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Undiagnosed Obstructive Sleep Apnea in Commercial Motor Vehicle Drivers: Application of STOP-Bang

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EXECUTIVE SUMMARY

Although several studies have estimated the prevalence of obstructive sleep apnea (OSA) in the commercial motor vehicle (CMV) driver population, limitations such as small sample sizes and study samples that are not representative of the industry have limited the generalizability of these study findings to the general CMV population. Validated sleep apnea screening questionnaires often used in clinical and research settings have been ineffective for CMV operations due to driver reluctance to disclose symptoms. The STOP-Bang is a subjective and objective screening tool that assesses snoring, tiredness, observed apneas, hypertension, Body Mass Index (BMI), age, neck circumference, and gender. The STOP-Bang has yet to be evaluated in CMV drivers; however, it has been evaluated for its ability to detect moderate-to-severe OSA in bus drivers and was determined to be "the most accurate screening tool among this safety-sensitive population."

The Commercial Driver Safety Risk Factors (CDSRF) study offers an opportunity to evaluate the STOP-Bang screening tool in a sample of 11,864 CMV drivers not previously diagnosed for or considered to potentially have OSA in order to provide insight on the prevalence of undiagnosed OSA. The CDSRF study results found that 7.2% of the driver study sample (n = 13,724) was diagnosed with OSA, and that 6.4% of the driver sample was categorized as potentially having OSA (according to the comments associated with their commercial driver medical examination, or CDME). CDME comments that would classify a driver as potentially having OSA were a sleep test referral from the medical examiner or documentation of signs and symptoms suggestive of OSA. The remaining drivers were considered undiagnosed for OSA as there was no indication from their CDME that they had ever been evaluated for OSA and the CDME did not feel that there was a need for the testing (86.4%; n = 11,864). In addition, there were 6,334 drivers in the CDSRF study that did not have enough data available to classify the driver for OSA. The current study also attempted to classify these drivers into either No OSA or OSA Potential based on the STOP-Bang screening tool. It is likely that a significant proportion of these "undiagnosed" or "not enough data" drivers would be moved to the "potential" OSA group had the STOP-Bang screener been applied. The likelihood of moderate-to-severe OSA in people with a BMI greater than 35 is 80%. Thus, approximately 3,300 drivers (≈24%) in the CDSRF study should have been diagnosed with moderate-to-severe OSA; however, only 7.2% (over a threefold difference) were diagnosed with OSA on their CDME. It is also likely that drivers who were high-risk, but undiagnosed, for OSA inflated the crash risk associated with this control group and made them seem more unsafe. In the CDSRF study, drivers with OSA who were currently being treated were significantly less likely to be involved in a total carrier crash, carrier preventable crash, and a national crash compared to drivers with undiagnosed OSA (≈40% reduction). Although these findings are encouraging and strongly support the safety benefits of OSA treatment, it may not be an accurate conclusion if, in fact, there are undiagnosed OSA drivers in the control group that are inflating that groups' safety record.

This study investigated the potential benefit of using a modified version of the STOP-Bang questionnaire to screen for OSA in the CMV population using data from the CDSRF study. Using the modified version of the STOP-Bang, 10 times more drivers (897 vs. 9,382) in the CDSRF study were classified as screening high for OSA (i.e., OSA Potential). These drivers should thus be referred for a sleep study to identify the presence of OSA. Although these drivers moved from the No OSA group to the Potential OSA group, analyses using Poisson regression models still found that the OSA Diagnosed: Treated group had a significantly lower crash rate

compared to the No OSA group. The efficacy of the STOP-Bang in screening for OSA in this population should be further evaluated.

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LIST OF ABBREVIATIONS AND SYMBOLS

AHI	Apnea Hypopnea Index
BMI	Body Mass Index
BQ	Berlin Questionnaire
CDME	Commercial Driver Medical Exam
CDSRF	Commercial Driver Safety Risk Factors Study
CI	confidence interval
CMV	commercial motor vehicle
CPAP	continuous positive airway pressure
DOT	Department of Transportation
ESS	Epworth Sleepiness Scale
FMCSA	Federal Motor Carrier Administration
MAP	Multivariable Apnea Prediction
OSA	obstructive sleep apnea
PAP	positive airway pressure
RR	relative risk
SB	STOP-Bang
SDB	sleep disordered breathing

CHAPTER 1. INTRODUCTION

OBSTRUCTIVE SLEEP APNEA

Obstructive sleep apnea (OSA) is a sleep disorder characterized by the repetitive occlusion (hypopnea) or collapse (apnea) of the upper airway for 10 seconds or more (Epstein et al., 2009). These bouts of closed airway create periods of low oxygen and high carbon monoxide concentrations in the blood (hypoxia and hypercapnia, respectively) and fragmented sleep. The hypoventilation triggers the sympathetic nervous system, causing the individual to gasp for air. This mechanism is what causes the cardiovascular response and drives the blood pressure and heart rate to rouse the body from sleep. The number of apneas and hypopneas that occur in each hour of sleep is called the Apnea Hypopnea Index (AHI). An individual with an AHI between 5 and 15 is diagnosed with mild OSA, between 15 and 30 with moderate OSA, and above 30 with severe OSA. Some signs of OSA are loud snoring and daytime sleepiness, which come directly from the fragmented sleep due to waking to gasp for air. There are two much less common types of sleep-disordered breathing (SDB), central sleep apnea and mixed sleep apnea, which have similar outcomes and treatments and are thus often used synonymously in literature.

