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# Commercial Motor Vehicle Health and Fatigue Study

Final Report

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Lighting	Technology
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## EXECUTIVE SUMMARY

Fatigue is a major risk factor in commercial motor vehicle operations, identified in naturalistic driving studies as a contributing factor in approximately 20 percent of safety-critical incidents. Understanding the nature of fatigued driving requires attention to several elements of the driving situation, including driver characteristics. The purpose of the present report is to explore driver body mass index (BMI) as a characteristic which may put one at increased risk for driving while fatigued.

Medical and transportation safety literature was reviewed to support the notion that obesity is linked with greater sleep problems and their associated consequences, such as excessive daytime sleepiness, which puts one at increased risk for driving while fatigued.

### *Analysis of Naturalistic Driving Data*

A major component of this report involves the reanalysis of a large naturalistic driving data set with 103 commercial drivers. Using two independent measures of fatigue (Observer Rating of Drowsiness [ORD] and Estimated Manual PERCLOS [EMP]), comparisons were made between drivers classified as being normal weight, overweight, or obese to determine if increased body mass is linked to a greater risk for fatigued driving.

BMI is an index of weight adjusted for the height of an individual. While BMI is not a direct measure of body fat, it is the most prevalent measure used in studies of overweight/obese individuals. BMI is calculated by dividing a person's weight in pounds by height in inches squared, multiplied by 705. The National Institutes of Health (NIH) defines normal weight individuals as having a BMI score of 18.5 – 24.9, whereas overweight individuals have a BMI of 25 – 29.9 and obese individuals have a BMI greater than or equal to 30 (National Institute of Diabetes and Digestive and Kidney Diseases, NIDDKD, 2007).<sup>(1)</sup>

Of the 103 drivers analyzed for this study, a majority (81.6 percent) were classified as either overweight or obese based on their BMI. A total of 55 drivers (53.4 percent) were classified as obese; this is a considerably higher percentage than is seen in the general U.S. population, recently estimated to be 34 percent (Centers for Disease Control and Prevention, 2007).<sup>(2)</sup>

The results of the fatigue analyses indicated that obese individuals had between 1.89 [Confidence Interval (CI) = 1.33 – 2.70] and 8.31 (CI = 5.38 – 12.84) times greater risk than normal weight individuals for driving while fatigued, depending on the fatigue measure used. When examining combinations of the BMI classifications, overweight/obese individuals had between 1.69 (CI = 1.19 – 2.40) and 8.95 (CI = 5.82 – 13.77) times greater risk than normal weight individuals for driving while fatigued for the EMP (threshold of 12 percent) and ORD measures. (Note that a significant odds ratio was not found for the EMP threshold of 8 percent for this comparison). Also, when comparing obese individuals to non-obese individuals (i.e., a combination of normal weight and overweight individuals), obese individuals were found to have between 1.22 (ORD; CI = 1.03 – 1.45) and 1.69 (EMP with 12 percent threshold; CI = 1.32 – 2.18) times greater risk for driving while fatigued across the fatigue measures.

Analyses were also performed to determine whether there is increased risk for experiencing a safety-critical event based on BMI. The odds ratios for these comparisons showed that overweight individuals were at 1.47 times greater risk (CI = 1.17 – 1.84) than normal weight individuals for experiencing a safety-critical event. However, there was no greater risk for experiencing a safety-critical event when comparing obese and normal weight individuals. Obese individuals were at 1.63 times greater risk (1.36 – 1.94) than overweight individuals for experiencing a safety-critical event, and were at 1.37 times greater risk (CI = 1.19 – 1.59) when compared to non-obese individuals. These findings support the notion that individuals with a higher BMI are at greater risk than normal weight individuals for experiencing a safety-critical incident.

When examining only safety-critical incidents where the truck driver was judged to be at-fault, there were some mixed results when comparing fatigue scores across BMI categories. Odds ratios indicated no significant differences when looking at the BMI categories (and various combinations) for ORD. However, obese individuals were at 3.09 times greater risk (CI = 1.08 – 8.82) than normal weight individuals for being above the EMP fatigue threshold of 12 percent in the 1 min before experiencing a safety-critical event. Combining classifications for this EMP threshold level also showed that overweight/obese individuals were at 2.87 times greater risk (CI = 1.01 – 8.14) than normal weight individuals for driving while fatigued just before a safety-critical incident, while obese individuals were at 1.99 times greater risk (CI = 1.02 – 3.88) than non-obese individuals. Similar results were found when using the lower EMP threshold of 8 percent.

As a whole, these results indicate a clear relationship between BMI and fatigued driving as well as BMI to safety-critical event involvement, which suggests that obese individuals are at greater risk than non-obese individuals. Limitations to this research which should be considered are the relatively small sample size (n=103), and the fact that drivers' height and weight were self-reported, which may have impacted the results.

### *Focus Group*

A focus group with five commercial drivers was held to explore perceived barriers to living a healthy lifestyle while on the road. The participants believed that environmental issues (e.g., the questionable nutritional quality of food served at truck stops; lack of access to a variety of restaurants) and organizational design issues (e.g., scheduling; company policies when loading/unloading; company support for health) were major barriers to living a healthy lifestyle while on the road.

Suggestions for improving commercial drivers' health included packing healthy foods from home (e.g., fruits and vegetables, cooked chicken) and storing them in a refrigerator in their truck. Another suggestion for drivers was to get out of the truck as often as possible to stretch, walk, or do light exercise.

Participants also suggested that truck companies get involved to improve their drivers' health by allowing time in drivers' schedules to stop for exercise (e.g., stretching and walking) and to prepare meals for themselves. It was also suggested that companies educate and motivate drivers to care for themselves by exercising and eating healthy foods. Participants also believed that

companies should work with receivers to allow drivers more flexibility for getting outside of their truck when it is being loaded/unloaded. Finally, it was suggested that companies work with truck stop owners to improve the nutritional quality of foods served as well as providing a variety of healthy food selections.

### *Conclusions*

A number of trucking fleets have shown increased interest in the health and wellness of their employees over the past decade. Based on the results of this report, it is recommended that action be taken to develop and test various methods for educating and motivating drivers to eat healthy foods, exercise, and manage their weight. In addition, efforts need to be made to gain the support of fleets and other organizations (e.g., truck stops) toward addressing the issue of obesity among this population. By integrating health and wellness programs throughout the commercial motor vehicle (CMV) culture and providing drivers with greater opportunity to plan/prepare meals, exercise, and rest, fleets will likely see improved employee morale, lower turnover, reduced medical costs and increased profits (Krueger et al., 2007).<sup>(3)</sup> Individual truck drivers who are able to control their weight or make improvements in physical health will reap the potential benefits of improved quality of life and greater longevity. Finally, if CMV drivers are healthier, thus reducing the accident risk identified in this report, society in general would benefit from greater traffic safety.



# TABLE OF CONTENTS

<b>LIST OF FIGURES.....</b>	<b>vii</b>
<b>LIST OF TABLES.....</b>	<b>ix</b>
<b>LIST OF ABBREVIATIONS AND SYMBOLS .....</b>	<b>xi</b>
<b>CHAPTER 1. INTRODUCTION.....</b>	<b>1</b>
<b>CHAPTER 2. LITERATURE REVIEW ON BODY MASS INDEX &amp; FATIGUE .....</b>	<b>3</b>
<b>DEFINITION AND PREVALENCE OF OVERWEIGHT AND OBESE INDIVIDUALS .....</b>	<b>3</b>
<b>OBESITY AND FATIGUE .....</b>	<b>4</b>
<b>SLEEP APNEA, FATIGUE, AND AUTOMOBILE ACCIDENTS .....</b>	<b>5</b>
<b>SUMMARY .....</b>	<b>7</b>
<b>CHAPTER 3. FATIGUE ANALYSES BY BODY MASS INDEX.....</b>	<b>9</b>
<b>METHODS .....</b>	<b>9</b>
<b>Data-gathering Equipment.....</b>	<b>9</b>
<b>Data Reduction and Identification of Safety-critical Events .....</b>	<b>12</b>
<b>Fatigue Measurements.....</b>	<b>14</b>
<b>RESULTS .....</b>	<b>16</b>
<b>BMI Classifications .....</b>	<b>16</b>
<b>ORD Results by BMI Classification for Total Driving Episodes .....</b>	<b>17</b>
<b>EMP Results by BMI Classification for Total Driving Episodes .....</b>	<b>18</b>
<b>Safety-Critical Event Involvement by BMI Classifications .....</b>	<b>20</b>
<b>ORD Scores by BMI Classification for At-Fault Safety-Critical Incidents .....</b>	<b>21</b>
<b>EMP Scores by BMI Classification for At-Fault Safety-Critical Incidents .....</b>	<b>22</b>
<b>Discussion of Results.....</b>	<b>25</b>
<b>CHAPTER 4. FOCUS GROUP.....</b>	<b>29</b>
<b>SUMMARY OF FOCUS GROUP.....</b>	<b>30</b>
<b>CHAPTER 5. HEALTH &amp; WELLNESS PROGRAMS FOR COMMERCIAL DRIVERS .....</b>	<b>33</b>
<b>SUMMARY .....</b>	<b>35</b>
<b>CHAPTER 6. CONCLUSIONS &amp; FUTURE RESEARCH.....</b>	<b>37</b>
<b>FUTURE RESEARCH.....</b>	<b>38</b>
<b>APPENDIX A: TELEPHONE RECRUITMENT SCRIPT FOR FOCUS GROUP.....</b>	<b>43</b>
<b>APPENDIX B: QUESTIONS TO GUIDE FOCUS GROUP.....</b>	<b>45</b>
<b>REFERENCES .....</b>	<b>47</b>





## LIST OF FIGURES

Figure 1. Photo. Encased computer and external hard drive installed under the passenger seat..	10
Figure 2. Photo. Encased computer and external hard drive installed in the truck's rear storage compartment. ....	10
Figure 3. Diagram. Camera directions and approximate fields of view. ....	11
Figure 4. Photo. Split-screen presentation of the four camera views. ....	12
Figure 5. Screen shot. ORD rating scale used by data analysts (adapted from Wierwille & Ellsworth, 1994). ....	15
Figure 6. Graph. ORD scores above/below threshold by BMI classification. ....	17
Figure 7. Graph. EMP scores above/below the 12% threshold by BMI classification. ....	18
Figure 8. Graph. EMP scores above/below the 8% threshold by BMI classification. ....	19
Figure 9. Graph. Safety-critical event involvement by BMI classification. ....	21
Figure 10. Graph. ORD scores by BMI classification for at-fault safety-critical incidents. ....	22
Figure 11. Graph. EMP scores by BMI classification for at-fault safety-critical incidents (12% threshold). ....	23
Figure 12. Graph. EMP scores by BMI classification for at-fault safety-critical incidents (8% threshold). ....	25
Figure 13. Diagram. Socio-Technical Systems Model (Emery & Trist, 1960). ....	38
Figure 14. Photo. Actigraph device. ....	40
Figure 15. Screen shot. Example of actigraphy data output. ....	40



## LIST OF TABLES

Table 1. Triggers and trigger values used to identify critical incidents.....	13
Table 2. ORD scores above/below threshold by BMI classification.....	17
Table 3. EMP scores above/below the 12% threshold by BMI classification.....	18
Table 4. EMP scores above/below the 8% threshold by BMI classification.....	19
Table 5. Safety-critical event involvement by BMI classification.....	20
Table 6. ORD scores by BMI classification for at-fault safety-critical incidents.....	22
Table 7. EMP scores by BMI classification for at-fault safety-critical incidents (12% threshold).....	23
Table 8. EMP scores by BMI classification for at-fault safety-critical incidents (8% threshold).....	24



## **LIST OF ABBREVIATIONS AND SYMBOLS**

ATRI	American Transportation Research Institute
BMI	Body Mass Index
CDIDS	Commercial Driver Individual Differences Study
CDL	Commercial Driver's License
CDLIS	Commercial Driver's License Information System
CI	Confidence Interval
CMV	Commercial Motor Vehicle
CPAP	Continuous Positive Airway Pressure
DAS	Data Acquisition System
DDWS FOT	Drowsy Driving Warning System Field Operational Test
DOT	Department of Transportation
EDS	Excessive Daytime Sleepiness
EMP	Estimated Manual PERCLOS
FARS	Fatality Analysis Reporting System
GES	General Estimates System
GPS	Global Positioning System
LCL	Lower Confidence Level
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
NIDDKD	National Institute of Diabetes and Digestive and Kidney Diseases
NIH	National Institutes of Health
NSTSCCE	National Surface Transportation Safety Center for Excellence
ORD	Observer Rating of Drowsiness
OSA	Obstructive Sleep Apnea

SDB	Sleep Disordered Breathing
SNI	Schneider National, Inc.
UCL	Upper Confidence Level
VTI	Virginia Tech Transportation Institute

## CHAPTER 1. INTRODUCTION

Fatigue<sup>1</sup> is a major risk factor associated with commercial motor vehicle (CMV) crashes. For example, McCartt, Rohrbaugh, Hammer, and Fuller (2000)<sup>(4)</sup> found that of 593 randomly selected long-distance truck drivers, 47.1 percent reported having fallen asleep at the wheel of their truck at some point, while 25.4 percent admitted having done so in the past year. While these instances of driving while fatigued do not necessarily end in a crash, the risk is certainly present. For example, fatigue is a frequently cited probable cause for CMV crashes (e.g., Transportation Safety Board, 1990).<sup>(5)</sup> This notion is supported both by retrospective and naturalistic driving studies (Hanowski, Wierwille, Garness, & Dingus, 2000; Transportation Safety Board, 1990; Wiegand, Hanowski, Olson, and Melvin, 2008).<sup>(6,5,7)</sup>

Researchers at the Virginia Tech Transportation Institute (VTTI) have completed several naturalistic driving studies which investigated fatigue as a contributing factor to safety-critical incidents involving large trucks. When studying local/short-haul truck drivers, Hanowski et al. (2000)<sup>(6)</sup> identified fatigue as a contributing factor in 21 percent of 249 critical incidents. These findings were recently replicated in an analysis of 16 months of continuous naturalistic driving data with 103 long-haul and line-haul commercial drivers (Wiegand et al., 2008).<sup>(7)</sup> In this study, fatigue was found to be a contributing factor in 16 percent of crashes and near-crashes (n = 134). Using naturalistic video data, Wiegand et al. (2008)<sup>(7)</sup> also implemented two independent measures of fatigue (described in more detail below) and found that for the Observer Rating of Drowsiness (ORD) measure, drivers were rated as fatigued in 26 percent of the total safety-critical events identified (n = 952). Using another measure of fatigue (PERCLOS, threshold of 8 percent; described more below), it was found that fatigue was a factor in 21 percent of total safety-critical events (n = 807). Given these findings, it is clear that fatigued driving among CMV drivers represents a significant issue worthy of further exploration to determine its risk factors.

