Expert Panel Report

Fatigue and Commercial Motorcoach/Bus Driver Safety

Expert Panel Members

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Presented to

The Federal Motor Carrier Safety Administration

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1. Introduction

The primary mission of the U.S. Department of Transportation's (DOT) Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries and fatalities involving commercial motor vehicles (CMVs), including large trucks and buses, in the United States of America. Of particular interest to FMCSA is the impact of non-pathologic fatigue, fatigue arising from insufficient sleep, adverse circadian phase, and high workload rather than from some underlying pathology (e.g., sleep disordered breathing).

A substantial body of evidence suggests that fatigue can impair a person's ability to drive safely. The risks associated with fatigue are larger for CMV drivers whose job requires driving long distances and working long hours. The subject of this report is the impact of, and risks associated with, fatigue in motorcoach/bus drivers. This topic is of particular interest to FMCSA because of the unique job functions and work environments that set motorcoach/bus drivers apart from other CMV drivers. For instance, motorcoach/bus drivers compared with truck drivers are reported to face extended workdays that require a variety of non-driving duties, intermittent or split-shift working periods, and the transport of, and interactions with, passengers.

On December 20, 2012, FMCSA invited a panel of experts in the area of fatigue and driving to discuss the risks associated with non-pathologic fatigue in motorcoach/bus drivers. This meeting was preceded by the preparation of a systematic evidence review which attempted to answer the following four key questions.

> **Key Question 1:** What impact does non-pathologic fatigue have on crash incidence and driving ability?
>
> **Key Question 2:** How much rest does a fatigued professional driver need to resume driving unimpaired?
>
> **Key Question 3**: How do motorcoach drivers differ from truck drivers in terms of the following attributes:
>
> A. Demographics (gender, age, race, etc.)?
> B. Job function (pre-trip preparations, roads and distances travelled, opportunities for rest, etc.)?
> C. Work environment (interactions with passengers, cabin ergonomics, schedules, shift cycles, etc.)?
> D. Health-related behaviors and disease characteristics (body mass index, caffeine and alcohol use, depression, cancer, etc.)?
>
> **Key Question 4**: Do identified differences between motorcoach and truck drivers increase (or decrease) the risks for acute non-pathologic fatigue?

As noted in the evidence review, the definition of "fatigue" varies in the literature but is usually associated with, indicated by, or defined as degraded performance. As a result, findings evaluated in the evidence report were based on study author definitions of fatigue, and included studies on drivers with non-pathologic. In the context of the operation of a CMV, non-pathologic fatigue was defined as being caused by factors such as insufficient sleep, disrupted circadian cycles, and driving-related stress or monotony.

During the December 20, 2012 meeting, the Expert Panel discussed the evidence report, prepared by Manila Consulting, and engaged in a facilitated discussion about the impact of fatigue on motorcoach drivers, and how to operationalize fatigue risk management in regulations targeted to the motorcoach/bus industry.

1.1 Purpose of the Current Report

This report summarizes the considerations and opinions of a panel of three experts (henceforth termed the expert panel) with regard to the impact of non-pathologic fatigue on CMV drivers.

2. Composition of the Expert Panel

Members of the expert panel and a brief biographical description are listed in Table 1.