Researchers have identified several risk factors for the development of OSA. The primary risk factor is excess body weight (Romero-Corral et al., 2010; Young et al., 2002). The longitudinal Wisconsin Sleep Cohort Study demonstrated that a 10% reduction in weight led to a 26% reduction of apnea and hypopnea incidents per hour of sleep, whereas a weight gain of 10% led to a sixfold increase in the chance of developing OSA (Peppard, Young, Palta, Dempsey, et al., 2000). Another physical attribute known to increase the risk of OSA is large neck circumference (Ardelean et al., 2014; Stradling & Crosby, 1991). Hoffstein and Mateika (1992) matched 312 individuals on Body Mass Index (BMI) and age and found that individuals with an AHI greater than 10 had a significantly larger neck circumference than those with an AHI less than 10, perhaps due to excess fat around the neck increasing the pressure on the breathing airway. A neck circumference over 16 inches for women or 17 inches for men correlates with OSA and is often used as a measurement for screening (Davies & Stradling, 1990). Other noted risk factors for apnea and hypopnea incidents are sex (male; Quintana-Gallego et al., 2004), age (over 65; Bixler et al., 1998), genetics (Redline & Tishler, 2000), and being a smoker (Wetter et al., 1994).

The constant disturbance of sleep and hypoventilation in individuals with OSA can exacerbate excess weight issues as well as lead to further detrimental health issues. Sleepiness is significantly predictive of being sedentary, which could lead to further weight gain (Chasens et al., 2009). In addition, researchers determined that severe OSA, independent of obesity, is associated with an increased preference for calorie-dense foods and that hormone imbalances caused by OSA increase appetite (Beebe et al., 2011; Phillips et al., 2000). Individuals with moderate or severe OSA have three times the adjusted odds of developing hypertension compared to individuals without OSA (Peppard, Young, Palta, & Skatrud, 2000), reflective of possible abnormalities in the sympathetic nervous system activity carrying over into wake time (Somers et al., 1995). They also are nine times more likely to develop metabolic syndrome, which is defined as the coexistence of at least three of the following disorders: obesity, hypertension, insulin resistance, impaired glucose tolerance, and dyslipidaemia (Coughlin et al., 2004). Wheaton et al. (2012) found that the prevalence of depression was two times higher among women and five times higher among men with OSA compared to those without OSA.

Fortunately, treatment has been developed to help individuals diagnosed with OSA combat all these negative effects.

OSA TREATMENT AND TREATMENT OUTCOMES

Most OSA treatments, including mandibular advancement devices, upper respiratory surgery, and weight reduction, improve OSA by advancing the tongue or preventing the backward movement of the tongue, thus reducing the tendency of upper airway collapse during sleep (Lettieri et al., 2011; Stephen et al., 2004). The most common and effective treatment is positive airway pressure (PAP) therapy (Li et al., 2013). PAP delivers pressurized air to the upper airway to maintain patency of the airway and prevent collapse (Gordon & Sanders, 2005). Continuous PAP (CPAP) machines provide patients with constant air pressure to maintain an open airway, whereas automatic PAP machines adjust to the minimum pressure needed to maintain an open airway and are often better tolerated by patients. In addition, PAP machines are the only treatment for which compliance data can be monitored remotely by physicians.

Studies have shown that there are immediate benefits from treatment for OSA using PAP. Researchers followed OSA patients treated with PAP and found significant decreases in BMI, weight, and waist circumference in as little as 3 months to 1 year after treatment (Loube et al., 1997; Oktay et al., 2009; Sharma et al., 2011). A study of depression in 293 patents with moderate to severe OSA demonstrated that after just 3 months of compliant CPAP treatment, depressive symptoms were reduced from 74.6% to 3.9% (Edwards et al., 2015). In addition, a study by Buxton et al. (2009) found that adequate sleep (which is improved with PAP treatment) was linked to healthy eating behaviors. Treatment with PAP could therefore lead to improved restfulness, weight loss, lower depression, and healthier eating, which, in turn, improves the overall quality of life of an individual with OSA. However, some OSA patients still remain non-compliant with PAP treatment due to discomfort with the mask, nasal congestion, mouth dryness, or machine noise (Pepin et al., 1995).

The most common symptom of OSA is excessive daytime sleepiness, which can result in poor judgement and impaired cognitive function, reaction time, and alertness (Engleman & Douglas, 2004). Sleepiness can make a driver more susceptible to being involved in a crash. Burks et al. (2016) conducted a retrospective cohort analysis of OSA-diagnosed commercial motor vehicle (CMV) drivers to investigate crash risk and compliance with PAP treatment. After matching for tenure and experience at hire, they found that drivers with no adherence to treatment had a preventable Department of Transportation (DOT)-reportable crash rate almost 5 times greater than that of the matched controls. The crash risk of drivers with full adherence to OSA treatment was similar to control drivers without OSA. The results of Burks et al. (2016) are in line with previous studies showing higher crash risk for drivers with SDB than those without (Stoohs et al., 1994). Thus, screening CMV drivers for OSA and assisting them with obtaining treatment is financially beneficial to truck fleets (Burks et al., 2019).

COMMERCIAL MOTOR VEHICLE DRIVER OSA RISK

The typical lifestyle of CMV truck drivers makes them inherently susceptible to the development of OSA. These drivers often spend long hours behind a wheel, leading to physical inactivity, irregular work and sleep hours, poor eating choices and habits, and mental and physical stress

(Mabry et al., 2016). According to current hours-of service regulations, a CMV driver can drive 11 hours of the maximum 14 on-duty hours each day, and a total of 60 hours in a consecutive 7-day span or 70 hours in a consecutive 8-day span (Federal Motor Carrier Safety Administration [FMCSA], 2017). CMV truck drivers may frequently invert their sleep-wake cycle in order to deliver items on time and remain within their hours of service, which can lead to circadian disruptions, sleepiness, and fatigue (Harma et al., 2002). The long work hours can lead to lack of time, opportunity, and motivation to engage in physical activity and also limit food options to locations that they can access with their truck. These options are mostly fast food restaurants and truck stops, which have limited healthy food choices. Finally, CMV drivers are most often isolated due to the nature of their job and have to deal with daily driving hazards, which can increase stress and depression (da Silva-Junior et al., 2009). These lifestyle factors increase CMV truck drivers' susceptibility to obesity, cardiovascular disease, and metabolic disorders, all of which are comorbidities found with OSA (Mabry et al., 2016).