Understanding the nature of fatigued driving requires attention to several elements of the driving situation, including driver characteristics (e.g., age), environmental parameters (e.g., road type, time of day, presence of other vehicles, and other drivers' behavior), vehicle factors (e.g., vibrations), and organizational policies and practices (e.g., hours-of-service regulations). This report focuses on characteristics of the *driver*, specifically driver health, and how one's body mass index (BMI) may be linked to driving while fatigued. This report consists of several sections, including: a literature review on health and its link to fatigue; reanalysis of the naturalistic data set Wiegand et al. (2008)<sup>(7)</sup> used to explore commercial driver fatigue; a summary of a focus group with commercial drivers which explored the perceived barriers to

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<sup>1</sup> While the authors of this report understand the distinction between the two terms, in this report, "fatigue" and "drowsiness" will be used interchangeably as is often done in the transportation safety literature. However, the meaning of these terms for the purposes of this report is more concurrent with the formal definition of "drowsiness" (i.e., "sleepiness"; Stutts, J.C., Wilkins, J.W., & Vaughn, B.V. [1999] Why do people have drowsy driving crashes? Input from drivers who just did. AAA Foundation for Traffic Safety. Washington, DC ).

living a healthy lifestyle on the road; and a summary of existing driver health and wellness programs.



## CHAPTER 2. LITERATURE REVIEW ON BODY MASS INDEX & FATIGUE

While some studies suggest that constrained and limited sleep schedules are the major underlying issues contributing to fatigue (e.g., Roehrs, Kryger, Roth, Dement, 2000)<sup>(8)</sup>, current research in the field of health and well-being has provided strong evidence for a link with obesity, and suggests that this relationship may have a more robust influence on fatigue and sleepiness in the U.S. (e.g., Vgontzas et al., 2006).<sup>(9)</sup> This issue is particularly important to examine with regard to CMV drivers, whose work schedules present few opportunities for exercise and proper nutrition (McCallum et al., 2003).<sup>(10)</sup>

The aim of the present review is to provide evidence for this link between personal health and fatigue, in particular the role of obesity in relation to an increased risk of driving while fatigued. Other principal causes of fatigue (i.e., sleep disorders) will also be reviewed with regard to obesity.

### DEFINITION AND PREVALENCE OF OVERWEIGHT AND OBESE INDIVIDUALS

The National Institutes of Health (NIH) define “overweight” and “obese” based on a measure known as BMI. BMI is an index of weight adjusted for the height of an individual. While BMI is not a direct measure of body fat, it is the most prevalent measure used in studies of overweight/obese individuals. BMI is calculated by:

$$\frac{\text{Weight (lbs)}}{\text{Height (in}^2\text{)}} \times 705$$

NIH defines normal weight individuals as having a BMI score of 18.5 – 24.9, whereas overweight individuals have a BMI of 25 – 29.9, and obese individuals have a BMI greater than or equal to 30 (National Institute of Diabetes and Digestive and Kidney Diseases, NIDDKD, 2007).<sup>(1)</sup>

The prevalence of overweight and obese individuals in the U.S. has doubled over the past three decades (Colditz, 2001; Audretsch & DiOrio, 2007)<sup>(11,12)</sup>, leading the World Health Organization (2008)<sup>(13)</sup> to decry the trend as an epidemic which poses a major risk for chronic diseases. Data gathered from 2001 to 2004 as part of the National Health and Nutrition Examination Survey suggest that approximately two-thirds of the U.S. adult population are overweight or obese, and estimates that of these 133.6 million individuals, nearly one-third may be characterized as obese (Kuczmarski & Flegal, 2000; NIDDKD, 2007).<sup>(14,1)</sup>

When considering CMV drivers as a population, there are few published reports of BMI as a demographic variable. Results from a survey conducted by Korelitz et al. (1993)<sup>(15)</sup> on 3,000 commercial drivers suggest that more than 40 percent were overweight, with the prevalence of obesity at 33 percent. A study of 4,826 randomly sampled commercial driver’s license (CDL) holders in the Philadelphia, PA area revealed that 49.6 percent of males were overweight based on a BMI value equal to or greater than 27.8 (Maislin, Dinges, Woodle, & Pack, 1997).<sup>(16)</sup> As these findings are over a decade old, it is reasonable to hypothesize that the prevalence of overweight/obesity among CMV drivers is even higher today, given the current rise in the national level of overweight/obesity.

## OBESITY AND FATIGUE

A large body of literature suggests that obesity plays a significant role in multiple health conditions such as diabetes, hypertension, stroke, and cardiovascular disease (Roberts & York, 2000).<sup>(17)</sup> In addition, research has consistently shown a significant relationship between obesity and multiple sleep-related problems such as Obstructive Sleep Apnea (OSA) and Excessive Daytime Sleepiness (EDS), both of which have been linked to risk factors for vehicular crashes (e.g., Krieger, 2007).<sup>(18)</sup>

OSA<sup>2</sup> is a chronic sleep disorder estimated to affect 2 to 4 percent of the U.S. adult population. It is characterized by persistent episodes of partial or complete obstruction of the upper airway during sleep, which results in a reduction of oxygen in the bloodstream. The brain reacts to the insufficient oxygen level by creating arousal to reopen the airway, often resulting in loud choking or snoring. These arousal events typically occur as often as 200-600 times per night, resulting in fragmented sleep. Individuals with untreated OSA typically suffer from a dramatic loss in deep, restorative sleep, which leads to feelings of excessive sleepiness during the day (Schwartz et al., 2008; Young, Palta, Dempsey, Skatrud, Weber, & Badr, 1993).<sup>(19,20)</sup>

While several risk factors have been identified for OSA (e.g., male sex, age), obesity is documented as one of the most robust (Mayo Clinic, 2008; Strollo & Rogers, 1996).<sup>(21,22)</sup> It is estimated that sleep apnea is present in approximately 40 percent of obese individuals, and 70 to 90 percent of OSA patients are obese (Wolk et al., 2003; Svatikova, Wolk, Gami, Pohanka, & Somers, 2005).<sup>(23,24)</sup> Gami et al. (2003)<sup>(25)</sup> suggest that while obesity may predispose one to OSA, OSA may in turn predispose individuals to increased obesity due to the effects of sleep deprivation on daytime sleepiness and disrupted metabolism. These findings suggest an independent and dynamic relationship between obesity and OSA.

OSA is linked with numerous symptoms, including excessive snoring, restless sleep, mood shifts (e.g., depression, anxiety, irritability), morning headaches, insomnia, trouble with concentration, hypertension, weight gain, nocturia, and night sweats. However, EDS is considered the most prominent symptom of OSA (National Heart, Blood, and Lung Institute, 2005).<sup>(26)</sup> EDS is a disorder in which there is a recurrent compulsion to sleep during inappropriate times, even when one has the will to remain awake (Resta et al., 2003).<sup>(27)</sup> The prevalence of EDS in the general population is estimated to range from 5 to 20 percent, depending on the measure used (Vgontzas, Bixler, & Chrousos, 2006).<sup>(9)</sup>

Several recent studies have reported evidence that obesity is associated with EDS and suggest that it may be a significant factor underlying the current elevated prevalence of fatigue and sleepiness in today's society (Vgontzas, Bixler, & Chrousos, 2006; Vgontzas & Kales, 1999;

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<sup>2</sup> The authors would like to note that there are three types of sleep apnea: obstructive, central, and mixed. However, obstructive sleep apnea (OSA) is the most common (American Sleep Apnea Association, [2008] Sleep apnea information. Retrieved November 12, 2008 from <http://www.sleepapnea.org/info/index.html?gclid=CMflvoan8pYCFQzHgodxzRXYg> ). Several studies cited in this document did not specify which type of sleep apnea was being addressed. In these cases, the authors of the present document assumed OSA was the specific type of sleep apnea being discussed.

Roehrs et al., 2000).<sup>(9,28,8)</sup> For example, in a sleep study assessing risk factors of EDS in a group of 1,741 individuals randomly recruited from a telephone book in Pennsylvania, Bixler and colleagues (2005)<sup>(29)</sup> reported a significantly greater prevalence of EDS among individuals with a BMI  $\geq$  28 compared to those with a lower BMI. Similar results were reported by both Resnick et al. (2006)<sup>(30)</sup> and Theorell-Haglow et al. (2006)<sup>(31)</sup>, whose analysis of large cross-sectional populations suggested that self-evaluated daytime fatigue and sleepiness were positively correlated with BMI.

Other studies have found a relationship between obesity and EDS in the absence of sleep disordered breathing (i.e., OSA). Vgontzas and colleagues (1998)<sup>(32)</sup> examined the relationship of obesity (with no OSA) to fatigue using both subjective and objective measures of sleepiness. Their findings showed greater reported daytime sleepiness in obese patients compared with non-obese controls as measured by total wake time, shorter sleep latencies, and decreased wake time after onset of sleep. These findings were later replicated by Punjabi et al. (1999), Resta et al. (2001), and Resta et al. (2003).<sup>(33,34,27)</sup> Bixler et al. (2005)<sup>(29)</sup> also showed that in a large randomized sample, obesity was a significant risk factor for EDS independently of OSA and age.

In summary, the findings above support the notion that obesity is strongly linked to OSA, which is associated with multiple symptoms affecting the quantity and quality of one's sleep. Further, even in the absence of OSA, obesity is a significant risk factor for experiencing EDS, which can impact not only one's health, but also one's safety and that of others. For example, Melamed & Oksenberg (2002)<sup>(35)</sup> found that individuals suffering from EDS are twice as likely to sustain an occupational injury than controls. Given these findings, could it be that overweight or obese individuals are more likely than normal weight individuals to experience fatigue which may place them at increased risk for a safety-critical incident while on the road?

## **SLEEP APNEA, FATIGUE, AND AUTOMOBILE ACCIDENTS**

While there is a plethora of research examining the relationship between obesity and numerous health conditions, there is a scarce amount exploring the influence of obesity on driver performance and safety. One source was found which reported that a recent analysis of Motor Carrier Management Information System (MCMIS) and Commercial Driver's License Information System (CDLIS) databases showed a 7 percent increase in the likelihood of experiencing a crash for obese drivers (Lantz, 2007).<sup>(36)</sup>

A greater literature exists on OSA and its relationship to commercial driving. OSA is a prevalent issue among CMV drivers and plays a significant role in both increased liability and healthcare expenses (Berger et al., 2005).<sup>(37)</sup> While Kryger et al. (2005)<sup>(38)</sup> predict that OSA afflicts approximately 4 percent of the U.S. adult population between the ages of 40 and 60, Pack, Dinges, and Maislin (2002)<sup>(39)</sup> investigated a sample of 406 CMV drivers and found that 6.9 percent had severe sleep apnea, 7.9 percent had moderate sleep apnea, and 21.2 percent had mild sleep apnea. Stoohs et al. (1995)<sup>(40)</sup> also assessed the prevalence of OSA and other forms of sleep disordered breathing (SDB) among truck drivers in the U.S. and reported that nearly 20 percent of drivers experienced regular sleep disturbances.

There is extensive support for the notion that patients with OSA are at greater risk for motor vehicle crashes (Aldrich, 1989; Barbe, Pericas, Munoz, et al., 1998; Findley, Unverzagt, &

Suratt, 1988; George, Nickerson, Hanly, et al., 1987; George & Smiley, 1999; Haraldsson, Carenfelt, Diderichsen, et al., 1990; Teran-Santos, Jimenez-Gomez, Cordero-Guevara, et al., 1999; Wu & Yan-Go, 1996; Young, Blustein, Finn, et al., 1997). (See references 41, 42, 43, 44, 45, 46, 47, 48, 49.) Patients with untreated OSA have an increased number of crashes which have been attributed to the increased inattention stemming from EDS (Haraldsson et al., 1990; Wu et al., 1996).<sup>(46,48)</sup> George et al. (1987)<sup>(44)</sup> reported that 27 individuals with a clinical diagnosis of OSA had an automobile accident rate more than twice that of a control group, while Findley et al. (1988)<sup>(43)</sup> found that the rate of crashes in a group of patients with documented OSA was 2.6 times that of all the licensed drivers in the state of Virginia. One major study which shows conflicting evidence to the above findings is the Pack, Dinges, and Maislin (2002)<sup>(39)</sup> sleep study in which no significant difference was found in crash rates between an OSA group and a control group. However, this same study found that when looking at the most severe vehicle crashes (multiple injuries and a vehicle being towed from the scene), those drivers in the severe OSA group were 4.6 times more likely than controls to be involved in such a crash.

With regard to specific impairments contributing to high automobile accident rates, Findley et al. (1995)<sup>(50)</sup> reported that OSA patients had poorer performance on a test of driving vigilance than did control subjects, and vigilance decreased as the severity of OSA increased. As such, the findings also supported the notion that impaired vigilance was associated with higher accident rates in patients with OSA as assessed by the computer program *Steer Clear*. Additional studies have also documented that participants with OSA are characterized by significant delays in reaction time and difficulty concentrating (Findley et al., 1986; Kales et al., 1985).<sup>(51,52)</sup>

George (2001)<sup>(53)</sup> examined motor vehicle collision data in a group of patients who had undergone OSA pre- and post- positive airway pressure treatment. When compared to controls matched for sex, age, and license classification, patients with OSA were found to be involved in a greater number of motor vehicle collisions than their counterparts before undergoing treatment. Most seminal of their findings, perhaps, lies in the post-treatment outcomes, where the number of motor vehicle collisions per driver/year was found to resume to a normal rate while driving exposure remained consistent. This suggests that any risk factors associated with OSA driving can be resolved through treatment. In line with these findings, and taking into account the noticeable sleepiness and impaired performance associated with OSA, Gurubhagavatula, Maislin, Nkwono, & Pack (2004)<sup>(54)</sup> suggest that it may be valuable to eliminate the presence of untreated OSA in commercial drivers. Using a community-based sample, this study identified commercial drivers with OSA who would derive safety-relevant benefits (i.e., reduction in crashes, improved driving performance) from positive airway pressure therapy. These authors concluded that a two-stage screening procedure encompassing questionnaire data (e.g., age, sex, height, weight, BMI) and blood oxygenation is most useful in identifying drivers with severe OSA and, in fact, is a highly accurate screening method.