Table 1: Members of the Medical Expert Panel

Name	Biographical Sketch
Gregory Belenky, M.D., DFAPA	Dr. Belenky is a professor, and the founding Director of the Sleep and Performance Research Center at Washington State University (WSU) Spokane. Prior to this, Dr. Belenky held the rank of Colonel in the U.S. Army Medical Corps, and served as Director of the Division of Neuroscience at the Walter Reed Army Institute of Research (WRAIR). During Dr. Belenky's stewardship at WRAIR, the program grew in national and international stature, producing groundbreaking research and publications in the areas of brain imaging in sleep and sleep deprivation, the performance effects of stimulants and sleep inducing drugs, and the effects of chronic sleep restriction on performance. Dr. Belenky received his MD degree from Stanford University, studying with the "father of sleep research", Dr. William Dement. He holds a BA degree in psychology from Yale University. He is a Distinguished Fellow of the American Psychiatric Association (DFAPA) and a member of the American Academy of Sleep Medicine, the Sleep Research Society, and the European Sleep Research Society; and he served on the Board of Directors of the National Sleep Foundation. Dr. Belenky is board certified in Psychiatry and Sleep Medicine by the American Board of Psychiatry and Neurology. He is a certified Somnologist – Expert in Sleep Medicine by the European Sleep Research Society. At WSU, his laboratory conducts lab-based and field studies of sleep and performance in humans. In field studies, his research team assesses the impact of work schedules on objectively-measured sleep and subsequent objectively-measured performance in people going about their normal routines of work, family, and community life. In the laboratory studies, Dr. Belenky's research team investigates under highly controlled conditions the effects of restricted sleep on performance and individual differences in performance in response to sleep restriction. The aim of this work is to develop more effective means of managing sleep to sustain performance.
Richard Hanowski, Ph.D.	Dr. Hanowski is the Director of the Center for Truck and Bus Safety at Virginia Tech Transportation Institute (VTTI). He has formal training in human factors engineering, systems design, safety, research methods, experimental design, statistics, training, and human computer interaction. His experience includes transportation human factors with both heavy and light vehicles, laboratory and field testing, real-time automobile and heavy vehicle simulation, advanced system development and testing, design guideline development, and human performance evaluation. Dr. Hanowski currently serves as the Project Manager for an Indefinite Delivery Indefinite Quantity contract for the Federal Motor Carrier Safety Administration. He also serves as the Fatigue Subject Matter Expert for the National Surface Transportation Safety Center for Excellence. Dr. Hanowski earned his Ph.D. in

Name	Biographical Sketch
	industrial and systems engineering from Virginia Tech. Dr. Hanowski is the author of more than 200 publications including journal articles, conference papers, book chapters, and technical reports. He has received several research awards including the 2011 SAE International L. Ray Buckendale Lecture Award; 2012 Paul S. Richards Endowed Distinguished Visiting Lecture in Occupational Health and HFES's 2012 Best *Ergonomics in Design* Article Award.
Paul P. Jovanis, Ph.D.	Dr. Jovanis is professor of civil engineering at Penn State University. Dr. Jovanis has over 34 years of experience in highway safety and traffic engineering. Dr. Jovanis has studied relationships between truck driving crash odds and hours of service for over 25 years. Using data supplied by cooperating carriers, Dr. Jovanis has published 11 papers in refereed journals including an award-winning paper during the 2012 Transportation Research Board Annual Meetings. Dr. Jovanis has conducting his studies under contract to USDOT, FMCSA and several motors carriers. Dr. Jovanis has recently been exploring the use of Bayesian hierarchical models and epidemiological methods (case-control and cohort techniques) in a range of road safety assessments. He has also published several papers analyzing naturalistic driving data for crash surrogates and near crash events. In addition, Dr. Jovanis has taught safety and traffic engineering courses at the undergraduate and graduate level for 21 years. Dr. Jovanis chaired the TRB Committee on Traffic Records and Accident Analysis for 6 years. He is currently chair of the TRB Safety Section and incoming chair of Safety And System Users Group.

3. Methodology

3.1 Brief Overview of Evidence Report Methodology

The opinions of the expert panel presented in this report were informed in part by the interpretation and assimilation of information presented in a comprehensive evidence report summarizing the evidence that is currently available in the literature related to the impact of non-pathologic fatigue on driver safety.

The associated evidence report titled, "Fatigue and Motorcoach/Bus Driver Safety," was developed following a systematic search for evidence accessible through several electronic databases. The electronic databases included (but were not limited to) Medline, PubMed (pre Medline), PsycINFO, CINAHL, and the Cochrane Library (through July 31, 2012). All searches were supplemented by hand searches of the published literature (e.g., bibliographies of identified relevant articles) and "gray literature" resources (e.g., Web searches).