It is difficult to determine the actual prevalence rate of OSA in the CMV driver population due to driver hesitancy to be screened or tested. A driver suspected of having OSA must undergo testing, and United States Department of Transportation (USDOT) regulations require a CMV driver diagnosed with OSA to be effectively treated in order to be medically qualified to drive. Additionally, undergoing the diagnostic and treatment set-up process can take time, meaning drivers could potentially lose wages. Therefore, CMV drivers may be hesitant to disclose symptoms for fear of losing their medical certification if OSA is suspected or diagnosed without effective treatment (Berger et al., 2012).

To estimate the prevalence of OSA in CMV drivers, Berger et al. (2012) conducted a retrospective analysis of 19,371 proprietary, online OSA-screening questionnaires completed by CMV drivers as part of an employer-mandated OSA program. The online questionnaire contained subjective and objective questions. They found that 30% of the CMV drivers screened as high risk for OSA. Of those drivers who were screened as high risk, 68% were found to have severe OSA and 80% had mild OSA. The authors concluded that the prevalence rate of OSA in CMV drivers was 21%. This is still viewed as a conservative estimate given that the screening tool relied (partly) on CMV driver self-reports, which may not be accurate due to less candid responses.

As 70% of diagnosed OSA is caused by obesity and 90% of CMV drivers are overweight or obese, it is anticipated that the prevalence of OSA among CMV drivers is much higher than among the general population (Mabry et al., 2016). Peppard et al. (2013) estimated the overall prevalence of OSA in the general population using polysomnography in 1,520 participants in the Wisconsin Sleep Cohort. They found that 26% of those tested had OSA, and 10% had moderate to severe OSA (i.e., AHI greater than 15 events/hour).

OSA SCREENING MEASURES FOR CMV DRIVERS

There is only one question inquiring about SDBs on the USDOT's Commercial Driver Medical Exam (CDME), a required medical evaluation for CMV drivers. The question asks whether the driver has any "sleep disorders, pauses in breathing while asleep, daytime sleepiness, or loud snoring." Not surprisingly, 85% of drivers who likely have OSA answer "no" to this question (Parks et al., 2009). The Epworth Sleepiness Scale (ESS) and Berlin Questionnaire (BQ) are

quick and inexpensive validated surveys to screen for OSA risk (Johns, 2000; Netzer et al., 1999). The ESS is an eight-question survey which asks respondents to rate their normal chances of dozing off under different activities. The BQ is a survey comprising 10 questions focused on snoring, daytime fatigue, including falling asleep while driving, stopped breathing during sleep, and the presence of high blood pressure. Similarly, the Multivariable Apnea Prediction Index is a 1-minute survey inquiring about apnea symptoms as well as age, sex, and BMI (Yang et al., 2018). Though these surveys work well in the general population, they are often ineffective in screening for OSA with CMV drivers due to their hesitancy to disclose OSA symptoms (Sharwood et al., 2012). Screening for OSA using objective (i.e., BMI, neck circumference, blood pressure) and subjective measures (i.e., sleep history and symptomology) was found to be effective at identifying 95% of CMV drivers who screened positive for OSA and had a positive OSA test (polysomnography; Talmage et al., 2008). Interestingly, none of the drivers diagnosed with OSA answered "yes" to the question on the CDME regarding having any signs of a sleep disorder. Thus, although elements of subjective screening tools are useful, CMV drivers are unlikely to respond honestly, thus supporting the need for objective OSA screening measures.

STOP-Bang

The STOP-Bang (SB) questionnaire is an eight-item OSA screening tool that incorporates subjective symptoms and objective OSA risk factors (See Appendix A; Chung et al., 2008). The SB assesses snoring, tiredness, observed apneas, hypertension, BMI, age, neck circumference, and gender (Firat et al., 2012). Silva et al. (2011) tested the SB in the general population with 4,770 participants in the Sleep Heart Health Study. They found it to have high sensitivity in detecting OSA. Research demonstrated the ability of the SB to successfully identify bus drivers at high risk of OSA, with a high sensitivity and negative predictive value (Firat et al., 2012). It has a simple scoring algorithm (Chung et al., 2014):

- Overall score of 0 to 2 is low risk of OSA.
- Overall score of 3 to 4 is an intermediate risk of OSA.
- Overall score of 5 or more is high risk of OSA.
- Score of 2 or more on STOP questions AND being male = high risk of OSA.
- Score of 2 or more on STOP questions AND BMI greater than 35 kg/m^2 = high risk of OSA.
- Score of 2 or more on STOP questions AND neck circumference greater than 17 inches for males, 16 inches for females = high risk of OSA.

SUMMARY OF CURRENT STUDY

Previous studies indicated there is underreporting of OSA among the CMV driver population (Berger et al., 2012; Hickman et al., under Agency review). Hickman et al. (under Agency review) found evidence to support underreporting of OSA in the Commercial Driver Safety Risk Factors (CDSRF) study, which collected survey and medical data from 20,745 CMV drivers recruited from a large for-hire trucking company. Only 7.2% of the drivers were diagnosed with OSA on their CDME. However, individuals with a BMI greater than 35 have an 80% likelihood of moderate-to-severe OSA (FMCSA, 2015); 30.7% of drivers in the CDSRF study had a BMI of 35 or greater, and thus, approximately 24% of those CMV drivers should be diagnosed with OSA. Consequently, it appears that the guidance on OSA screening in the CDME may be

insufficient in determining a driver's OSA susceptibility. Drivers suffering from untreated OSA can be susceptible to sleepiness while driving, which can increase crash risk. Due to the SB's low cost, ease of administration, and high sensitivity, it may be an ideal candidate for screening CMV drivers for OSA, but it has yet to be validated within this population (Chung, et al., 2016).

This study applied the SB to non-OSA drivers and drivers who previously did not have enough information to be categorized into an OSA group in the CDSRF study to identify if these drivers screen high for OSA. This study also reanalyzed the data in the CDSRF to assess if treating OSA reduces crash risk (as there are likely to be drivers in the non-OSA group that screen high on the SB and thus should be recategorized in the Potential OSA group). These drivers may inflate the crash risk in the non-OSA group. Thus, the current study recategorized non-OSA drivers who screened high on the SB to the Potential OSA groups and removed these drivers from the non-OSA group.