Efforts to identify commercial drivers with OSA is essential as treatment would reduce cardiovascular disease, hypertension, and diabetes—three of the most expensive health expenditures in the CMV driver population (Young et al., 2002).<sup>(55)</sup> Berger et al. (2005)<sup>(37)</sup> examined a commercial recognition and treatment program for OSA which incorporated objective screening tools. For drivers with OSA who received treatment (with a continuous positive airway pressure treatment device), there was a 47.8 percent reduction in health care

costs (per member, per month), and a 73 percent reduction in preventable driving accidents among a sample of 225 drivers.

## **SUMMARY**

The research cited above provides evidence of a strong link between obesity and fatigue, and suggests that obesity may be a risk factor for driving while fatigued. Given that commercial drivers are exposed to a sedentary lifestyle (McCallum et al., 2003)<sup>(10)</sup> and spend long, irregular hours on the road, it seems logical that they are a high risk population for both obesity and fatigued driving.



## CHAPTER 3. FATIGUE ANALYSES BY BODY MASS INDEX

The following analyses were leveraged from data gathered during the Drowsy Driving Warning System Field Operational Test (DDWS FOT). The DDWS FOT was an evaluation of a drowsy driving warning system which yielded 12.3 terabytes of continuously recorded data, making it the largest known on-road study ever conducted by the U.S. Department of Transportation (DOT). The project collected extensive normative data on driving conditions, driver behaviors, safety-critical traffic events and baseline driving epochs. Several reports describing the results of the first 12 months of driving data from the DDWS FOT are available for further information, including details regarding the naturalistic methodology (Hanowski, Blanco, Nakata, et al., 2005; Hickman, Knippling, Olson, et al., 2005).<sup>(56,57)</sup> An additional 4 months of driving data were analyzed and coded, and two independent measures of fatigue, described below, were performed on the driving events for the entire DDWS FOT data set for a National Surface Transportation Safety Center for Excellence (NSTSCE)-funded study investigating environmental variables associated with fatigued driving (Wiegand et al., 2008).<sup>(7)</sup> Given the large amount of data collected for the DDWS FOT, this database is an excellent resource for data mining and exploring various topics in the realm of CMV driving safety. The stakeholders for NSTSCE recognized the usefulness of this large data set and commissioned the present study involving exploration of driver health and its relation to fatigue.

Driver participants' height and weight, which were self-reported upon beginning the DDWS FOT, were used to calculate driver BMI, and each driver was classified as either normal weight, overweight, or obese based on the parameters established by the NIH (NIDDKD, 2007).<sup>(1)</sup> The most fundamental analyses in the current study were descriptions and comparisons of instances where driver fatigue ratings were below versus above their relative thresholds. In addition, odds ratio statistics were performed to make comparisons of relative risk between BMI groupings.

The odds ratio is an estimate of relative risk, which is calculated by comparing the odds of some outcome occurring (e.g., fatigue rating above or below threshold) given the presence of some predictor factor, condition, or classification (e.g., normal weight versus overweight individuals). It is usually a comparison of the presence of a condition to its absence (e.g., fatigued and non-fatigued). Odds ratios of "1" indicate that the outcome is equally likely to occur given the condition. An odds ratio greater than "1" indicates that the outcome is more likely to occur given the condition. Odds ratios of less than "1" indicate that the outcome is less likely to occur (Pedhazur, 1997).<sup>(58)</sup> The odds ratio figures presented in this report are accompanied by a CI. An odds ratio is considered statistically significant if the CI does not include 1.0.

### METHODS

Below is a summary of the original DDWS FOT methodology as well as the fatigue measures used by Wiegand et al. (2008).<sup>(7)</sup> A full description of the methodology for the DDWS FOT can be found in Hanowski et al. (2005).<sup>(56)</sup>

#### Data-gathering Equipment

The data gathering from commercial trucks occurred in a naturalistic driving environment during normal operations. The participant sample included two different long-haul operation types

(truckload and less-than-truckload) and was intended to be generally representative of the long-haul and line-haul commercial vehicle driver population.

Forty-six truck tractors operated by three motor carriers were instrumented with data collection equipment. A Data Acquisition System (DAS) was installed in tractors to collect data continuously whenever the instrumented trucks were on and in motion. The DAS consisted of an encased unit housing a computer and external hard drive, dynamic sensors, an interface with the existing vehicle network, an “incident box,” and video cameras. Figure 1 shows an example of the encased unit installed under the passenger seat, while figure 2 shows an example of a DAS located in the truck’s rear storage compartment.



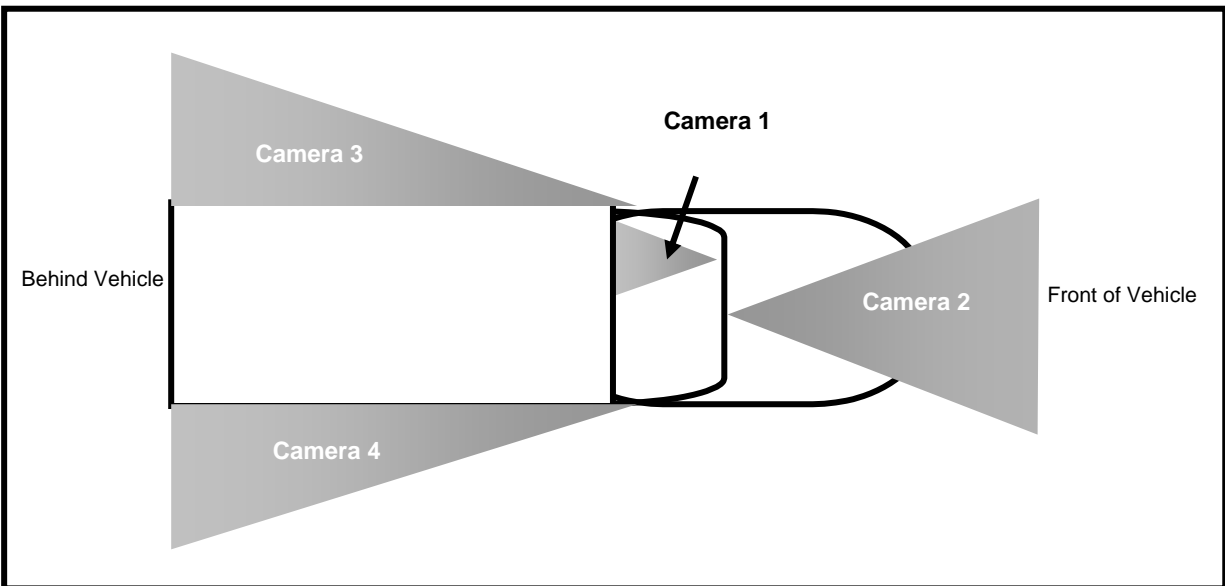
**Figure 1. Photo. Encased computer and external hard drive installed under the passenger seat.**



**Figure 2. Photo. Encased computer and external hard drive installed in the truck's rear storage compartment.**



Three types of data were collected continuously by the vehicle instrumentation: video, dynamic sensor, and audio. The four video cameras were oriented as follows: (i) forward road scene, (ii) backward from driver's face camera, (iii) rearward from the left side of the tractor, and (iv) rearward from the right side of the tractor. Figure 3 displays the camera views and approximate fields-of-view. Low-level infrared lighting (not visible to the driver) illuminated the vehicle cab so drivers' faces and hands could be viewed via the camera during nighttime driving. No cameras or other sensors were mounted on trailers. Therefore, there was no recorded view directly behind the truck and trailer, although following vehicles could usually be partially seen in the rearward side view cameras. The limited number of cameras, all tractor-mounted, restricted the analysis to primarily those events occurring in front and at the sides of the instrumented vehicle.



**Figure 3. Diagram. Camera directions and approximate fields of view.**

As shown in figure 4, the four camera images were multiplexed into a single image. A time-stamp (.mpg frame number) was also included in the .mpg data file but was not displayed on the screen. The frame number was used to synchronize the video (in .mpg format) and the truck/performance data (in .dat format).



**Figure 4. Photo. Split-screen presentation of the four camera views.**

Recorded dynamic data included basic vehicle motion parameters, such as speed, longitudinal acceleration (e.g., indicative of braking levels), and lateral acceleration. Vehicles were also equipped with Global Positioning System (GPS) sensors, lane trackers, and forward-looking radar units. The audio data were from an “incident box” with a push button and microphone for drivers to make verbal comments about traffic incidents. This feature was rarely used by drivers.

### **Data Reduction and Identification of Safety-critical Events**

There were three primary steps in detecting and classifying safety-critical events: (i) identifying potential events (mostly through the use of an event trigger program), (ii) checking the validity of these triggered events, and (iii) applying a data directory to verified conflict events. To identify events, a software program scanned the dynamic data set to identify notable actions, including hard-braking, quick-steering maneuvers, and short times-to-collision (close proximity with consideration of both range and range rate). Threshold values of these parameters (or “triggers”) were established to flag events for further review. Events could also be flagged by the driver via the incident button mentioned above. Finally, analysts reviewing the data could fortuitously identify safety-critical events not associated with the above triggers during their general review of the data, but this process was not comprehensive due to the huge size of the data set. Table 1 shows the seven triggers and their event signatures developed for this data.

**Table 1. Triggers and trigger values used to identify critical incidents.**

Trigger Type	Event Signature
Longitudinal Acceleration	<p>(1) Acceleration or deceleration greater than or equal to <math> 0.35g </math>. Speed greater than or equal to 15 mi/h.</p> <p>(2) Acceleration or deceleration greater than or equal to <math> 0.5g </math>. Speed less than or equal to 15 mi/h.</p>
Time-to-Collision	<p>(3) A forward time-to-collision value of less than or equal to 1.8 s, coupled with a range of less than or equal to 150 ft, a target speed of greater than or equal to 5 mi/h, a yaw rate of less than or equal to <math> 4^\circ/s </math>, and an azimuth of less than or equal to <math> 0.8^\circ </math>.</p> <p>(4) A forward time-to-collision value of less than or equal to 1.8 s, coupled with an acceleration or deceleration greater than or equal to <math> 0.35g </math>, a forward range of less than or equal to 150 ft, a yaw rate of less than or equal to <math> 4^\circ/s </math>, and an azimuth of less than or equal to <math> 0.8^\circ </math>.</p>
Swerve	(5) Swerve value of greater than or equal to 3. Speed greater than or equal to 15 mi/h.
Critical Incident Button	(6) Activated by the driver upon pressing a button, located by the driver's visor, when an incident occurred that he/she deemed critical.
Analyst Identified	(7) Event that was identified by a data reductionist viewing video footage; no other trigger listed above identified the event (i.e., Longitudinal Acceleration, Time-to-Collision, etc.).

Events were then reviewed to ensure that they represented actual safety-significant scenarios. Many events meeting the minimum dynamic trigger criteria were not actual crash threat situations. These were termed “non-conflicts.” Those events were judged via thorough review of the video to be true conflicts, and thus to have safety significance, were classified through the use of a detailed data directory. A detailed and comprehensive data directory of 54 variables and data elements was developed for analyzing events in this data set. This included classification variables relating to each overall event, to the instrumented vehicle or V1 (the truck) and driver, and (to a limited extent) the other involved vehicle/driver (V2) or non-motorist. Most of the variables in the data directory were the same as, or similar to, those used in major national crash databases such as the General Estimates System (GES), the Fatality Analysis Reporting System (FARS), and the Large Truck Crash Causation Study (LTCCS). In some cases, data element choices for some variables were revised to capitalize on the principal advantage of naturalistic

driving (i.e., the fact the event could be directly observed as opposed to reconstructed after the fact).

By their nature, the configuration of the instrumentation and the event detection routines limited the number of other vehicle encroachments toward instrumented vehicles (i.e., V1) that could be captured. For example, a vehicle (V2) rapidly closing toward the rear of V1's trailer could create a near-crash or other traffic conflict, but this dynamic event would not ordinarily be detected by the instrumented vehicle's sensors or the subsequent data analysis. The study methodology (i.e., instrumentation suite and associated data analysis procedures) differentially detected instrumented vehicle encroachments toward other vehicles as opposed to other vehicle encroachments toward instrumented vehicles. This differential detection meant that the apportionment of events in the current data set as truck driver-initiated (truck "at fault") or other driver-initiated (truck "not at fault") did not represent the universe of such events that occurred in actual driving. However, all events that were detected could be analyzed based on "instant replays" of video data and associated dynamic data recordings of the events. This analysis captured both the observable causal sequences leading to events as well as the conditions and correlates of event occurrence.

### **Fatigue Measurements**

Two measures of driver fatigue were employed in this study. The first is a subjective rating of drowsiness known as the ORD. Data analysts were instructed to watch the driver's face and body language for 1 min prior to the event trigger. As described by Wierwille and Ellsworth (1994)<sup>(59)</sup>, signs indicative of drowsiness include rubbing the face or eyes, facial contortions, moving restlessly in the seat, and slow eyelid closures. Data analysts were trained to look for these signs of drowsiness and make a subjective, but specific, assessment of the level of drowsiness. After watching the video data for 1 min prior to an event trigger, data analysts employed a rating scale to record an ORD level (see figure 5). The rating scale used by Wierwille and Ellsworth was printed on paper and analysts in that study marked a point on the horizontal line. In the present study, analysts moved a cursor on a computer monitor to the desired ORD. ORD was recorded using a 100-point continuous rating scale where a number from 0 to 100 was assigned based on the linear position chosen by the analyst. ORD scores of > 40 are considered indicative of fatigue (Hanowski, Wierwille, Garness, & Dingus, 2000)<sup>(6)</sup>.

It should be noted that for the first 12 months of data collected for this project, ORD was scored by a single individual for the 915 safety-critical events and 1,072 baseline epochs. This individual is considered VTTI's resident expert at ORD given her level of experience and the perceived accuracy of her ratings. However, the additional 4 months of data which were added for the current study followed a somewhat different methodology for arriving at ORD scores for the 302 safety-critical events and 981 baseline epochs identified in this additional portion of data (Note: due to budget limitations, the first 12 months of data were not rescored). Three trained raters made independent ORD ratings for each event and baseline epoch, and an average of the three scores was then taken as the ORD score. It is believed that averaging across three raters accounts for some of the inter-rater variability that is common with such subjective measures. Descriptive statistics performed on the three raters' ORD scores showed that they had nearly identical mean ORD ratings across the total number of events/baseline epochs rated.

(Rater 1 Mean = 38.4, SD = 11.4; Rater 2 Mean = 39.4, SD =12.2; Rater 3 Mean = 39.1, SD = 12.4).