It is important to note at this point that, as described in the evidence report, large gaps in available research related to the risk of fatigue and/or sleepiness in commercial motorcoach/bus drivers necessitated consideration of literature on this topic in CMV truck drivers, and in general passenger (non-CMV) drivers. Moreover, the limited data available on nonpathologic fatigue (i.e., that which is not due to a sleep disorder such as sleep apnea or some other health condition) and crash risk required consideration of less direct evidence on the impact of fatigue on crash risk (e.g., demanding driving patterns that may lead to fatigue and increase the risk for crash and/or impair driving performance), and again, in drivers other than motorcoach/bus drivers for which there is no data currently available.

Refer to the evidence report for the detailed methodology, including search terms, inclusion and exclusion criteria, and abstraction and interpretation of the evidence. Refer to Appendix A for a summary of the key findings of the evidence report.

3.2 The Expert Panel Meeting and Opinion Formulation

On December 20, 2012, FMCSA, Manila Consulting, and the three members of the expert panel convened a one-day conference to discuss available evidence related to non-pathologic fatigue and its potential impact on driver safety. Prior to the facilitated discussion of the expert panel, senior research analysts from Manila presented the key findings of the evidence report to the expert panel, highlighting the limitations of the available literature specifically pertaining to commercial motorcoach/bus drivers. A summary of the findings of the evidence report are presented in Appendix A.

The specific objectives of this meeting included the following:

- To review key findings of an evidence report prepared by MANILA Consulting Group, Inc.
- To achieve consensus and provide opinions to FMCSA regarding:
    - The potential impact of non-pathological fatigue on motorcoach/bus driving safety;
    - Critical factors among drivers that contribute to fatigue; and
    - How to operationalize fatigue risk management in regulations for motorcoach drivers
- To identify areas where future research is needed

In developing their opinions or guidance for FMCSA, members of the expert panel were guided by the following principles. Specifically, their recommendations should be based on scientific evidence whenever possible[1] and their unique and qualified expert opinion in the absence of conclusive evidence; they should be concise and explicit; and they should be actionable.

This document summarizes the key themes and opinions that emerged from the day-long, in-person meeting with the expert panel.

[1] Recommendations from the Expert Panel, for which no supporting evidence was identified and which are thus based on expert opinion, are identified as such.

4. Facilitated Discussion

4.1 Impact of Non-pathologic Fatigue on Crash Incidence and Driving Ability

The evidence report addressed this topic under key question 1.[2] As summarized in the associated evidence report, a number of driving factors or patterns have been studied in the fatigue and crash risk literature. These include factors related to driving schedule, such as time-of-day driving, hours driven per day and week, and the duration of breaks and rest. Evidence synthesized in the evidence report (which derived from the CMV truck driving literature) suggests that the incidence of crash increases after 5 or 6 hours of driving and continues to increase through the end of driving time at 8 to 11 hours (*Kaneko et al., 1991;Park et al., 2005; Jovanis et al., 2011; Jones and Stein, 1987; McCartt et al.1998*). Additionally, data from a naturalistic driving study has also demonstrated that the number of safety critical events is high in the first hour of driving as well (*Hanowski*, *et al., 2007*), although this finding was not replicated in another similar study using a different fleet of drivers (*Blanco et al., 2011*).

It is also important to note that findings from recent research using a naturalistic driving method with truck drivers found that risk of driving incidents or safety critical events was associated with the total hours worked and not just the number of hours driving; that is, both driving and non-driving work are important factors for driving safety (*Blanco et al., 2012; Soccolich et al. 2012*). Additionally, crash incidence has been shown to be highest during overnight and early morning hours (*Hickman et al., 2005; Park et al. 2005; Jones and Stein, 1987; Jovanis et al., 1991; Massie et al., 1997; and NTSB, 1996*).