CHAPTER 2. METHODS

This study analyzed previously collected data from a large study of CMV drivers (Hickman et al., under Agency review). The CDSRF study included 20,745 CMV drivers recruited from a large for-hire trucking company. Researchers collected survey data from participants as well as medical data from the CMV drivers' CDME and Brief Medical Screen. The Initial Driver Survey included the ESS, BQ, basic demographic information, driving history, and quality-of-life questions.

Drivers from the CDSRF study were categorized into one of five OSA groups:

- OSA Diagnosed: Treated
- OSA Diagnosed: Untreated
- OSA Diagnosed: Unsure of Treatment
- OSA Potential, or High Risk
- No OSA, or Non-high Risk Using Only the CDME Data

In the CDSRF study, drivers marked as receiving treatment for a sleep disorder in the CDME were marked as one of the "OSA Diagnosed" groups, depending on treatment behavior, and were excluded from additional regrouping in the current study. If the CDME indicated that a driver was high risk for OSA (i.e., typically referred for polysomnography test but not given an actual diagnosis), the driver was marked as "OSA Potential" and excluded from regrouping in the current study. If the CDME did not indicate the driver as screening high for OSA, the driver was categorized as "No OSA." Drivers whose CDME did not provide enough information to categorize a driver as "No OSA," "OSA Potential," or one of the "OSA Diagnosed" groups were excluded from further analysis in the CDSRF. However, in this study the drivers were categorized as "Not Enough Data." The "No OSA" and "Not Enough Data" driver groups were evaluated for regrouping in the current study using the SB method.

The current study used the survey, CDME, and Brief Medical Screen to apply the SB to participants not diagnosed with OSA. A total of 13,724 CMV drivers had the Initial Driver Survey and at least some data from the CDME or Brief Medical Screen. In the CDSRF study, 981 of those drivers had been diagnosed with OSA, 879 were classified in the Potential OSA group, and the remaining 11,864 drivers were labeled as "No OSA." In addition, there were 6,334 drivers who were missing too much CDME data to be grouped into an OSA category in the CDSRF study.

SB SCORING

The SB questionnaire was not included in the CDSRF; however, some items in the SB were included in the data sources. Table 1 displays the questions from the SB (first column) and the question(s) in the CDSRF that matched the corresponding item in the SB (second column). For example, answering "yes" to item #1 of the SB, "Do you snore loudly (loud enough to be heard through closed doors or your bed-partner elbows you for snoring at night)?" would correspond to two items in the BQ (see Table 1). Drivers who answered, "as loud as talking," "louder than talking," or "very loud–can be heard in adjacent rooms" in response to "Your snoring is…," as well as "yes" to the item "Has your snoring ever bothered other people?" on the BQ would correspond to a "yes" in item #1 on the SB.

Table 1. SB and analogous items in the CDSRF.

SB Question	Question(s) in CDSRF That Match SB
1) Do you Snore Loudly (loud enough to be heard through closed doors or your bed-partner elbows you for snoring at night)?	Item from BQ: Your snoring is = • *As loud as talking* OR • *Louder than talking* OR • *Very loud- can be heard in adjacent rooms.* **OR** Item from BQ: Has your snoring ever bothered other people? = • *Yes*
2) Do you often feel Tired, Fatigued, or Sleepy during the daytime (such as falling asleep during driving or talking to someone)?	Item from BQ: During waking time, do you feel tired, fatigued or not up to par = • *Nearly every day* OR • *3-4 times a week* OR • *1-2 times a week* **OR** Item from BQ: How often do you feel tired or fatigued after sleep = • *Nearly every day* OR • *3-4 times a week* OR • *1-2 times a week* **OR** Item from BQ: How often have you fallen asleep while driving a vehicle = • *Nearly every day* OR • *3-4 times a week* OR • *1-2 times a week* **OR** Item from ESS: The TOTAL value of the ESS was above 11
3) Has anyone Observed you Stop Breathing or Choking/Gasping during your sleep?	Item from BQ: Has anyone noticed that participant quit breathing during sleep? = • *Nearly every day* OR • *3-4 times a week* OR • *1-2 times a week* OR • *1-2 times a month*

SB Question	Question(s) in CDSRF That Match SB
4) Do you have or are being treated for High Blood Pressure?	Item from BQ: Do you have high blood pressure? = • *Yes* **OR** Information from CDME: High Blood Pressure is indicated as a diagnosed medical condition and being treated (compliant or non-compliant)
5) Body Mass Index more than 35 kg/m^2?	Information from CDME: BMI greater than 35 when calculated from height and weight data
6) Age older than 50?	Information from CDME or Driver Survey: Age is greater than 50 years old
7) Neck size large? (Measured around Adams apple) For male, is your shirt collar 17 inches/43 cm or larger? For female, is your shirt collar 16 inches/41 cm or larger?	Information not Available
8) Gender = Male?	Information from CDME: • *Gender* = Male

As shown in Table 1, neck circumference is an objective screening question in the SB; however, neck circumference data were not collected in the CDSRF. Therefore, the application of the SB in categorizing CMV drivers as high risk for OSA excluded this information and used "No" as the default response for this item, resulting in a conservative categorization of OSA.

APPLYING THE SB FOR OSA RISK CLASSIFICATIONS

Using the SB, each of the 18,198 CMV drivers originally in the No OSA group or without enough medical data for diagnosis from the CDSRF was recategorized as "No OSA," "OSA Potential," or "Not Enough Data." This was accomplished through a revised SB scoring system due to (1) the unavailability of neck circumference in the CDSRF data, and (2) some drivers not having all the data responses needed to score each question on the modified SB (i.e., they were missing data). In order to retain as many participants as possible in the analysis, drivers' data were evaluated using an algorithm developed in this study based on the number of available responses from the CDSRF that translated to items on the SB. A number of valid data responses (driver responses with data in the CDSRF), dependent on the specific questions with valid responses, were required to categorize each driver on the SB.