**Table 1. Descriptive statistics performed on the three raters' ORD scores**

Rater	Mean	SD
1	38.4	11.4
2	39.4	12.2
3	39.1	12.4



**Figure 5. Screen shot. ORD rating scale used by data analysts (adapted from Wierwille & Ellsworth, 1994).**

00 = Not Drowsy – No signs of being drowsy

25 = Slightly Drowsy – Driver shows minor signs of being drowsy (single yawn, single stretch, droopy eyes for a short period of time); quickly recovers; does not have any apparent impact on vehicle control.

50 = Moderately Drowsy – Driver shows signs of being drowsy (yawns, stretches, moves around in seat, droopy eyes for a slightly longer period of time; minor blinking); takes slightly longer to recover; does not have any apparent impact on vehicle control.

75 = Very Drowsy – Driver shows signs of being drowsy (yawns often, has very heavy/droopy eyes, frequent blinking); duration lasts much longer; does not have any apparent impact on vehicle control.

100 = Extremely Drowsy – Driver shows extreme signs of being drowsy (yawns often, has very heavy/droopy eyes, has trouble keeping eyes open, very frequent blinking); duration lasts much longer; has apparent impact on vehicle control.

The second fatigue measure employed was PERCLOS, which is a mathematically defined proportion of a time interval that the eyes are 80 percent to 100 percent closed (Wierwille, Ellsworth, Wreggit, Fairbanks, and Kirn, 1994).<sup>(60)</sup> It is a measure of slow eyelid closure not inclusive of eye blinks. While an eye blink is typically a very quick closure and re-opening of the eyes, “slow eye closures” are relatively gradual eye movements where the eyelids droop and close slowly. PERCLOS is a valid indicator of fatigue which is significantly correlated with lane departures and lapses of attention, and is considered by some in the transportation safety field to be the “gold standard” of drowsiness measures (Knipling, 1998).<sup>(61)</sup>

This study utilized a manual coding scheme for calculating an estimate of PERCLOS, which is referred to in this report as *estimated manual PERCLOS* (EMP). Data analysts would locate an event trigger (or a set point of a baseline epoch) and would rewind the video data by 3 min 10 s (1900 syncs; data are gathered at 10Hz, so each sync represents 1/10 of a second). Reductionists would then code EMP sync-by-sync using the following operational definitions:

*Eyes Open:* Eyes are visibly open

*Eyes Closed:* Eyes are visibly closed or mostly closed (including blinks)

*Eyes Not Visible:* When the eyes literally cannot be seen (due to obstruction, face out-of-camera view, head turned to monitor mirrors, heavy shadow, etc.)

Rapid eye blinks had to be eliminated from the data when calculating EMP. For the purposes of this analysis, a “blink” was defined as an eye closure of 1 sync. Anything longer than 1 sync was considered a slow eye closure and, therefore, was used in the EMP calculation. Also, if an event had more than 20 percent of the video coded as “Eyes Not Visible”, then an EMP was not performed.

EMP scores  $\geq 12$  were the criterion for identification of safety-critical events or baseline epochs involving driver fatigue/drowsiness (Wierwille, Hanowski, Olson et al., 2003).<sup>(62)</sup>

Using the threshold values for the two fatigue measures, a series of odds ratio calculations was performed to compare the estimated relative risk of drivers experiencing fatigue/drowsiness under various driver conditions (e.g., normal weight vs. overweight/obese).

## **RESULTS**

### **BMI Classifications**

Drivers’ BMIs were calculated using their self-reported height and weight. As previously explained, BMI can be calculated by dividing a person’s weight in pounds by height in inches squared, multiplied by 705. This resulted in classifying the 103 drivers as follows:

- Normal (18.5 – 24.9 BMI): 19 drivers (18.4%)
- Overweight (25 – 29.9 BMI): 29 drivers (28.2%)
- Obese ( $\geq 30$  BMI): 55 drivers (53.4%)

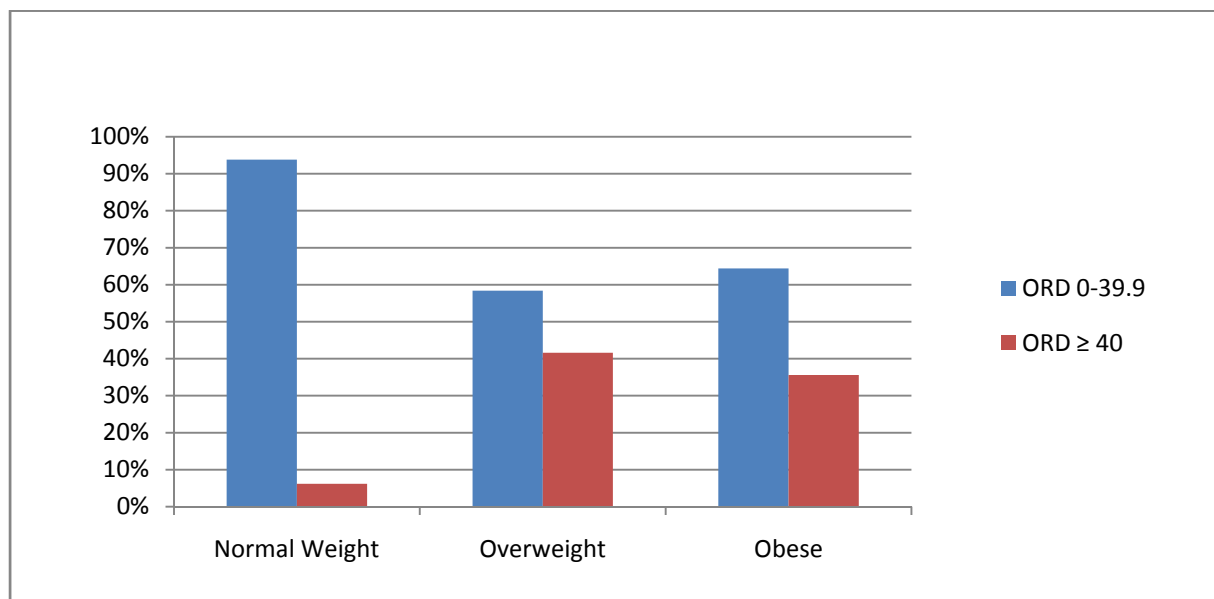
Based on the above, 82 percent of the drivers in this sample were classified as being either overweight or obese.

### ORD Results by BMI Classification for Total Driving Episodes

Table 2 shows descriptive statistics for ORD scores above and below the fatigue threshold of 40 for each of the BMI classifications (figure 6 shows this data in a bar graph). While normal weight individuals were above the fatigue threshold in only 6.2 percent of the total driving episodes analyzed, overweight individuals and obese individuals were over the fatigue threshold in 41.6 percent and 35.6 percent of these episodes, respectively.

**Table 2. ORD scores above/below threshold by BMI classification.**

ORD	Normal Weight		Overweight		Obese		Total
0 - 39.9	346	93.8%	365	58.4%	1017	64.4%	1728
≥ 40	23	6.2%	260	41.6%	562	35.6%	845
Total	369	100.0%	625	100.0%	1579	100.0%	2573



**Figure 6. Graph. ORD scores above/below threshold by BMI classification.**

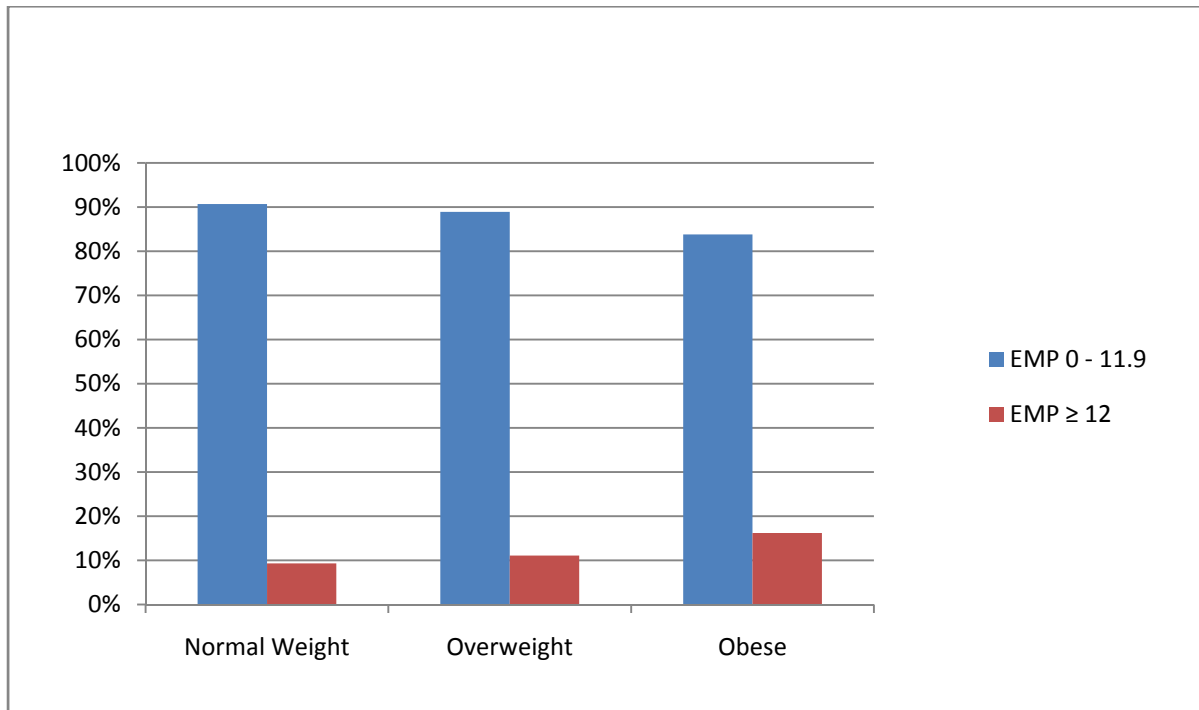
Odds ratio calculations revealed that overweight individuals were at 10.72 times greater risk (CI = 6.83 – 16.82) than normal weight individuals for being rated as over the ORD threshold, while obese individuals were at 8.31 times greater risk (CI = 5.38 – 12.84) than normal weight individuals for being above the threshold. An odds ratio combining overweight and obese individuals revealed that this group was at 8.95 times greater risk (CI = 5.82 - 13.77) than normal weight individuals for being rated as over the ORD threshold. Overweight individuals were at 1.29 times greater risk (CI = 1.07 – 1.56) than obese individuals for being above the ORD fatigue threshold. Finally, obese individuals were at 1.22 times greater risk (CI = 1.03 – 1.45) than non-obese individuals for being rated above the ORD fatigue threshold.

### EMP Results by BMI Classification for Total Driving Episodes

Table 3 shows descriptive statistics for EMP scores above and below the fatigue threshold of 12 percent for each of the BMI classifications (figure 7 shows this data in a bar graph). While normal weight individuals were above the fatigue threshold in only 9.3 percent of the total driving episodes analyzed, overweight individuals and obese individuals were over the fatigue threshold in 11.1 percent and 16.2 percent of these episodes, respectively.

**Table 3. EMP scores above/below the 12% threshold by BMI classification.**

PERCLOS	Normal Weight		Overweight		Obese		Total
0 - 11.9	391	90.7%	491	88.9%	1135	83.8%	2017
≥ 12	40	9.3%	61	11.1%	220	16.2%	321
Total	431	100.0%	552	100.0%	1355	100.0%	2338



**Figure 7. Graph. EMP scores above/below the 12% threshold by BMI classification.**

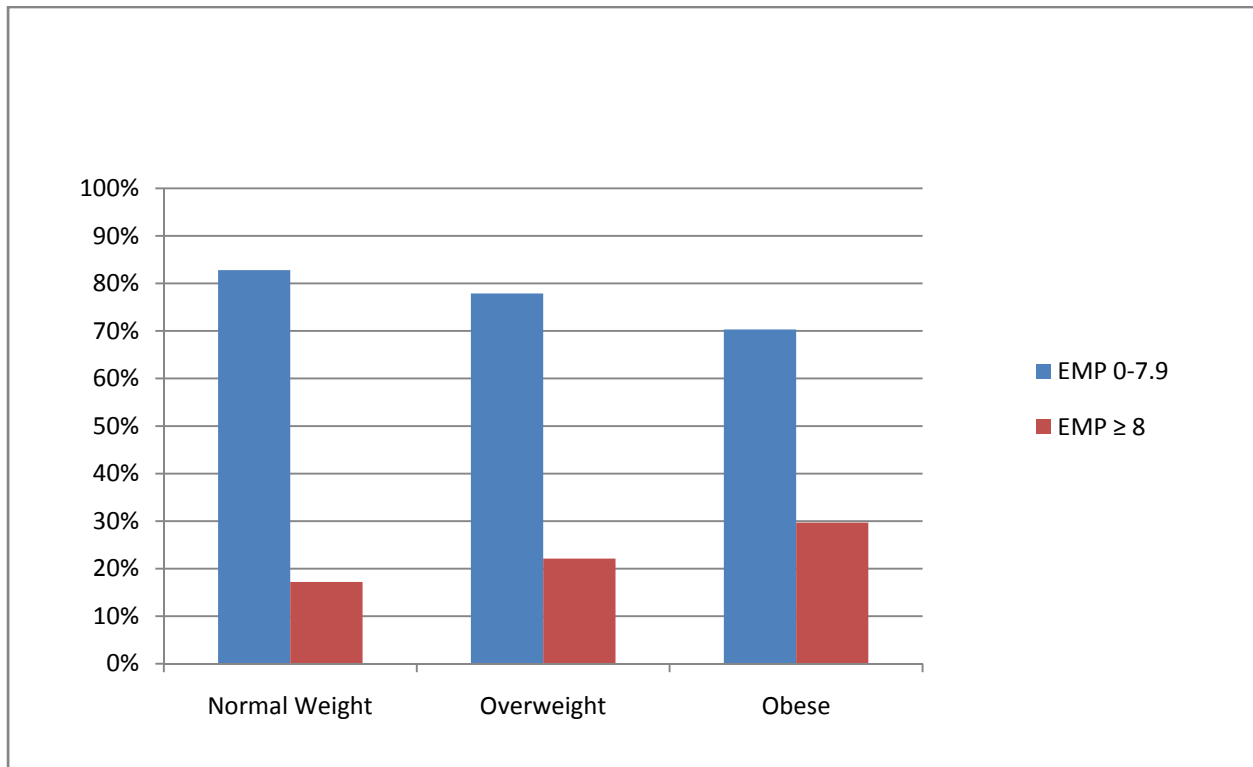
Odds ratio calculations revealed no greater risk for overweight individuals to be over the EMP fatigue threshold when compared to normal weight individuals (OR = 1.21; CI = 0.80 – 1.85). However, obese individuals were at 1.89 times greater risk (CI = 1.33 – 2.70) than normal weight individuals for being above the threshold. An odds ratio combining overweight and obese individuals revealed that this group was at 1.69 times greater risk (CI = 1.19 – 2.40) than normal weight individuals for being rated as over the EMP threshold. Obese individuals were at 1.56 times greater risk (CI = 1.15 – 2.11) than overweight individuals for being above the EMP fatigue threshold. Finally, obese individuals were at 1.69 times greater risk (CI = 1.32 – 2.18) than non-obese individuals for being rated above the EMP fatigue threshold.