Following a brief summary of the findings in the evidence report related to this topic, the expert panel spent time discussing the relationship of crash incidence to a number of factors that have been linked with fatigue. The panel noted that there is evidence that crash incidence increases in a nonlinear fashion (e.g., exponentially) with increasing driving time or time-on-duty, a key risk factor for fatigue. Dr. Jovanis noted that to some degree, this effect may be partially explained in the driving literature by decreasing sample sizes with longer duty times. However, he also noted that in his work, he has consistently observed a nonlinear increase in crash risk with increasing driving time, particularly for driving periods that extend beyond eight and nine hours (*Jovanis, et al., 2012, Lin et al, 1994*).

The panel agreed that 'time-on-task' (which is equivalent to the amount of time spent on duty and driving in CMV drivers) is a key factor in performance decrements over time. It was noted that it is unclear what this non-linear function looks like (e.g., when the inflection point begins and how steep the performance drop is), but that it exists, and is moderated by a number of

[2] As noted in the evidence report, no data was identified that pertained specifically to motorcoach/bus drivers. Dr. Jovanis noted that while somewhat dated, he was aware of two studies (Harris and Mackie, 1972; and Mackie and Miller, 1978) that addressed to some degree, the relationship between fatigue and driver safety among motorcoach/bus drivers, and suggested that this material be reviewed for inclusion in the evidence report. It was agreed that this information would be obtained following the meeting and considered for possible inclusion in the report.

factors. Dr. Belenky argued that one of the most important factors moderating time-on-task performance decrements is receiving an adequate number of hours of sleep prior to the start of duty. He further suggested that the non-linear increase in crash risk after extended driving periods may reflect the point at which work-time combined with non-work (social and family) obligations reaches a critical point and results in reduced overall sleep time. This is consistent with data from a study he recently conducted were he observed that total sleep time was reduced for a group of motorcoach/bus drivers during on-duty days compared with their off-duty days, and that the longer the duty time, the shorter the total sleep time recorded (*Belenky et al., 2012*).

Very early on in the facilitated discussion, the expert panel emphasized the need to operationally define fatigue. A number of constructs related to fatigue were identified by the panel. For instance, a number of factors, in addition to time-on-task have been considered in the literature in modeling the dynamics of fatigue, including: 1) workload, 2) time awake, 3) total sleep time/24 hours, 4) cumulative sleep loss over extended periods of time, 5) sleep inertia, 6) circadian influences, and 7) environmental moderators such as stress, emotions, and drugs, etc.

There are a number of definitions for fatigue. For instance, it has been defined in the literature as a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair an individual's alertness and ability to safely operate [a vehicle] or perform safety related duties.

The panel also noted that defining fatigue is also important for the purpose of examining the literature in the evidence report because it reveals some its limitations of the literature, such as whether confounding factors were controlled for, particularly in studies that look at fatigue on crash risk. However, in the context of driver safety and establishing regulations to reduce the impact of fatigue, the expert panel agreed that fatigue needs to be operationally defined.

4.2 Operational Definition of Fatigue

OPINION OF THE PANEL: Develop an operational definition for fatigue that can be used to consider current regulations and where they can be adjusted to reduce the potential for fatigue.

Dr. Belenky described fatigue as an outcome of three factors: sleep loss, adverse time of day (adverse circadian rhythm), and high workload (e.g., time on task), as measured subjectively by self-reported assessment of fatigue and objectively by measures in performance degradations.