Table 2 shows the number of "yes" responses on the modified SB based on data from the CDSRF (first column), the required number of valid responses needed for OSA status classification (second column) and the modified SB OSA classification used in the current study (third column). For example, using the scoring method in Row 2 of Table 2, if a driver had one "yes" response on the SB (column) and a minimum total of four valid data responses in the CDSRF (Column 2), the driver was classified as "No OSA." However, if a driver had at least two or more "yes" responses from the STOP questions and was male, they would be categorized as "Potential OSA" using the modified SB OSA classification (see Row 8 in Table 2). The

classifications in Table 2 were applied to the 18,198 drivers from the CDSRF study in the No OSA group or the group without enough medical data. The original SB scoring methodology can be found in Appendix A.

Table 2. Revised SB scoring.

Number of "YES" responses in modified or original SB	Number of Valid Data Responses in CDSRF	SB OSA Classification with revised scoring
≤ 1	≥ 3 STOP questions AND Gender and BMI Responses	"No OSA"
1	4	"No OSA"
2	5	"No OSA"
3	6 and responses do not fit the Gender/BMI + 2 STOP Question criteria	"No OSA"
4	7 and responses do not fit the Gender/BMI + 2 STOP Question criteria	"No OSA"
≥ 5	≥ 5	"Potential OSA"
≥ 2 AND Male Gender Response	≥ 2 STOP questions AND Male Gender Response	"Potential OSA"
≥ 2 AND BMI over 35 Response	≥2 STOP questions AND BMI Response	"Potential OSA"
	None of the above criteria met	"Not Enough Data"

COMPARING SAFETY ANALYSIS OF OSA RISK AFTER SB APPLICATION

To assess the impact of OSA on safety outcomes (i.e., regrouping No OSA drivers to Potential OSA), two different modeling procedures were used and compared to the CDSRF (Hickman et al., under Agency review).

Analysis by Age Quartile and OSA Group Status

Using the redistributed OSA status groupings from the SB (i.e., "OSA Potential" and "No OSA"), the calculation of safety outcome frequencies replicated the methodology in Hickman et al. (under Agency review) and described here. Poisson regression models were used to analyze the impact of the OSA group on safety outcome frequency for each of four safety outcomes (carrier crashes, carrier preventable crashes, national crashes, and moving violations). More specifically, these analyses replicated the analyses in Hickman et al. (under Agency review) with the new OSA groupings.

The model followed the distribution:

$$Y_i \sim Poisson(E_i, \lambda_i)$$

where Y_i was the number of crashes for driver i; E_i was the total exposure for driver i; and λ_i was the expected safety outcome rate for driver i.

For each driver, the number of safety outcomes of each type was calculated. Driver exposure was also determined, both in total tenure days at the carrier (for testing safety outcomes of carrier

crashes and carrier preventable crashes) and total days for the data collection period (for testing safety outcomes of national crashes and moving violations). Each driver was labeled with their OSA group status, which could include one of the following: No OSA; OSA Diagnosed: Treated; OSA Diagnosed: Untreated; OSA Diagnosed: Unsure of Treatment; and OSA Potential. As in Hickman et al. (under Agency review), driver age and BMI were included in the model.

The model assessing safety outcome rate with a log link function was as follows:

$$\log(\lambda_i) = \beta_0 + \beta_{OSA\ Group} X_i^{OSA\ Group} + \beta_{\text{age}} X_i^{\text{age}} + \beta_{\text{BMI}} X_i^{\text{BMI}}$$

where $X_i^{OSA\ Group}$ was the value of variable *OSA Group* for driver i; X_i^{age} and X_i^{BMI} were the age and BMI for driver i, respectively; and βs are the corresponding regression coefficients. The reference level for the categorical variable $X_i^{OSA\ Group}$was the No OSA group. Each non-reference level had $\beta_{OSA\ Group}$ as a coefficient, and exp $\left(\beta_{OSA\ Group}\right)$ measured the relative risk (RR) of the corresponding level compared to the No OSA group reference level.

Individual models were built for each of four age quartiles, with each model including only drivers within the age quartile and each safety outcome type. The age quartiles included ages 21 to 33 years old, 34 to 42 years old, 43 to 51 years old, and 52 years and older. For the carrier crashes and carrier preventable crashes safety outcomes, the rate used driver carrier tenure days as the exposure value. For the national crashes and moving violations safety outcomes, the rate used driver total days for the data collection period as the exposure value.

Results of the models are presented as the RR (with 95% confidence intervals [CIs]) of involvement in a safety outcome for the OSA group compared to the No OSA reference group. The results from the current models and those from the CDSRF final report (Hickman et al., under Agency review) were compared to understand how the SB screener impacted the findings.

Analysis by OSA Group Status

A second, simplified analysis was performed to assess the differences in safety outcome rate by OSA group status. The analysis used Poisson regression models like before but did not include age and BMI as coefficients. As above, the number of safety outcomes, total exposure, and OSA group status were calculated for each driver.

The model was specified as follows:

$$Y_i \sim Poisson(E_i, \lambda_i)$$

where Y_i was the number of crashes for driver i; E_i was the total exposure for driver i; and λ_i was the expected safety outcome rate for driver i.

$$\log(\lambda_i) = \beta_0 + \beta_{OSA\ Group} X_i^{OSA\ Group}$$

where $X_i^{OSA\ Group}$ was the value of variable *OSA Group* for driver i and βs were the regression coefficients. Once again, the reference level for the categorical variable $X_i^{OSA\ Group}$was the No OSA group. Each non-reference level had $\beta_{OSA\ Group}$ as a coefficient, and exp $\left(\beta_{OSA\ Group}\right)$

measured the RR of the corresponding level compared to the No OSA group reference level. Results of the models are presented in this report as RR (with 95% CIs) of involvement in a safety outcome for the OSA group compared to the No OSA reference group.