While the above analyses use >12 percent as the EMP fatigue threshold (as recommended in Wierwille et al. 2003), other research involving the evaluation of DDWS technology used the PERCLOS threshold value of 8 percent to give drivers an initial advisory warning regarding their level of fatigue (Wierwille et al., 2003; Hanowski, Blanco, Nakata, et al., in press).<sup>(62,56)</sup> Table 4 shows the descriptive statistics for EMP scores equal to/above and below the threshold of 8 percent for each of the BMI classifications (figure 8 shows this data in a bar graph).

**Table 4. EMP scores above/below the 8% threshold by BMI classification.**

PERCLOS	Normal Weight		Overweight		Obese		Total
0-7.9	391	82.8%	430	77.9%	953	70.3%	1774
≥ 8	81	17.2%	122	22.1%	402	29.7%	605
Total	472	100.0%	552	100.0%	1355	100.0%	2379



**Figure 8. Graph. EMP scores above/below the 8% threshold by BMI classification.**

While normal weight individuals were above the 8 percent threshold for 17.2 percent of their driving episodes, overweight individuals and obese individuals were above the threshold for 22.1 percent and 29.7 percent of their driving episodes, respectively.

Odds ratio calculations revealed no greater risk for overweight individuals to be over the EMP fatigue threshold of 8 percent when compared to normal weight individuals (OR = 1.37; CI = 1.0 – 1.87). However, obese individuals were at 2.04 times greater risk (CI = 1.56 – 2.66) than normal weight individuals for being above the threshold. An odds ratio combining overweight

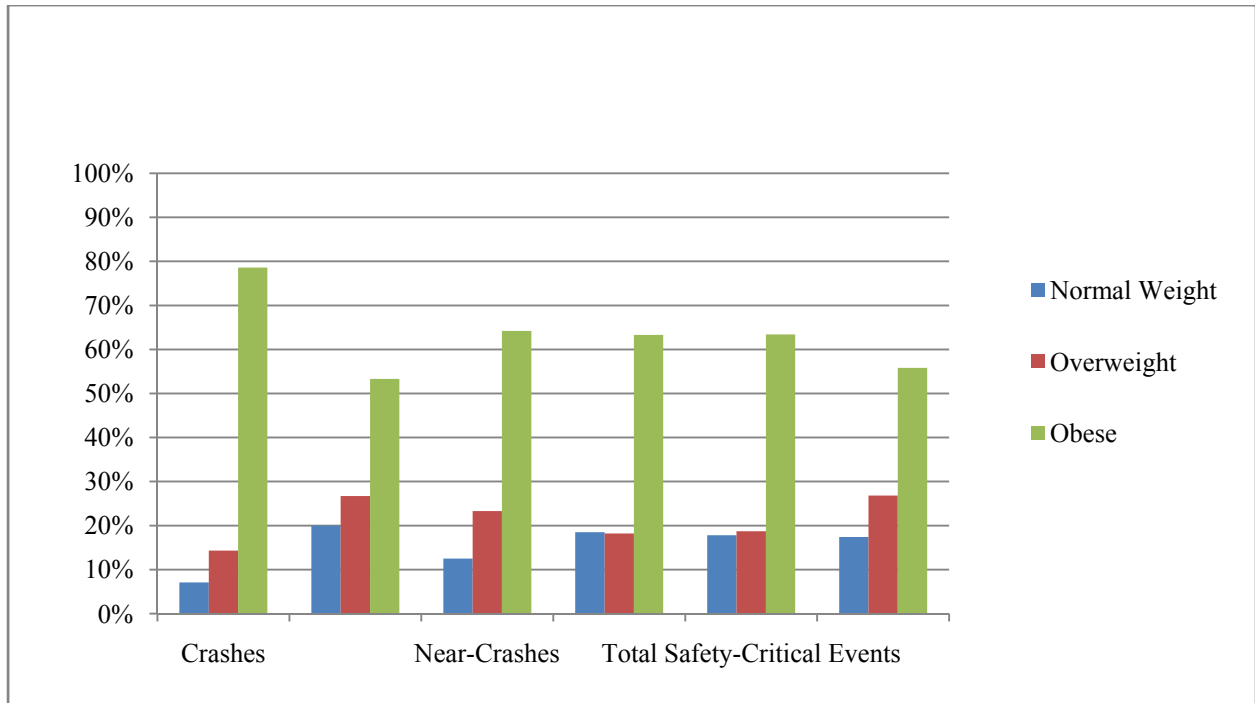
and obese individuals showed no greater risk for this grouping being over the fatigue threshold (OR = 1.22; CI = 0.94 – 1.59) compared to normal weight individuals. Obese individuals were at 1.49 times greater risk (CI = 1.18 – 1.88) than overweight individuals for being above the EMP fatigue threshold. Finally, obese individuals were at 1.62 times greater risk (CI = 1.34 – 1.97) than non-obese individuals for being rated above the EMP fatigue threshold of 8 percent.

### Safety-Critical Event Involvement by BMI Classifications

Table 5 shows the descriptive statistics for safety-critical events and baseline epochs per BMI Classification (figure 9 shows this data in a bar graph). Obese individuals were involved in the greatest proportion of safety-critical events (63.4 percent), while overweight and normal weight individuals were more similar to one another at 18.7 percent and 17.8 percent, respectively. Having randomly sampled baseline epochs available allows for the determination of the relative frequency of safety-critical events, which is the frequency of safety-critical events for a particular condition when all instances of the condition are taken into account (i.e., total safety-critical events / [total safety-critical events + baseline epochs]). The relative frequencies of safety-critical event involvement for normal weight, overweight, and obese individuals were .38, .29, and .40, respectively.

**Table 5. Safety-critical event involvement by BMI classification.**

Weight Classification	Crashes		Crash: Tire Strike		Near-Crashes		Crash-Relevant Conflicts		Total Safety-Critical Events		Baseline Epochs	
	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage	Count	Percentage
Normal Weight	1	7.1%	3	20.0%	15	12.5%	198	18.5%	217	17.8%	357	17.4%
Overweight	2	14.3%	4	26.7%	28	23.3%	194	18.2%	228	18.7%	550	26.8%
Obese	11	78.6%	8	53.3%	77	64.2%	676	63.3%	772	63.4%	1146	55.8%
Total	14	100.0%	15	100.0%	120	100.0%	1068	100.0%	1217	100.0%	2053	100.0%



**Figure 9. Graph. Safety-critical event involvement by BMI classification.**

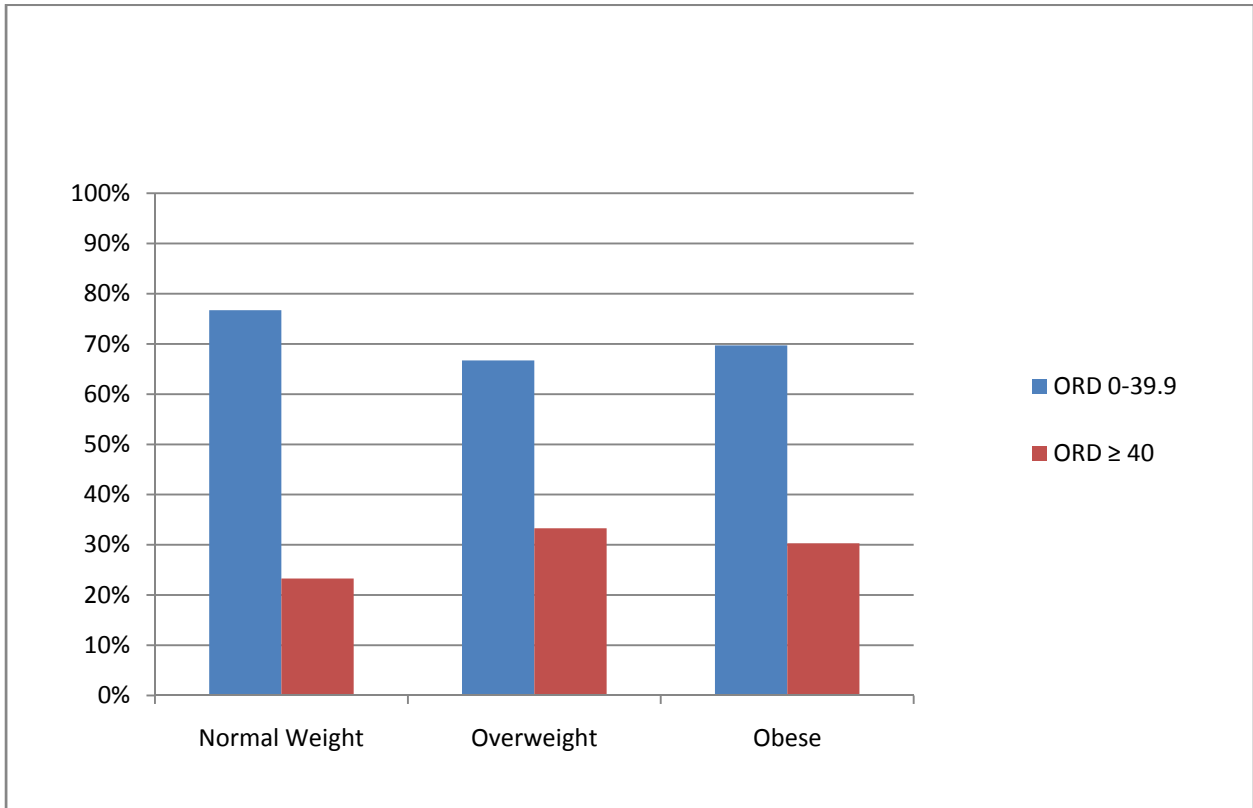
Odds ratio calculations revealed that overweight individuals were at 1.47 times greater risk (CI = 1.17 – 1.84) for experiencing a safety-critical event compared to normal weight individuals. However, obese individuals were at no greater risk (OR = 1.11; CI = 0.91 – 1.34) than normal weight individuals for experiencing a safety-critical event. An odds ratio combining overweight and obese individuals revealed that this group was at no greater risk (OR = .97; CI = 0.81 – 1.17) than normal weight individuals for experiencing a safety-critical event. Obese individuals were at 1.63 times greater risk (CI = 1.36 – 1.94) than overweight individuals for experiencing a safety-critical event. Finally, obese individuals were at 1.37 times greater risk (CI = 1.19 – 1.59) than non-obese individuals for experiencing a safety-critical event.

**ORD Scores by BMI Classification for At-Fault Safety-Critical Incidents**

Table 6 shows the descriptive statistics for ORD scores per BMI classification for safety-critical incidents where the truck driver was judged to be at-fault (figure 10 shows this data in a bar graph). While normal weight individuals were above the fatigue threshold for 23.3 percent of at-fault incidents, overweight and obese individuals were over the threshold in 33.3 percent and 30.3 percent of incidents, respectively.

**Table 6. ORD scores by BMI classification for at-fault safety-critical incidents.**

VI at Fault	Normal Weight		Overweight		Obese		Total
	Count	Percentage	Count	Percentage	Count	Percentage	
0 - 39.9	102	76.7%	78	66.7%	326	69.7%	506
≥ 40	31	23.3%	39	33.3%	142	30.3%	212
Total	133	100.0%	117	100.0%	468	100.0%	718



**Figure 10. Graph. ORD scores by BMI classification for at-fault safety-critical incidents.**

Odds ratio comparisons revealed no significant differences in risk for being above the ORD threshold in at-fault safety-critical incidents for the following comparisons:

- Overweight versus normal weight (OR = 1.65; CI = 0.94 – 2.87)
- Obese versus normal weight (OR = 1.43; CI = 0.92 – 2.24)
- Obese versus overweight (OR = 0.87; CI = 0.87; CI = 0.57 – 1.34)
- Overweight/Obese versus normal weight (OR = 1.47; CI = 0.95 – 2.29)
- Obese vs. non-obese (OR = 1.12; CI = 0.80 – 1.57)

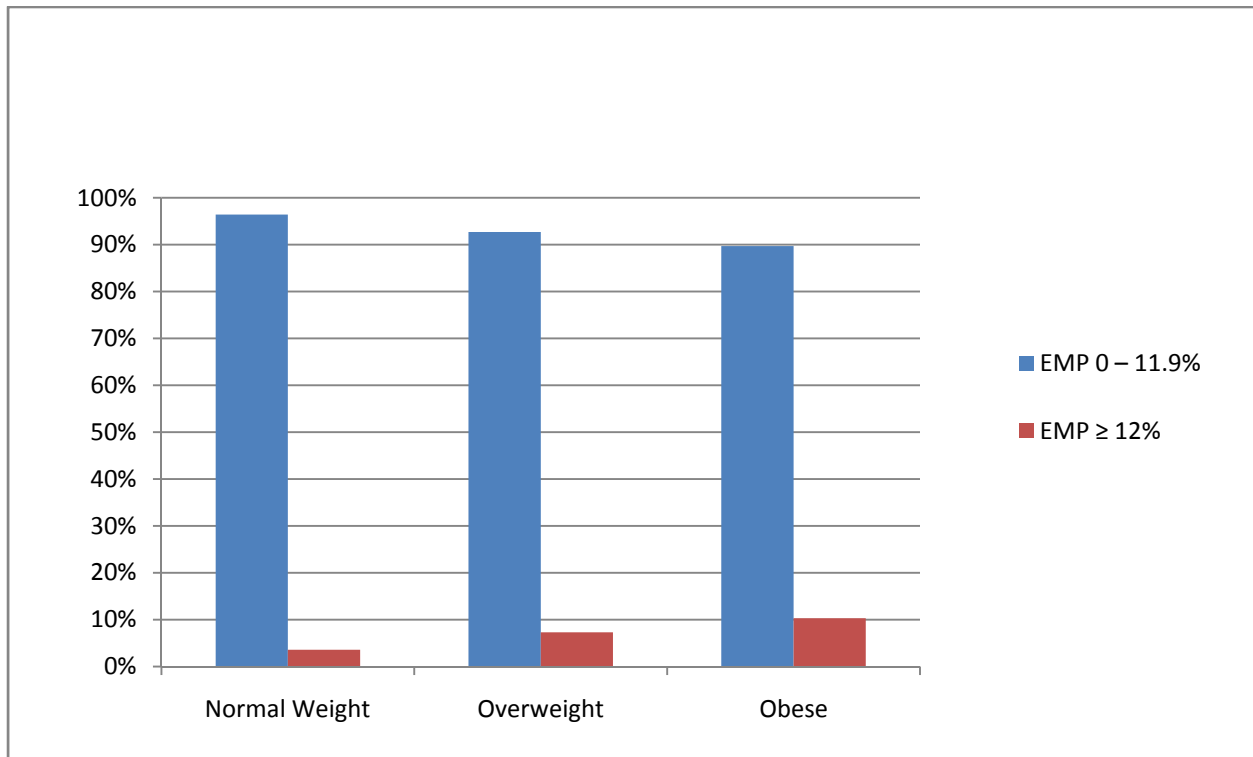
**EMP Scores by BMI Classification for At-Fault Safety-Critical Incidents**

Table 7 shows the descriptive statistics for EMP scores per BMI classification for safety-critical incidents where the truck driver was judged to be at-fault (figure 11 shows this data in a bar

graph). While normal weight individuals were above the fatigue threshold in 3.6 percent of at-fault incidents, overweight and obese individuals were over the threshold in 7.3 percent and 10.3 percent of incidents, respectively.