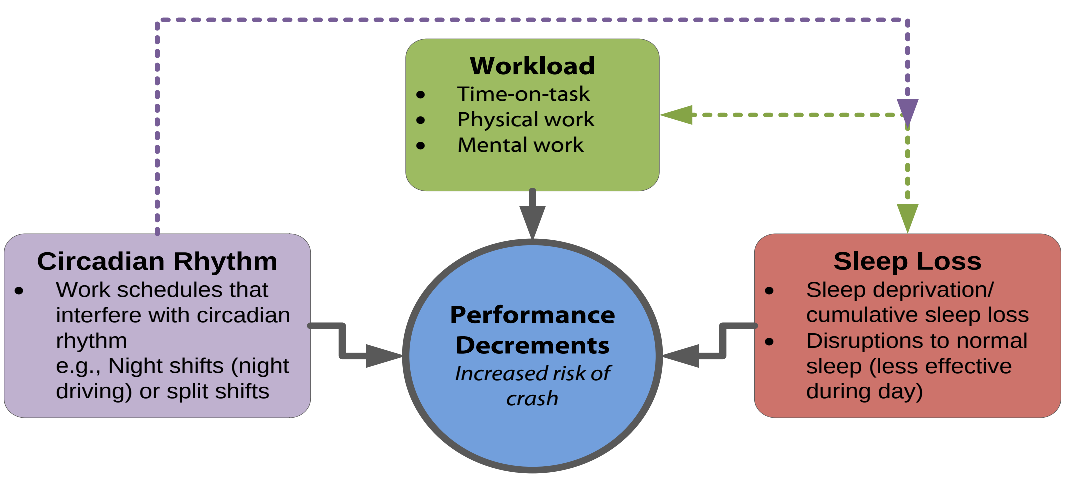
The key impact of fatigue-causing factors that is important for driver safety is its impact on performance. Increased fatigue results in degradations in performance. The panel identified a number of factors that are known to contribute to or moderate the level of fatigue in commercial drivers. The factors identified by the panel as critical to commercial truck and/or motorcoach/bus driver performance included those identified below (depicted in Figure 1).

- **Circadian Rhythm**
  - Work schedules that compete against normal circadian rhythm
  - Night shift/night driving which:
    - Includes driving at a time (during the night) when performance is reduced because an individual is working through a circadian low point
    - Requires obtaining sleep during the day (which is not as restorative as sleep during night time because it is harder to sleep during peaks in the circadian rhythm; *Belenky et al., 2012*)

  Note*: Dr. Jovanis also noted however, that there are reports in the literature that driving at night has also been reported in the literature as being associated with lower crash risk given that drivers are driving during periods with less traffic/fewer people on the road. One paper* (Lin et al., 1994) *shows elevated risk during some night and early morning hours and lower risk during others.*

- **Workload (particularly when it interferes with normal sleep)**
  - Time on task (e.g., long driving periods and/or long duty times which can reduce sleep time if appropriate rests are not taken)
  - Physically-demanding work (although Dr. Jovanis noted that physical work has also been shown to temporarily improve alertness/arousal via the Yerkes-Dodson Law)
  - Mental fatigue that might result from repetitive or monotonous work (although it was noted that monotony doesn't necessarily cause fatigue but that it unmasks underlying sleepiness that might be present because of accumulating sleep loss)
- **Reduced Sleep Time or Sleep Disruption**
  - Sleep deprivation/insufficient sleep (leads to degraded performance secondary to cumulative sleep loss)
  - Disruptions to normal sleep (e.g., sleep during the day which is not as restorative, because it is not as long as sleep during night)

Figure 1: Preliminary Base Model of Fatigue and Crash Risk



Measures of Fatigue: The panel described various ways of measuring fatigue. For instance, fatigue can be self-reported subjectively with one or more different instruments. Two instruments widely used in operational studies of sleep and performance and fatigue risk management in operational settings include the Samn-Perelli questionnaire (*Samn & Perelli, 1982*), and the Karolinska Sleepiness Scale (*Akerstedt & Gilborg, 1990*). It can also be measured objectively in the laboratory using circadian rhythms, performance measures (e.g., for driving with lane departures, etc.), or sleep measures (e.g., actigraphy).

