10%)	
Lapses categories				
Lapses (<95th percentile)*	40 (98%)	69 (97%)	74 (31%)	0.182
Lapses ( $\geq$ 95th percentile)*	1 (2%)	2 (3%)	7 (9%)	
Mean slowest 10% reaction time categories				
Mean slowest 10% reaction time (<95th percentile)*	41 (100%)	70 (98%)	73 (90%)	0.013
Mean slowest 10% reaction time ( $\geq$ 95th percentile)	0 (0%)	1 (2%)	8 (10%)	

BMI, body mass index. Percentages have been rounded to the nearest integer.

\**n* of cases (%).

PVT has been used for these purposes, “real-time” in an occupational clinic.

The frequency of the “microsleeper” response profile among male participants was 2% in nonobese subjects, 8% in the entire study population, and 17% among subjects obese by both BMI ( $\geq$ 30 kg/m<sup>2</sup>) and body fat ( $\geq$ 25 kg/m<sup>2</sup>). Thus, the microsleppers 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 microsleppers. 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% to 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, although 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 kg/m<sup>2</sup>. 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,<sup>27–28,34–35</sup> 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

**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 (< or ≥95th percentile of observations) According to Body Fat Categories

	Body Fat Categories			P
	<15% n = 43 (22%)	15 to ≤25% n = 86 (45%)	≥25% n = 61 (32%)	
Maximum reaction time categories				
Maximum RT (<95th percentile)*	42 (98%)	84 (98%)	55 (92%)	0.16
Maximum RT (≥95th percentile)*	1 (2%)	2 (2%)	5 (8%)	
Super lapses categories				
Super lapses (<95th percentile)*	42 (98%)	87 (99%)	55 (89%)	0.01
Super lapses (≥95th percentile)*	1 (2%)	1 (1%)	7 (11%)	
Lapses categories				
Lapses (<95th percentile)*	41 (95%)	85 (98%)	57 (92%)	0.44
Lapses (≥95th percentile)*	2 (5%)	3 (2%)	5 (8%)	
Mean slowest 10% reaction time categories				
Mean slowest 10% reaction time (<95th percentile)*	42 (98%)	87 (99%)	55 (89%)	0.01
Mean slowest 10% reaction time (≥95th percentile)*	1 (2%)	1 (1%)	7 (11%)	

BMI, body mass index. Percentages have been rounded to the nearest integer.  
\*n of cases (%).

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.

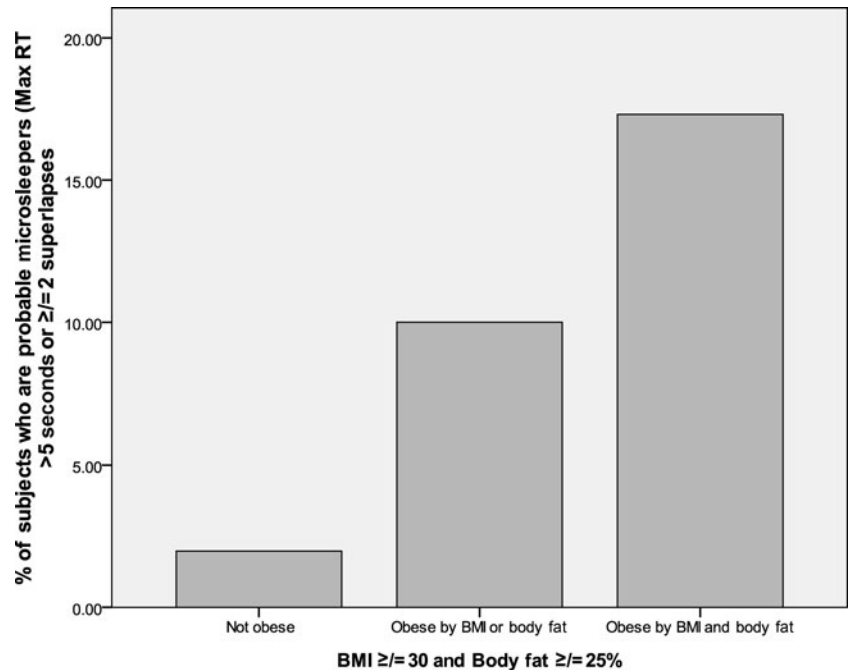
A case-control study published in 2004 by Verstraeten et al, showed that patients with OSA had visual vigilance decrements characterized by lapses of attention, slowed information processing, and decreased short-term memory span.<sup>36</sup> Similarly, in a recent study with a driving simulation test, Tippin et al found that drivers with OSA have significantly impaired visual vigilance compared to drivers without neurological or sleep disorders.<sup>37</sup> 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 although shorter lapses (500 to 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.<sup>26</sup> Moreover, this investigation found that 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,<sup>14,16</sup> in our current study population the mean Epworth Sleepiness Scale score was only 3 of 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<sup>14</sup> 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 CDMEs 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 (eg, overnight PSG, multiple sleep latency test [MSLT], or maintenance of wakefulness test [MWT]) on all participants. Therefore, this 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,<sup>2</sup> 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 Fig. 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

**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 4.** Comparison of Microsleepers and Non-Microsleepers

	Microsleepers (n = 15)	Non-Microsleepers (n = 178)	P
Age (yr)*	34.5 (± 10)	35.7 (± 10.3)	0.65
BMI*	32.3 (± 4.6)	28.7 (± 5)	0.01
Body fat %*	27.0 (± 4.8)	22.0 (± 6.7)	0.002
Systolic BP (mm Hg)*	122.4 (± 8.3)	122.7 (± 13.2)	0.91
Diastolic BP (mm Hg)*	79.0 (± 6.5)	78.0 (± 9.8)	0.48
Neck circumference (in)*	17.0 (± 1.2)	16.3 (± 1.2)	0.11
Epworth sleepiness scale score*	2.8 (± 4.2)	2.7 (± 2.5)	0.92
Obesity (body fat ≥25% and/or BMI > 30)†	11 (73%)	70 (39%)	0.01
Lapses categories			
Lapses (<95th percentile)†	8 (53%)	175 (98%)	<0.001
Lapses (≥95th percentile)†	7 (47%)	3 (2%)	
Mean slowest 10% reaction time categories			
Mean slowest 10% reaction time (<95th percentile)†	6 (40%)	178 (100%)	<0.001
Mean slowest 10% reaction time (≥95th percentile)†	9 (60%)	0 (0%)	
Total errors categories			
Total errors (<95th percentile)†	12 (80%)	172 (97%)	0.003
Total errors (≥95th percentile)†	3 (20%)	6 (3%)	

BMI, body mass index; BP, blood pressure.

\*Mean (± SD).

†n of cases (%).

of demographic and anthropometric data for this 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 microsleep 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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