CHAPTER 3. RESULTS

SB REASSESSMENT OF OSA STATUS

The application of the SB assessment identified 8,503 drivers as "OSA Potential" who were formerly "No OSA" or previously identified as not having enough data to make an OSA determination. These drivers joined the 879 drivers already included in the "OSA Potential" group from the original CDSRF. Table 3 displays the driver counts for all the OSA groupings, showing the counts when using original CDSRF data (via the CDME) and after SB application (third column). The bottom row in Table 3 represents drivers without enough data to have been properly assigned to an OSA group. Using only CDME data, 6,334 drivers were not grouped into an OSA status because of insufficient data; however, a significant portion of these drivers were reassigned using the SB assessment, leaving only 56 drivers with insufficient data to assign to an OSA group. In Table 4, the percentage of assessed drivers in each OSA risk group is shown. Using CDME data to determine OSA status, the percentage of drivers in the "OSA Potential" risk group was 6.40% and in the "OSA Diagnosed" risk groups totaled 7.15%. When the SB assessment was applied, the percentage of drivers in the "OSA Potential" risk group grew to 46.91%. The percentage of drivers in the "OSA Diagnosed" risk groups totaled 4.90%.

Table 3. Driver counts for CDME and SB OSA risk groups.

OSA Group	Driver Counts using CDME Data	Driver Counts after Applying SB
No OSA	11,864	9,639
OSA Potential	879	9,382
OSA Diagnosed: Treated	724	724
OSA Diagnosed: Untreated	139	139
OSA Diagnosed: Unsure of treatment	118	118
Total Number of Drivers Included in Follow-Up Analysis (Sum of All Drivers with an OSA Group)	13,724	20,002
Not enough data	*6,334*	*56*

Table 4. OSA risk group percentage of total drivers included in analysis for CDME and SB OSA risk groups.

OSA Group	Percentage of Drivers with an OSA Group – CDME Data	Percentage of Drivers with an OSA Group – Driver Counts after Applying SB
No OSA	86.45%	48.19%
OSA Potential	6.40%	46.91%
OSA Diagnosed: Treated	5.28%	3.62%
OSA Diagnosed: Untreated	1.01%	0.69%
OSA Diagnosed: Unsure of treatment	0.86%	0.59%

POISSON REGRESSION MODEL RESULTS ASSESSING SAFETY OUTCOME RISK BY OSA GROUP STATUS AND AGE QUARTILE

The following results are from the Poisson regression models that assessed safety outcome rates by OSA group status in each age quartile, controlling for BMI. The age quartiles were 21 to 33 years old, 34 to 42 years old, 43 to 51 years old, and 52 years and older.

The number of drivers in each OSA group and age quartile are listed in the tables below. Table 5 includes the drivers from the carrier-level crash analysis using non-zero carrier exposure data. Table 6 includes the drivers from the national crash analysis using non-zero national exposure data.

Table 5. Number of drivers by OSA status groups and age quartile for carrier crash safety outcome analysis.

OSA Status Group	Drivers 21 to 33 Years	Drivers 34 to 43 Years	Drivers 43 to 51 Years	Drivers 52 Years and Older
No OSA	2,577	2,186	2,227	1,402
OSA Diagnosed: Treated	91	137	135	133
OSA Diagnosed: Untreated	19	35	37	22
OSA Diagnosed: Unsure of Treatment	10	24	22	39
OSA Potential	1,752	1,794	2,041	2,267
Not Enough Data	2	6	7	32

Table 6. Number of drivers by OSA status groups and by age quartile for national crash and violation safety outcome analysis.

OSA Status Group	Drivers 21 to 33 Years	Drivers 34 to 43 Years	Drivers 43 to 51 Years	Drivers 52 Years and Older
No OSA	2,794	2,373	2,437	1,483
OSA Diagnosed: Treated	109	176	217	220
OSA Diagnosed: Untreated	25	40	45	28
OSA Diagnosed: Unsure of Treatment	11	25	28	51
OSA Potential	1,929	1,994	2,317	2,758
Not Enough Data	2	6	8	36

Table 7 shows the RRs and 95% CIs for each of these models. The comparison for each row in the table is to the group of drivers who did not have OSA for the same age quartile. Significant RRs at the $\alpha = 0.05$ level are denoted with an * and are set in bold font. There were four

significant findings. Drivers aged 34 to 42 with diagnosed and treated OSA were 82% less likely to be involved in a carrier preventable crash than drivers who did not have OSA. Drivers with diagnosed but untreated OSA were 2.21 times more likely to be involved in a carrier preventable crash (age group 43 to 51 years), 2.60 times more likely to be involved in a national crash (age group 21 to 33 years), and 2.42 times more likely to be involved in a violation (age group 52 years and older) compared to drivers without OSA. All other comparisons between age quartiles and OSA groups found no significant differences in risk of involvement in a safety outcome.

Table 7. RRs and 95% CIs for OSA (controlling for BMI).