**Table 7. EMP scores by BMI classification for at-fault safety-critical incidents (12% threshold).**

<b>V1 at Fault</b>	<b>Normal Weight</b>		<b>Overweight</b>		<b>Obese</b>		<b>Total</b>
0 – 11.9%	108	96.4%	101	92.7%	350	89.7%	559
≥ 12%	4	3.6%	8	7.3%	40	10.3%	52
<b>Total</b>	<b>112</b>	<b>100.0%</b>	<b>109</b>	<b>100.0%</b>	<b>390</b>	<b>100.0%</b>	<b>611</b>



**Figure 11. Graph. EMP scores by BMI classification for at-fault safety-critical incidents (12% threshold).**

An odds ratio calculation revealed no significant difference in risk for being above the EMP fatigue threshold when comparing overweight individuals to normal weight individuals (OR = 2.14; CI = 0.62 – 7.32). However, an odds ratio shows that obese individuals were at 3.09 times greater risk (CI = 1.08 – 8.82) than normal weight individuals for being above the fatigue threshold. There was no greater risk for being above the fatigue threshold when comparing obese and overweight individuals (OR = 1.44; CI = 0.65 – 3.18). Overweight/obese individuals were at 2.87 times greater risk (CI = 1.01 – 8.14) than normal weight individuals for being above

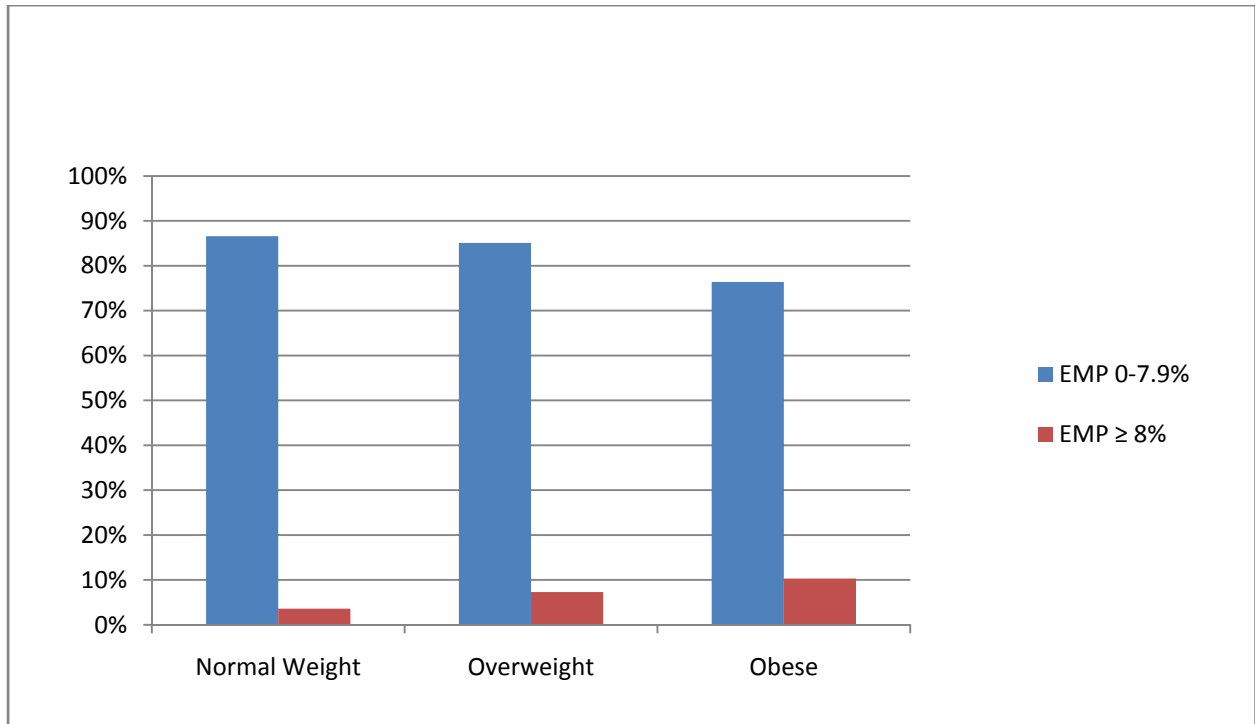
the fatigue threshold. Finally, obese individuals were at 1.99 times greater risk (CI = 1.02 – 3.88) than non-obese individuals for being above the fatigue threshold.

Table 8 shows the descriptive statistics for EMP scores per BMI classification for safety-critical incidents where the truck driver was judged to be at-fault (figure 12 shows this data in a bar graph). While normal weight individuals were above the fatigue threshold of 8 percent for 13.4 percent of their at-fault safety-critical incidents, overweight and obese individuals were above the threshold for 14.9 percent and 23.6 percent of their at-fault incidents, respectively.

**Table 8. EMP scores by BMI classification for at-fault safety-critical incidents (8% threshold).**

<b>VI at Fault</b>	<b>Normal Weight</b>		<b>Overweight</b>		<b>Obese</b>		<b>Total</b>
< 8%	97	86.6%	86	85.1%	298	76.4%	481
≥ 8%	15	13.4%	15	14.9%	92	23.6%	122
Total	112	100.0%	101	100.0%	390	100.0%	603

An odds ratio calculation revealed no significant difference in risk for being above the EMP fatigue threshold of 8 percent when comparing overweight individuals to normal weight individuals (OR = 1.13; CI = 0.52 – 2.44). However, an odds ratio shows that obese individuals were at 2.0 times greater risk (CI = 1.10 – 3.61) than normal weight individuals for being above the fatigue threshold. There was no greater risk for being above the fatigue threshold when comparing obese and overweight individuals (OR = 1.77; CI = 0.98 – 3.21). Overweight/obese individuals were at no greater risk (OR = 1.80; CI = 1.0 – 3.23) than normal weight individuals for being above the fatigue threshold. Finally, obese individuals were at 1.88 times greater risk (CI = 1.20 – 2.96) than non-obese individuals for being above the fatigue threshold of 8 percent.



**Figure 12. Graph. EMP scores by BMI classification for at-fault safety-critical incidents (8% threshold).**

### Discussion of Results

Of the 103 drivers analyzed for this study, a majority (81.6 percent) were classified as either overweight or obese based on their BMI. A total of 55 drivers (53.4 percent) were classified as obese, which is considerably more than the prevalence of obesity among the general population, recently estimated to be 34 percent in the U.S. (Centers for Disease Control and Prevention, 2007).<sup>(2)</sup> This finding alone is important, as it demonstrates the relative extent of the problem of obesity among this population.

Before discussing the results relevant to fatigue, it is important to highlight the distinction between the two fatigue measures. Specifically, ORD ratings take into account the physical appearance of the driver (e.g., drooping facial features indicative of drowsiness) and behaviors (e.g., yawning), while EMP is based solely on the percentage of a time interval the eyes were 80 to 100 percent closed, non-inclusive of blinks. This difference in scope of the two fatigue measures may explain why the results of the two are somewhat different. For example, the odds ratios for being above the ORD threshold tended to be higher than those for EMP (e.g., 8.95 vs. 1.69 for overweight/obese individuals being above the fatigue threshold compared to normal weight individuals, respectively). Nonetheless, even with their different scope in fatigue assessment, the two measures suggest the same general conclusion: that being overweight and/or obese is a risk factor for driving while fatigued.

The strongest evidence for this conclusion is seen when comparing obese individuals to normal weight individuals. Obese individuals were between 1.89 (CI = 1.33 – 2.70) and 8.31 (CI = 5.38

– 12.84) times greater risk than normal weight individuals for driving while fatigued, depending on the fatigue measure used. When comparing obese individuals to overweight individuals, there was a discrepancy between the two fatigue measures. Overweight individuals were at 1.29 times greater risk (CI = 1.07 – 1.56) than obese individuals for being above the ORD fatigue threshold; however, when considering EMP scores, obese individuals were at 1.56 (CI = 1.15 – 2.11) and 1.49 times greater risk (CI = 1.18 – 1.88) than overweight individuals for driving while over the 12 percent and 8 percent EMP fatigue thresholds, respectively. Overweight individuals tended to have higher ORD scores than normal weight individuals, but this relationship was not replicated when considering EMP. Again, these discrepancies may be due to the difference in scope of the two measures, although they are consistent in terms of the direction of the effect.

When examining combinations of the BMI classifications, overweight/obese individuals were between 1.69 (CI = 1.19 – 2.40) and 8.95 (CI = 5.82 – 13.77) times greater risk than normal weight individuals for driving while fatigued for the EMP (threshold of 12 percent) and ORD measures. (Note a significant odds ratio was not found for the EMP threshold of 8 percent for this comparison.) Also, when comparing obese individuals to non-obese individuals (i.e., a combination of normal weight and overweight individuals), obese individuals were found to have between 1.22 (ORD; CI = 1.03 – 1.45) and 1.69 (EMP with 12 percent threshold; CI = 1.32 – 2.18) times greater risk for driving while fatigued across the fatigue measures.

Analyses were also performed to determine whether there is increased risk for experiencing a safety-critical event based on BMI. The odds ratios for these comparisons showed that overweight individuals were at 1.47 times greater risk (CI = 1.17 – 1.84) than normal weight individuals for experiencing a safety-critical event. However, there was no greater risk for experiencing a safety-critical event when comparing obese and normal weight individuals. Obese individuals were at 1.63 times greater risk (1.36 – 1.94) than overweight individuals for experiencing a safety-critical event, and had 1.37 times greater risk (CI = 1.19 – 1.59) when compared to non-obese individuals. These findings support the notion that individuals with a higher BMI are at greater risk for experiencing a safety-critical incident. Similar results were documented by Lantz (2007)<sup>(36)</sup>, who analyzed 171,502 drivers' BMIs from the CDLIS database to find that obese individuals had a 7 percent increase in the likelihood of a crash compared to non-obese individuals.

When examining only safety-critical incidents where the truck driver was judged to be at-fault, there were some mixed results when comparing fatigue scores across BMI categories. Odds ratios indicated no significant differences when looking at the BMI categories (and various combinations) for ORD. However, obese individuals were at 3.09 times greater risk (CI = 1.08 – 8.82) than normal weight individuals for being above the EMP fatigue threshold of 12 percent in the 1 min before experiencing a safety-critical event. Combining classifications for this EMP threshold level also showed that overweight/obese individuals were at 2.87 times greater risk (CI = 1.01 – 8.14) than normal weight individuals for driving while fatigued just before a safety-critical incident, while obese individuals were at 1.99 times greater risk (CI = 1.02 – 3.88) than non-obese individuals. Similar results were found when using the lower EMP threshold of 8 percent.



As a whole, these results indicate a clear relationship between BMI and fatigued driving as well as between BMI and safety-critical event involvement, which suggests that obese individuals are at greater risk than non-obese individuals.



## CHAPTER 4. FOCUS GROUP

A 1-hour focus group with professional truck drivers was held at VTTI to solicit perspectives on the barriers to living a healthy lifestyle while on the road. VTTI maintains a participant database of individuals who have either participated in VTTI research in the past or who have contacted VTTI to request that they be added to the participant database for recruitment in driving studies. This database also includes information regarding whether a potential participant has a CDL. Individuals with a CDL were contacted to request their participation in this focus group (see appendix A for telephone recruitment script).

Five individuals who were currently employed as CMV drivers (4 male, 1 female) participated, with an age range of 40-57 years (mean age = 48.6). The participants had a range of 3-20 years of professional truck driving experience (mean = 11 years), and reported a range of 9-14 hours in their vehicle per work-related trip (mean = 11 hours).

The focus group took place in a conference room at VTTI. Once present, participants introduced themselves, and the experimenter discussed the goal of the focus group, which was to solicit their perspectives and opinions regarding barriers to living a healthy lifestyle while on the road. Appendix B includes a list of questions that guided the focus group. Below is a summary of comments and opinions gathered from the focus group discussion:

### **“Lazy Mindset”**

- Participants believed that driving for long periods of time creates a “lazy mindset”. This was described in several ways. Several individuals felt that sitting all day makes one want to do nothing but sit once they get home. Others felt that since they work such long hours, they don’t want to be active while not driving. They would prefer to relax or spend time with their family.

### **Quality of Food on the Road**

- The participants all agreed that the food available to truck drivers on the road is of poor quality.
- Truck stops are the primary sources of food since one would have to disconnect their load to drive “bobtail” to other restaurants.
- The food at truck stops is mainly fried and even “healthy” foods (e.g., vegetables) are saturated in butter and salt. While some truck stops have salad bars, the produce is generally of poor quality, there is little variety, and the salad bar is more expensive than other entrees.
- Most entrees include very large portions.

### **Organizational Barriers**

- Many trucking fleets do not allow converters which would allow drivers to have microwaves in their truck. Drivers felt they could eat healthier if they were capable of preparing meals in a microwave.