4.3 Driving and Rest/Sleep Patterns that Contribute to Fatigue While Driving

4.3.1 What effect does time of day of driving have on driving performance?

In the context of the circadian rhythm, Dr. Belenky noted that certain times during the day are likely to be challenging for performance. For instance, between 4 am and 8 am. However, he noted that the circadian cycle is a sine wave and that there is not a single point in time when performance suddenly drops off or improves. Dr. Jovanis inquired as to whether or not this time frame is problematic only for individuals who are sleep deprived or for all individuals. Dr. Belenky noted that this time frame (4 am-to-8 am) is associated with reductions in performance even in individuals who are well rested, and is largely the result of the circadian rhythm (*Dijk, Duffy, and Czeisler, 2009*).

Consistent with this, a number of studies in the literature (*Hickman et al., 2005; Park et al. 2005; Jones and Stein, 1987; Jovanis et al., 2011; Massie et al., 1997; and NTSB, 1996*) suggests that the relative risk (or odds as measured in some studies) for a crash in professional drivers is higher when driving occurs overnight and/or in the early morning hours. This is consistent with the lows in the circadian rhythm.

Dr. Hanowski noted that the rate of safety critical events observed in naturalistic driving studies during the period of 4 am and 8 am do increase, but may in part be attributed to an increase in traffic volume in the morning rush hour period *(Hanowski, et al., 2009)*. He noted that in data that his lab will be publishing in the near future, drivers may actually be self-regulating alertness levels during periods when drivers are most likely to experience fatigue (e.g., night driving, circadian lows). For instance, his lab has found that drivers made relatively more phone calls and spent more time talking on their CB radios during circadian low periods; this may be attributed to drivers using voice-interaction as an alerting mechanism to help address fatigue (*Toole, L.M, in press*).

The panel described several other factors that may help drivers (including motorcoach/bus drivers) during their circadian lows:

- Coffee or other caffeinated beverages
- Short (20-30 minute) naps preceded by ingestion of a caffeinated beverage (particularly during afternoon circadian lows) such that caffeine is exerting effects upon awakening, including reducing fatigue and sleep inertia.

Another suggestion proposed by Dr. Hanowski, based on studies with team drivers among commercial truck drivers, is driving with a partner (*Dingus et al., 2002*). Team or partner driving may be particularly useful in the motorcoach industry in high risk situations, such as driving at night. Under current regulations for truck drivers this is logistically more difficult, but when this was more feasible under previous regulations, this was found to be effective. However, unlike trucks with sleeper berths, motorcoaches rarely have appropriate in-cab rest facilities for drivers.

Another suggestion, which the panel also noted would provide support in dealing with passenger/industry pressures faced by motorcoach/bus drivers would be to incorporate forced breaks from the driving schedule into regulation. Literature has demonstrated that breaks from driving are beneficial in reducing safety critical events in naturalistic data (*Soccolich et. al., 2012*). If breaks were a requirement in the regulations for hours of service, passengers and/or industry could not intimidate drivers when they are required by law to take a break.

As presented in the Fatigue evidence report, in the background section, the implementation of mandatory breaks is an approach that has been attempted in other countries. See Table 2, below.

Table 2: Comparative Summary of International Hours of Service Regulations

Regulation	Australia[a]	Canada[b]	European Union[c]	NAFTA/ Mexico-domiciled	United States/ FMCSA[c¤]
Maximum On-Duty Time	17 Hours	14 hours per day	Not Specified	15 hours following 8 consecutive hours off duty	15 hours following 8 consecutive hours off duty
Maximum Daily Driving Time	Not Specified	13 hours per day	9 hours per day	10 hours following 8 consecutive hours off duty	10 hours following 8 consecutive hours off duty
Maximum Continuous Driving Time	5 hours	Not Specified	4.5 hours	Not Specified	Not Specified
Minimum Mandatory Break Time	20 minutes after 5 hours of working	Not Specified	45 minutes after 4.5 hours of driving	Not specified	Not specified
Time Off After Days of Driving	27 hours in 72 hours working	36/72 hours in 70/120 hours working	45 hours after 6 days of driving	8 consecutive hours off after 10 hours of driving	8 consecutive hours off after 10 hours of driving
Total Driving Time per Period	168 hours in 14 days	70/120 hours in 7/12 days	56 hours per week (7 days)	60/70 hours in 7/8 consecutive days respectively	60/70 hours in 7/8 consecutive days respectively