Safety Outcome and Age Quartile	No OSA	Diagnosed: Treated	Diagnosed: Untreated	Diagnosed: Unsure	Potential
Total Carrier: 21 to 33	1.00	1.06 (0.645, 1.71)	1.40 (0.57, 3.41)	0.00 (0, Inf)	0.95 (0.81, 1.12)
Total Carrier: 34 to 42	1.00	0.67 (0.43, 1.04)	0.74 (0.33, 1.69)	0.57 (0.14, 2.32)	0.99 (0.83, 1.18)
Total Carrier: 43 to 51	1.00	0.76 (0.52, 1.13)	1.37 (0.72, 2.60)	1.48 (0.69, 3.16)	0.99 (0.83, 1.17)
Total Carrier: 52+	1.00	0.81 (0.53, 1.22)	1.08 (0.51, 2.29)	0.32 (0.08, 1.28)	0.85 (0.70, 1.02)
Carrier Preventable: 21 to 33	1.00	0.47 (0.19, 1.18)	1.53 (0.48, 4.86)	0.00 (0, Inf)	0.96 (0.77, 1.19)
Carrier Preventable: 34 to 42	1.00	**0.18*** (0.07, 0.51)	0.85 (0.31, 2.32)	0.49 (0.07, 3.53)	0.87 (0.69, 1.10)
Carrier Preventable: 43 to 51	1.00	0.84 (0.48, 1.47)	**2.21*** (1.01, 4.81)	2.42 (0.98, 5.97)	1.14 (0.90, 1.45)
Carrier Preventable: 52+	1.00	0.66 (0.35, 1.25)	0.89 (0.28, 2.81)	0.31 (0.04, 2.24)	0.80 (0.62, 1.04)
National Crashes: 21 to 33	1.00	0.53 (0.21, 1.33)	**2.60*** (1.12, 6.01)	2.14 (0.52, 8.70)	1.05 (0.84, 1.32)
National Crashes: 34 to 42	1.00	0.49 (0.23, 1.02)	1.14 (0.41, 3.14)	0.00 (0, Inf)	1.04 (0.82, 1.32)
National Crashes: 43 to 51	1.00	0.69 (0.40, 1.18)	1.66 (0.79, 3.47)	0.42 (0.06, 2.99)	1.09 (0.87, 1.37)
National Crashes: 52+	1.00	1.30 (0.79, 2.13)	0.81 (0.20, 3.32)	0.72 (0.23, 2.30)	0.99 (0.78, 1.27)
Violations: 21 to 33	1.00	0.44 (0.19, 1.01)	1.20 (0.44, 3.26)	0.72 (0.10, 5.16)	0.94 (0.78, 1.14)
Violations: 34 to 42	1.00	0.76 (0.43, 1.35)	1.43 (0.62, 3.30)	0.00 (0, Inf)	1.05 (0.84, 1.29)
Violation: 43-51	1.00	0.58 (0.31, 1.10)	0.79 (0.25, 2.53)	1.02 (0.25, 4.18)	1.21 (0.97, 1.51)
Violation: 52+	1.00	0.64 (0.33, 1.23)	**2.42*** (1.05, 5.59)	1.04 (0.38, 2.85)	1.04 (0.81, 1.33)

** indicates a significant RR at the α = 0.05 level*

POISSON REGRESSION MODEL RESULTS ASSESSING SAFETY OUTCOME RISK BY OSA GROUP

Poisson regression models were used to compare the safety performance of the No OSA group to the other OSA groups. Drivers in the model had to have positive, non-zero exposure to be included in the model. In each safety metric, the number of crashes or violations was predicted

by OSA group, with an offset term for exposure. In the carrier crash models (all crashes and preventable crashes), the carrier exposure term was used. In the national crash and moving violation models, the national exposure term was used.

Total Carrier Crashes

Table 8 shows the RRs and corresponding 95% CIs from the model using total carrier crashes. The comparison in each row is to the non-OSA group. Significant RRs at the $\alpha = 0.05$ level are denoted with an *. Drivers with diagnosed and treated OSA had a 22% lower risk of being involved in a carrier crash compared to drivers who did not have OSA. No other comparisons were statistically significant.

Table 8. Poisson regression RRs and 95% CIs for total carrier crashes.

Predictor Variables	Risk Ratio	Lower CI	Upper CI
OSA Diagnosed: Treated	0.78*	0.64	0.95
OSA Diagnosed: Untreated	1.08	0.74	1.57
OSA Diagnosed: Unsure of Treatment	0.74	0.41	1.34
OSA Potential	0.93	0.86	1.00

** indicates a significant RR at the α = 0.05 level*

Carrier Preventable Crashes

Table 9 shows the RRs and 95% CIs from the model using carrier preventable crashes. The comparison in each row is to the non-OSA group. Significant RRs at the $\alpha = 0.05$ level are denoted with an *. Drivers with diagnosed and treated OSA were 50% less likely to be involved in a carrier preventable crash compared to the drivers who did not have OSA. No other comparisons were statistically significant.

Table 9. Poisson regression RRs and 95% CIs for carrier preventable crashes.

Predictor Variables	Risk Ratio	Lower CI	Upper CI
OSA Diagnosed: Treated	0.50*	0.36	0.70
OSA Diagnosed: Untreated	1.24	0.76	2.00
OSA Diagnosed: Unsure of Treatment	0.89	0.42	1.87
OSA Potential	0.90	0.81	1.00

** indicates a significant RR at the α = 0.05 level*

National Crashes

Table 10 shows the RRs and 95% CIs from the model using national crashes. The comparison in each row is to the non-OSA group. Significant RRs at the $\alpha = 0.05$ level are denoted with an *. Drivers with diagnosed and untreated OSA were 1.66 times more likely to be involved in a national crash than drivers who did not have OSA. None of the remaining comparisons were statistically significant.

Table 10. Poisson regression RRs and 95% CIs for national crashes.

Predictor Variables	Risk Ratio	Lower CI	Upper CI
OSA Diagnosed: Treated	0.83	0.63	1.11
OSA Diagnosed: Untreated	1.66*	1.06	2.59
OSA Diagnosed: Unsure of Treatment	0.69	0.31	1.54
OSA Potential	1.10	0.99	1.23

Moving Violations

Table 11 displays the RRs and 95% CIs from the model for moving violations. The comparison in each row is to the non-OSA group. Significant RRs at the $\alpha = 0.05$ level are denoted with an *. Drivers with diagnosed and treated OSA had a 47% lower risk of a moving violation compared to drivers who did not have OSA. No other comparisons were statistically significant.

Table 11. Poisson regression RRs and 95% CIs for moving violations.

Predictor Variables	Risk Ratio	Lower CI	Upper CI
OSA Diagnosed: Treated	0.53*	0.39	0.73
OSA Diagnosed: Untreated	1.25	0.79	1.96
OSA Diagnosed: Unsure of Treatment	0.64	0.30	1.34
OSA Potential	1.04	0.94	1.14

** indicates a significant RR at the $\alpha = 0.05$ level*

CHAPTER 4. DISCUSSION

Currently, the Medical Examiner's Handbook (FMCSA, n.d.) does not provide any advisory criteria for OSA. The only OSA guidance for medical examiners is one question on the required CDME inquiring whether the driver has any "sleep disorders, pauses in breathing while asleep, daytime sleepiness, or loud snoring." A medical examiner can attempt to acquire information regarding the possibility of sleep disorders if time permits and they are trained specifically on what to look for. However, relying on drivers to be open and frank is insufficient in screening for OSA in this population. The SB is a simple and quick questionnaire that uses objective and subjective information that can assist medical examiners in identifying drivers who should be tested for OSA.