- Some of the loading areas will not allow drivers to get out of their truck when loading/unloading. This would be an opportune time for drivers to stretch, get some exercise by walking, etc.
- Driving schedules may keep drivers from eating regularly. This means drivers are often snacking on readily available snacks (e.g., crackers/chips). Most drivers said they only have time to eat one meal a day, and are otherwise just eating unhealthy snacks.
- Driving schedules also leave little time for exercise.
- Some fleets have exercise equipment for drivers, but the location of the equipment is inconvenient and in an area where drivers seldom are (e.g., at headquarters).
- Participants indicated that trucking fleets do not consider driver health, diet and exercise a priority beyond having their drivers pass their DOT physicals. While they may mention health on paper, they do not create an organizational culture which truly supports their drivers in living a healthy lifestyle.

### **What Do Drivers Do To Improve/Maintain Healthy Living?**

- Some drivers have refrigerators in their trucks, and they pack lunches with low fat foods and fruits/vegetables.
- Walk as much as possible when outside of the truck.
- Some drivers travel with a dog, which forces them out of the truck and allows them to get exercise while walking the dog at stops.
- Some drivers carry simple exercise props with them on the road, such as a jump rope.

### **What Can Be Done to Improve the Health of Truck Drivers?**

- Companies could schedule drivers more consistently so they have the opportunity to develop regular eating and exercise routines. Exercising regularly is most easily achieved when there is a consistent routine, and drivers feel they are unable to do this given their hectic schedules.
- Participants felt that someone needs to intervene on the companies running the truck stops to encourage them to prepare healthier meals (e.g., eliminating some of the fat, salt, and butter) and have more variety in healthy food selections. They should also have quick meals to go (e.g., sandwiches) that are not fried.
- Shippers/receivers apparently delay drivers well beyond what is expected, which increases stress and decreases their opportunities to eat, exercise, etc.
- Participants felt that truck drivers need to be motivated. They agreed that information on how to eat healthy and exercise tips while on the road should be made available by fleets or the government. They also felt that truck drivers need to understand the consequences associated with living an unhealthy versus a healthy lifestyle. For instance, being healthy means better quality of life, improved sleep, etc.

## **SUMMARY OF FOCUS GROUP**

The five commercial drivers that participated in this 1-hour focus group agreed that overweight and obesity is a major concern in their line of work. The participants believed that environmental issues (e.g., the nutritional quality of food served at truck stops, lack of access to a variety of restaurants) and organizational design issues (e.g., scheduling, company policies when loading/unloading, company support for health) were major barriers to living a healthy lifestyle

while on the road. These results support past research by McCallum et al. (2003)<sup>(10)</sup> who, in an analysis of factors involved in the assessment of commercial driver fatigue, listed extended work and/or commuting periods, poor diet and nutrition, inadequate exercise opportunities, sleep deprivation and sleep disruption, and unpredictable work schedules as operational risk factors. All of these factors contribute to health issues resulting from a sedentary lifestyle, increasing the risk of obesity and, consequentially, the potential for increased fatigue.

Suggestions for improving commercial drivers' health included packing healthy foods from home (e.g., fruits and vegetables, cooked chicken) and storing them in a refrigerator in their truck. Another suggestion for drivers was to get out of the truck as often as possible to stretch, walk, or do light exercise.

Participants also suggested that truck companies get involved to improve their drivers' health by allowing time in drivers' schedules to stop for exercise and to prepare meals for themselves. It was also suggested that companies educate and motivate drivers to care for themselves by exercising and eating healthy foods. Participants also believed that companies should work with receivers to allow drivers more flexibility for exiting the truck when it is being loaded/unloaded. Finally, it was suggested that companies work with truck stop owners to improve the nutritional quality of foods served in addition to providing a variety of healthy food selections.

A number of trucking fleets have shown increased interest in the health and wellness of their employees over the past decade. Chapter 5 includes a summary of several health and wellness programs recently implemented among major trucking fleets.



## CHAPTER 5. HEALTH & WELLNESS PROGRAMS FOR COMMERCIAL DRIVERS

It has been suggested that employing healthier drivers can possibly assist in an increase in highway safety by means of reducing accident risk (Krueger, Brewster, Dick, Inderbitzen, & Staplin, 2007).<sup>(3)</sup> Several programs have been implemented by trucking fleets in the U.S. to address health concerns (e.g., diet, exercise, and disordered breathing) associated with the sedentary lifestyle of commercial drivers. These programs, described below, seek to assist commercial drivers in making health and lifestyle changes, while increasing the likelihood of building a healthy work force while simultaneously encouraging safe driving practices on the highway.

*Gettin' in Gear.* The *Gettin' in Gear Wellness Program* (Krueger et al., 2007)<sup>(3)</sup> has functioned as a catalyst in the commercial driving industry, moving other companies to cultivate their own programs. *Gettin' in Gear*, sponsored by FMCSA, focuses on elements of general wellness, fitness, and health for CMV drivers and their families. This program was adapted into a 3-hour train-the-trainer course by the American Transportation Research Institute (ATRI) with the goal of encouraging employers to be proactive and show support for the program (Krueger & Brewster, 2002).<sup>(63)</sup> *Gettin' in Gear* addresses seven threats to commercial drivers' health and fitness: 1) Smoking and tobacco use, 2) Obesity/being overweight, 3) Hypertension, 4) Poor eating habits, diet, nutrition, 5) Alcohol, drugs, and chemical substances, 6) Lack of physical activity and fitness, and 7) Psychological stress and mental fitness. Ultimately, *Gettin' in Gear* seeks to provide guidance rooted in preventative medicine on how to overcome the most common health threats facing commercial drivers and to assist in personal wellness plan development. *Gettin' in Gear* is personalized to fit individual drivers' wellness needs and is centered on four health issues to be attended to while at home and on the road. Known as the "4-R Road Challenge", the four Rs in the program are: 1) Refueling, 2) Rejuvenating, 3) Relating, and 4) Relaxing (Krueger & Brewster, 2002).<sup>(63)</sup>

*Trucks, Inc.* Trucks, Inc. (a regional truck-load carrier serving the southern U.S.) has taken a unique approach in developing a health and wellness program as part of the company's self-funded health insurance program. This carrier conducted substantial research in order to correlate drivers' well-being to safety performance. Utilizing the *Gettin' in Gear* course in conjunction with workers' compensation resources from insurance providers, the company educates drivers on safety and wellness factors with supplemental information about proper exercise, nutrition, and smoking cessation (Krueger et al., 2007).<sup>(3)</sup> Additionally, an annual DOT physical exam is conducted on-site by a physician's assistant and physical results are tracked by the company to identify drivers who need additional training based on the diagnoses made during those exams. For example, if a driver's annual blood work suggests risk factors for high cholesterol or prostate cancer, that employee would receive a follow-up consultation; and if a driver's exam results had borderline values, he/she would be rechecked more frequently than would the company's healthy drivers. Furthermore, drivers are encouraged to use exercise equipment that is available 24 hours a day at company facilities. As a result of these efforts, Trucks, Inc. has reported savings of more than \$250,000 in medical insurance costs through early diagnosis of health issues. Specifically, the company has reported (as of 2007) early identification of numerous pre-diabetic conditions, two cancer cases, and five pre-heart attack conditions (Krueger et al., 2007).<sup>(3)</sup>

*Drivers as Road Athletes and Bus Athlete Systems.* Similar to *Gettin' in Gear*, the Drivers as Road Athlete System and the Bus Athlete System are two programs also designed to target the specific obstacles associated with the CMV driving occupation to maintaining a healthy lifestyle. These programs are interactive in nature, encouraging truck and bus operators to become concerned with their own health and safety by encouraging drivers to exercise control over their physical and mental well-being, while thinking of themselves as “road athletes” (Krueger et al., 2007; Shapiro, 2005).<sup>(3,64)</sup> To facilitate this mindset, drivers are given workbooks which outline a new game to reach health or safety goals each day. As part of utilizing this system, participating drivers are provided with a motivational talk and relevant roundtable discussion between coworkers and safety experts on audio CDs. Furthermore, drivers are given an “Athlete System Game Book” that presents a safety and lifestyle issue every workday for 1 year with short goals to carry out. Games involve physical exercises, counting calories and other nutritional elements, and stress-reducing activities. Parallel to *Gettin' in Gear*, the Drivers as Athletes System addresses 12 areas of healthy lifestyles: nutrition, physical fitness, mental fitness, stress reduction, attitude and happiness, sleep, substance abuse, time management, motivation, disease prevention, weight/obesity, and relaxation (Krueger et al., 2007).<sup>(3)</sup> Diverging from *Gettin' in Gear*, the program also addresses safety factors which include: weather conditions, driving regulations, passenger safety, compliance, injury prevention, employee-employer relations, and pre- and post-trip inspections.

*Schneider National, Inc.* Since 1998, Schneider National, Inc. (SNI; Green Bay, WI) has made substantial efforts to cut down on fatigued driving after discovering that nearly 1 out of every 3 drivers was inflicted with the risk of sleep-disordered breathing (e.g., OSA) and co-morbid disorders (Berger, Sullivan, Owen, & Wu, 2005).<sup>(37)</sup> After initiating a program to treat drivers diagnosed with OSA, SNI discovered a \$538 per driver month health care savings among drivers treated for one year with a Continuous Positive Airway Pressure (CPAP) device, along with a 55 percent greater retention rate among participating drivers as compared to the entire fleet (Krueger et al., 2007).<sup>(3)</sup> As a result of these findings, SNI drivers referred to physicians for OSA testing currently incur no out-of-pocket costs. In addition, SNI provides on-site physical therapists who are trained to identify drivers suspected of OSA, and who also provide disease management coaching centered on health issues such as cardiovascular fitness, diabetes, and asthma. SNI also sends text messages to their drivers who are on the road to remind them to participate in sleep-study appointments, and monthly newsletters that provide tips for spousal identification of OSA-related symptoms are sent to homes. Furthermore, successfully treated OSA drivers are interviewed while recorded on tape to provide information to their peers on their new sense of well-being (Berger et al., 2005; Krueger et al., 2007).<sup>(37,3)</sup>

*On-site Doctors and Nurses.* Celadon Group Inc. (Indianapolis, IN) has taken measures to prevent obesity while simultaneously battling fatigue. On-site nurses encourage drivers to receive blood pressure and cholesterol checks, and on-call doctors are also available. The company pays for all medical expenses associated with this basic care and reports that, by doing so, they have reduced their annual health care expenses (Canadian Press, 2007).<sup>(65)</sup> J.B. Hunt, one of the largest trucking fleets in the U.S., also offers free health coaching and wellness programs for both drivers and office personnel, while Melton Truck Lines, Inc. has also made steps to improving driver wellness by replacing sodas in vending machines with diet drinks, water, and green tea (Fox News, 2007).<sup>(66)</sup>



*Greyhound Lines, Inc.* Another company providing employees with health and wellness options is Greyhound Lines, Inc. This employer offers drivers enrolled in its health and welfare plan with programs on disease management, wellness options, a 24-hour health information hotline, and online tools (Krueger et al., 2007).<sup>(3)</sup> In particular, the disease management program is available to individuals with chronic conditions that include but are not limited to obstructive pulmonary disease, heart disease, and asthma. Drivers are able to develop a personalized action plan with a doctor's guidance and are given contact with a personal registered nurse who is their source for guidance in addition to educational and emotional support, and is there to assist with confronting the medical condition. Other helpful features of this program are discounts on fitness club memberships, massage therapy, chiropractic care, and smoking cessation options. Furthermore, Greyhound Lines, Inc. has developed an online tool to help track daily steps and walking distance of drivers who choose to use a pedometer offered as part of the wellness program (Krueger et. al, 2007).<sup>(3)</sup>

## **SUMMARY**

The programs described above represent the forerunners of efforts to improve driver health and wellness. These programs include educational, motivational, and supportive tactics for encouraging driver participation. While it is likely that other programs exist, they are not publicly documented and thus are not described here. It is expected that health and wellness programs will grow in popularity as fleets come under close scrutiny for issues such as OSA among drivers (e.g., requiring a sleep test for drivers with a BMI  $\geq 30$ ; FMCSA, 2008).<sup>(67)</sup> No documentation was found regarding the outcomes of the programs described. It is important that carriers share their health and wellness program components with each other and report associated outcomes so that best practices can be determined for the industry.



## CHAPTER 6. CONCLUSIONS & FUTURE RESEARCH

This report focused on the driver characteristic of BMI and its relation to fatigued driving. Literature was reviewed to provide support for the notion that obesity is linked to sleep problems (e.g., OSA) and fatigue-relevant outcomes (e.g., EDS). In addition, analyses of naturalistic driving data supported the notion that obesity is a risk factor for driving while fatigued. A focus group was held with commercial drivers to investigate perceived barriers to living a healthy lifestyle while on the road. Finally, several existing health and wellness programs were briefly described.

The findings of this report indicate that obesity is a major problem in CMV operations. Of the 103 drivers analyzed for this study, a majority (81.6 percent) were classified as either overweight or obese based on their BMI scores. This finding alone is important, as it demonstrates the relative extent of the problem of obesity among this population. Not only is obesity a risk factor for several serious health problems, but it also affects one's sleep quality and feelings of fatigue during the day. This has obvious safety implications for CMV drivers, who spend a majority of their time on the road and thus have greater exposure to the potential of driving while fatigued than do other non-commercial drivers.

The results of the naturalistic driving data analysis efforts described in this report led to the conclusion that being overweight and/or obese is a risk factor for driving while fatigued. The strongest evidence for this conclusion is seen when comparing obese individuals to normal weight individuals. Obese individuals were between 1.89 (CI = 1.33 – 2.70) and 8.31 (CI = 5.38 – 12.84) times greater risk than normal weight individuals for driving while fatigued, depending on the fatigue measure used.

The data analysis also showed that individuals with a higher BMI are at greater risk for experiencing a safety-critical incident when compared to those with a lower BMI. Similar results were documented by Lantz (2007)<sup>(36)</sup>, who analyzed 171,502 drivers' BMIs from the CDLIS database to find that obese individuals had a 7 percent increase in the likelihood of a crash compared to non-obese individuals.

As a whole, these results indicate a clear relationship between BMI and fatigued driving as well as between BMI and safety-critical event involvement, which suggests that obese individuals are at greater risk than non-obese individuals.