Using the SB questionnaire, more drivers were grouped as OSA Potential or No OSA than in the CDSRF data set. The OSA Potential group in the current study included 9,382 drivers (over 10 times the number in the CDSRF). The OSA Potential drivers included 6,462 drivers reassigned from the No OSA group, 2,042 reassigned from the Not Enough Data group, and 879 drivers from the CDSRF grouping. Almost 47% of the drivers in the current study were grouped as OSA Potential and would require a polysomnography test to determine a diagnosis of OSA. Popević et al. (2017) screened 100 hundred CMV drivers for OSA using the SB questionnaire and determined OSA status with polysomnography. Researchers found that 57% of the drivers who screened as potentially having OSA by the SB received positive results for OSA from their polysomnography. If 57% of this study's drivers were diagnosed with OSA based on the result of the polysomnography test, the current sample would include ≈ 31.6% diagnosed with OSA. This would be larger than other studies that suggest ≈ 25% of the CMV population has OSA (Berger et al., 2012; Mabry et al., 2016; Peppard et al., 2013), but is likely more accurate than the 7.2% diagnosed in the CDSRF. The SB application in the current study also identified an additional 4,236 drivers who did not have enough data for analysis in the CDSRF study as low risk for OSA. The No OSA group included 5,403 drivers who did not change groups after SB application. Additionally, the screening of drivers using the SB reduced the number of drivers whose risk of OSA was unknown, providing medical examiners with better precision in identifying drivers with a low risk of OSA.

Poisson regression models were used to assess different safety outcomes by OSA group status and age quartile, controlling for BMI. This was a replication of the analysis used in Hickman et al. (under Agency review) but using the SB recategorization in the current study. The results in the current study were similar to those reported in the CDSRF with respect to two findings. First was the risk in safety outputs between the OSA Diagnosed: Untreated group and the No OSA group, with several age quartiles showing a significant increased risk in the rate of safety outputs for the OSA Diagnosed: Untreated compared to the No OSA group. Second, a prominent finding in the CDSRF was the significantly reduced risk in the rate of safety outputs between the OSA Diagnosed: Treated group and the No OSA group in the 34 to 42 age quartile. This finding was a bit surprising, as prior studies found that treating OSA lowers risk compared to drivers without OSA (Burks et al., 2016). The recategorization in the current study (i.e., removing those drivers who potentially have OSA from the No OSA group and moving them into the Potential OSA group) did not find a different output.

However, there was one primary difference between the analysis outputs in the CDSRF and the current study. The current study did not find any significant outputs when comparing the OSA Potential group and the No OSA group. Those assigned to the OSA Potential group by medical examiners in the CDSRF likely exhibited symptomology that indicated it was highly likely they had OSA, whereas the current study included a more liberal OSA screening approach that likely included 20% or more of the drivers who would not be diagnosed with OSA. Thus, these recategorized drivers in the current study might have been enough to push down the rate in safety outputs in the OSA Potential group so they were not significantly different from the No OSA group.

In addition to following Hickman et al.'s (under Agency review) methodology in comparing safety outcomes using age quartile, the current study also compared safety outputs based solely on OSA groupings. Drivers in the OSA Diagnosed: Treated group were half as likely to be in a carrier preventable crash, 47% less likely to be involved in a moving violation, and 22% less likely to be involved in a carrier crash than drivers in the No OSA group. However, the age quartiles were used in the CDSRF, as older drivers were far more likely to be diagnosed with health conditions, including OSA, but were also significantly safer than younger drivers across all the safety outputs. Thus, these outputs should be interpreted with caution. Drivers with untreated OSA were 1.66 times more likely to be involved in a national crash than drivers who did not have OSA. This result supports the findings in Hickman et al. (under Agency review), where age quartiles were used, and those in Burks et al. (2016).

The efficacy of the SB in screening for OSA in this population should be further evaluated. Screening CMV drivers with the SB and then conducting a polysomnography test for an OSA diagnosis would determine how well the SB is able to screen CMV drivers for OSA. However, it is clear that the SB provides a better screening evaluation for CMV drivers undergoing a CDME than the current guidance given to medical examiners (i.e., no guidance on how to screen for OSA other than one question) in referring drivers for a polysomnography test.

LIMITATIONS

This study relied on data collected for the CDSRF. Limitations regarding the collection of these data can be found in Hickman et al. (under Agency review). In addition, the application of the SB did not include neck circumference; thus, the groupings do not reflect what the SB might recommend were this information available.

APPENDIX A. STOP-BANG QUESTIONNAIRE

Please answer the following questions below to determine if you might be at risk.

1) Do you Snore Loudly (loud enough to be heard through closed doors or your bed-partner elbows you for snoring at night)?
   Yes No

2) Do you often feel Tired, Fatigued, or Sleepy during the daytime (such as falling asleep during driving or talking to someone)?
   Yes No

3) Has anyone Observed you Stop Breathing or Choking/Gasping during your sleep?
   Yes No

4) Do you have or are being treated for High Blood Pressure?
   Yes No

5) Body Mass Index more than 35 kg/m^2?
   Yes No

6) Age older than 50?
   Yes No

7) Neck size large? (Measured around Adams apple)
   For male, is your shirt collar 17 inches / 43cm or larger?
   For female, is your shirt collar 16 inches / 41cm or larger?
   Yes No

8) Gender = Male?
   Yes No

Scoring or general population
OSA - Low Risk : Yes to 0 - 2 questions
OSA - Intermediate Risk : Yes to 3 - 4 questions
OSA - High Risk : Yes to 5 - 8 questions
or Yes to 2 or more of 4 STOP questions + male gender
or Yes to 2 or more of 4 STOP questions + BMI > 35kg/m2
or Yes to 2 or more of 4 STOP questions + neck circumference 17 inches / 43cm in male or 16 inches / 41cm in female

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