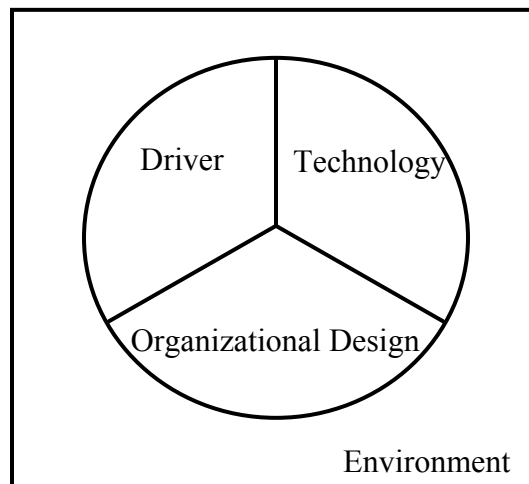
OSA is an issue that has recently received increased attention from fleet managers and the government (e.g., FMCSA). For example, the U.S. DOT's Medical Review Board recently recommended that it become mandatory for CMV drivers with a BMI of 30 or greater (the threshold for obesity) to complete a sleep test to determine if an OSA diagnosis is warranted (FMCSA, 2008).<sup>(67)</sup> Drivers who are diagnosed with OSA are not permitted to drive until they receive treatment, so this proposed rule will have a major impact on the trucking industry. Fleets will incur significant costs due to the testing and treatment of OSA, plus the time and productivity lost due to OSA-positive drivers being taken off the road until they receive treatment. It is predicted that fleets will invest more resources into developing driver health and

wellness programs to combat this issue, and may even begin screening potential hires based on their BMI.

With that being said, it will be important for researchers to aid in the development of health and wellness programs using empirically supported tactics to educate and motivate CMV drivers toward living a healthy(ier) lifestyle. Beyond developing the programs, researchers and practitioners will also need to carefully determine how the programs are implemented and how their effectiveness is measured so they can be monitored and improved over time.

## **FUTURE RESEARCH**

An adaptation of the Socio-Technical Systems Model (STS; Emery & Trist, 1960)<sup>(68)</sup> provides a holistic view of transportation safety by focusing on four main subsystems (see figure 13) and how these subsystems interact with and influence one another. These four subsystems are 1) the driver, 2) the driving environment, 3) technology/equipment, and 4) organizational design (i.e., policies, regulations, etc.).



**Figure 13. Diagram. Socio-Technical Systems Model (Emery & Trist, 1960).**

While the present research primarily focused on aspects of the driver and organizational design subsystems, it is important that all aspects of the STS model be considered when developing new research.

For example, based on the results of this report, it is recommended that preventative action be taken to develop and test various methods for educating and motivating drivers to eat healthy foods, exercise, and manage their weight. One method for disseminating such information would be to create a user-friendly outreach website, thus addressing the driver and technology subsystems of STS. Such a website could include dietary information, healthy eating tips, convenient exercise routines while on the road, statistics and summarized research on healthy/obesity, and descriptions of “best practices” from case studies of driver health programs. Keeping the website dynamic in nature by regularly updating it with new information and providing forums, bulletin boards, and online weight-loss competitions would be a method for

encouraging repeat visits by users. The NSTSCE Stakeholder Committee has recently approved research to develop such an outreach website, which is expected to be launched in late 2009.

The results of this report also indicate that organizational design and environmentally-focused efforts need to be made to gain the support of fleets and other organizations toward addressing the issue of obesity among this population. For example, by intervening on and collaborating with truck stop owners/administration, efforts can be made to provide truck drivers with healthier food alternatives. This would include providing a variety of healthy food choices (e.g., fruit, vegetables) and preparing existing food items in a healthier manner (e.g., using less salt and butter in the preparation of food). Also, by integrating health and wellness programs throughout the CMV culture and providing drivers with greater opportunity to plan/prepare meals, exercise, and rest, fleets will likely see improved employee morale, lower turnover, reduced medical costs, and increased profits (Krueger et al., 2007).<sup>(3)</sup>

In terms of the technology subsystem of the STS model, several studies are currently undergoing preparation under the sponsorship of NSTSCE which will use technology to address issues relevant to OSA and driver fatigue. These studies are summarized below.

*Impact of OSA on Commercial Driving.* The purpose of this study is to explore the safety impact of sleep apnea on the trucking industry. A sample of up to 600 commercial drivers with a BMI  $\geq$  30 will be tested for OSA using a home diagnostic device. Half of these drivers will have their results analyzed immediately, and those diagnosed with OSA will receive treatment involving the use of a CPAP device. The other half of the sample will not have their results analyzed for a period of 6-12 months. During this time period, all of the drivers in this study will be tracked to identify if/when they have a safety-critical event. This will allow the exploration of the impact of treated vs. untreated sleep apnea on driving performance, particularly with regard to involvement in a high risk driving event.

In addition, a sleep apnea screening survey will be implemented and a logistic regression analysis will be performed to determine which driver characteristics comprise the strongest equation for predicting the presence of OSA. This prediction equation will then be tested on a separate sample of drivers to evaluate its reliability and validity in predicting a positive OSA diagnosis.

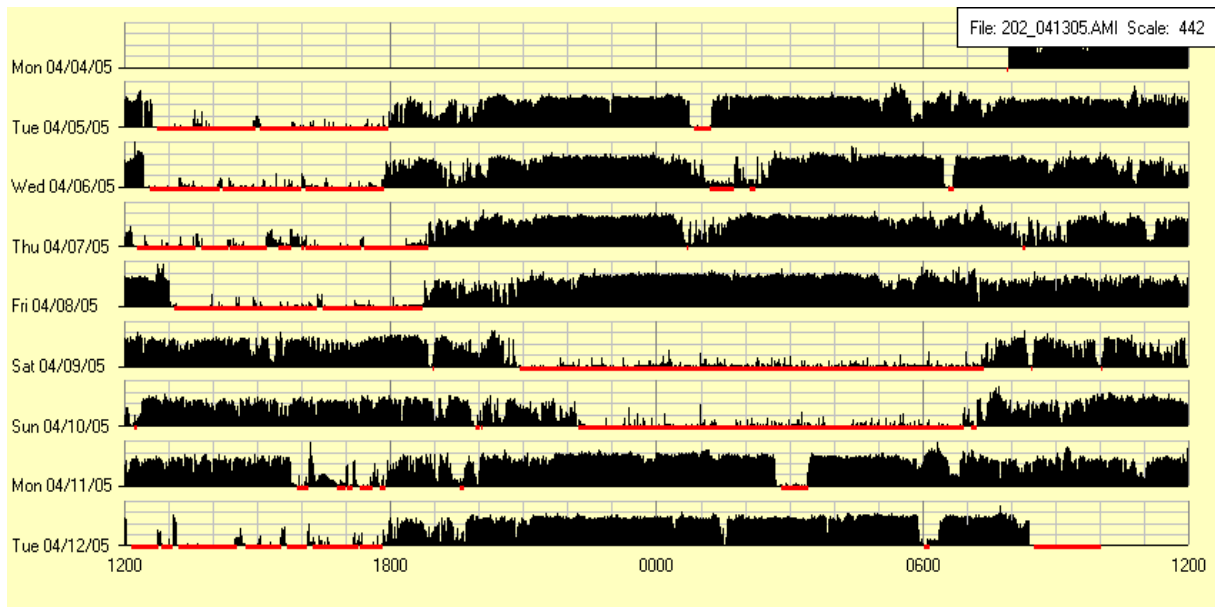
*Sleep of Commercial Motor Vehicle Drivers, an International Perspective.* This study will examine the sleep of truck drivers from the three countries (U.S., Canada, and Mexico) and evaluate this as a function of federal regulations, company policies, and driver beliefs and opinions. Sleep quality and quantity will be measured by driver logs, as well as by using actigraphs.

An actigraph is worn like a wristwatch on an individual's dominant hand (see figure 14). This device measures motion as a function of time and provides an assessment of sleep quantity and sleep quality based on this movement. For example, when drivers lay down to go to sleep, there is a marked decrease in motion detected by the actigraph watch. Instances of the driver "tossing and turning" can be detected which indicates periods of interrupted sleep. Figure 15 shows an example of actigraphy data output.

This study may reveal interesting differences among participants from the different countries, and may lead to collaborative international studies of CMV operations and safety. The ultimate goal would be to obtain funding to complete a naturalistic driving study whereby fleets from the U.S., Mexico, and Canada would participate.



**Figure 14. Photo. Actigraph device.**



**Figure 15. Screen shot. Example of actigraphy data output.**

In addition to the studies described above, NSTSCE is sponsoring a large-scale study of driver individual differences and the increased or decreased risk of experiencing a safety-critical event or violation associated with those differences. This study, described below, will begin in 2009 and will continue for a period of five years.

*Commercial Driver Individual Differences Study (CDIDS).* The CDIDS affords a unique opportunity to examine a wide array of driver and situational factors and determine the prevalence of these factors and increased or decreased crash and incident risk associated with

them. Extreme groups based on risk outputs (e.g., drivers with no crashes/violations, or low risk, versus drivers with crashes/violations, or high risk) will be investigated to maximize the contrast between groups and thus associations with correlating factors. The comparison of cases (high-risk drivers) to controls (low-risk drivers) will permit the derivation of odds ratios and other statistics quantifying the risk associated with various driver factors, including demographic information, medical conditions, personality traits/states, personal attitudes, and behavioral history. Not only will the risk associated with these individual factors be determined; assessments of individual risk factors will be combined into a multiple-factor “best prediction” of increased risk. The risk predictions, whether based on single or multiple combined factors, have important, near-term applications to improving motor carrier safety management.

The purpose of the CDIDS is to identify commercial driver individual differences which may be associated with greater risk for experiencing a crash or violation. Primarily, these will consist of personal factors such as demographic characteristics, medical conditions, personality traits, personal attitudes, and behavioral history. Risk factors may also include work environmental conditions, such as carrier operations type and driver compensation method. The study will identify risk factors by linking the characteristics of individual drivers with their driving records during the duration of the study, especially with regard to the occurrence or absence of crashes (at-fault crashes when feasible to determine the distinction), moving violations, and vehicle inspection violations.

This study will consist of a medical examination and battery of psychological and behavioral history measures administered to up to 21,000 drivers such that approximately 3,000 cases and 3,000 controls can be identified. To facilitate the project, VTTI has teamed with Road Ready, a company that provides medical examinations to commercial vehicle drivers as part of the CDL requirements, J.B. Hunt, and C.R. England, two of the largest trucking fleets in the U.S. In addition to J.B. Hunt and C.R. England, other relatively large carrier fleets have expressed strong interest in participating in this study.

The CDIDS is similar to the current study in that it focuses on individual driver characteristics. However, while the current study focused solely on BMI as an individual difference, the CDIDS will focus on a wide array of driver individual differences, therefore identifying medical conditions and psychological factors which will need to be addressed to improve the safety of commercial drivers. In addition, this research may lead to future initiatives to improve commercial driver health and well being. Individual truck drivers who are able to improve or maintain a healthy lifestyle will reap the potential benefits of improved quality of life and greater longevity. Finally, if CMV drivers are healthier, thus reducing the accident risk identified in this report, society in general would benefit from greater traffic safety.





## APPENDIX A: TELEPHONE RECRUITMENT SCRIPT FOR FOCUS GROUP

### COMMERCIAL DRIVER HEALTH AND FATIGUE STUDY

**Using the VTTI participant database, select those individuals who have indicated they hold a Commercial Driver's License.**

Script:

*Hello, may I speak to [NAME]? My name is \_\_\_\_\_, and I'm a researcher at the Virginia Tech Transportation Institute/Smart Road. I found your name on our list of individuals who have indicated interest in participating in our studies. Do you have a minute to hear about one of our new studies?*

**IF "NO":** *Is there a better time to reach you? Make a note to call the person back, if applicable. If s/he does not seem to be interested ask: Would you like to stay on our list, or would you like your name removed? If applicable, remove the person's name from list and let database manager know. Thank the person for his/her time.*

**IF "YES":** *We are holding a focus group with professional truck drivers to discuss challenges to living a healthy lifestyle while on the road. The focus group will be held here at VTTI and will take approximately one hour. If you agree to participate, you will join up to 5 other truck drivers and 2 researchers in the discussion, and you will be compensated \$20/hour.*

*The focus group will focus on your diet and exercise habits as a professional truck driver, challenges to living a healthy lifestyle while on the road, and any suggestions you may have for other drivers trying to improve their diet/exercise habits.*

*Does this sound like something you would be interested in?*

**IF "NO":** *Thank you for your time. Would you like to stay on our list, or would you like your name removed? Remove name from list and let database manager know, if this is the case, and thank the person for his/her time.*

**IF "YES":** *Great. We are planning to have the focus group on [DATE/TIME]. Does this day/time work for you?*

**IF "NO":** *We are trying to hold the focus group on [DATE/TIME], but if we are unable to get enough people involved, we may try to reschedule. If that is the case, is it okay if I call you again to see if you are available?*

**IF "YES":** *Thank you. Do you know where we are located? Give directions to Building 2 of VTTI. We will give you a call the day before the focus group to remind you. If you need to reach me, please call [NUMBER]. See you on [DATE/TIME].*

*One last thing. Do you have any coworkers who you think would be interested in participating? If so, ask for that person's contact information. If not, thank the individual and say goodbye.*



## APPENDIX B: QUESTIONS TO GUIDE FOCUS GROUP

### Protocol

- **Once participants arrive and are seated in the conference room, begin the informed consent process by reading aloud the purpose of the research. Then ask participants to read the entire document. Allow enough time for participants to complete the process and ask if anyone has questions once complete.**
- **Say:** *Before we begin, we would like to ask everyone to please be respectful of one another. Please take turns speaking, do not interrupt, and be respectful of others' opinions.*
- *If it is okay with everyone, let's go around the room and introduce ourselves by our first name (or a first name of your choice). You do not have to introduce yourself if you are not comfortable.*
- Begin posing the questions below.

### Focus Group Questions

1. On average, how many hours of a work day do you spend on the road?
2. Studies have shown that truck drivers have a greater instance of being overweight and/or obese than the general population. Why do you think this is the case?
3. What are challenges to living a healthy lifestyle as a professional truck driver?
4. Do you have easy access to healthy food choices while on the road?
5. What are things you do to try to stay in shape and eat healthy?
6. What are things some other professional drivers may do to stay in shape and eat healthy?
7. Does your company promote good health to its drivers? If so, how?
  - a. Do you think these efforts are effective?
  - b. What would make them more effective?
8. What kinds of information would be useful to you in terms of living a healthier lifestyle while on the road?
  - a. If you were given suggestions for simple exercises and healthy dietary options/alternatives while on the road , would you try them?
9. Do you have any tips or suggestions for living a healthier lifestyle while on the road?



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