4.3.2 What is the effect of split sleep (sleep divided into two or more bouts) on performance?

Dr. Belenky discussed that evidence shows that consolidated sleep in the day is not as effective as consolidated sleep at night (Belenky et al., 2012). He also noted that split sleep, with one sleep interval in the day, and another around or near the circadian low is actually more effective or restorative than one longer consolidated sleep period in the day. During the day, attempting to sleep competes with the circadian rhythm and is more difficult. As a result, sleep obtained during this time is less restorative and many people will be unable to remain asleep for a full 7-8 hours during daytime hours.

The panel suggested that one possible way to promote rest during the day is making available sleeping facilities for use during non-driving hours, particularly when it is impractical for such drivers to travel home in between shifts. However, it was noted that this might not be practical for a variety of motorcoach/bus drivers who transport passengers to and from distant locations (e.g., while waiting for a tour group to return from a sightseeing expedition from the motorcoach).

Another option posed by the panel during the discussion was to allow motorcoach/bus drivers the ability to rest on the vehicle during non-driving and non-work times. According to current regulations, this is not an option because drivers who are parked and inside the bus, are still considered on duty. They are not considered 'off-duty" until they exit the bus. The panel noted that drivers should be permitted to remain on the bus while it is not in transit in order to rest, and this should not be considered on duty time. The driver would be able to sleep on the bus, but not be penalized for staying on the bus. However, it was also acknowledge, that adequate rest facilities are generally not available on board motorcoaches/buses (e.g., sleeper berths).

4.3.3 What is the effect of early starts and associated sleep truncation on performance?

Dr. Belenky noted that, because of circadian rhythm, it is difficult for most individuals to go to sleep earlier in the evening (before about 9 or 10 pm) in order to get extra sleep to accommodate early starts to their day and still get a total of 7-8 hours of sleep per night. As a result, early start times (that require people to be awake at 3 or 4 am) are going to result in truncated sleep time, and likely result in a negative impact on driver performance. In a motorcoach/bus driver study released in 2012, Belenky et al. reported that earlier duty start times were associated with significantly less total time sleeping prior to the start of the shift.

That panel noted that regulatory changes regarding hours of service need to incorporate elements of sustainability because sleep loss is cumulative. The regulations should ensure enough opportunity for sleep, work, and non-work activity in every 24-hour period.

The panel also noted that the use of the Samn-Perelli fatigue scale (*Samn & Perelli, 1982*) or another self-reported fatigue scale both before shift and after shift, could be used on a large scale to evaluate various work-rest schedules. Additionally, asking drivers prior to their shifts about their level of fatigue gives some responsibility to the driver to ensure that he/she is adequately rested prior to starting their driving shift, and responsibility to the motorcoach company to ensure drivers are fit for duty at the start of each shift.

4.4 Operationalizing Fatigue Risk Management in Regulations for Motorcoach Drivers

OPINION OF THE PANEL FOR FMCSA:

- ***Consider restricting the hours-of-service rules for bus/motorcoach drivers to a fixed 24 period similar to those employed for commercial truck drivers***
- ***Consider restricting work start-times to limit irregular work shifts during work intervals and ensure opportunities for consolidated sleep***
- ***Consider use of risk-management processes for demonstrating alternative means of compliance***
- ***Identify mechanisms that allow for the direct monitoring of performance during driving (e.g., use of devices that track lane departures) to monitor fatigue in real time***

Dr. Belenky suggested that from an operational perspective, FMCSA should be thinking about how to engineer or regulate issues that lead to fatigue. This can be done setting regulations that ensure that commercial drivers have adequate time for sleep per day, and to the extent possible, during sleep-propitious times of the day (i.e., during circadian low points, the most restorative periods for sleep in the day). Performance, he argued, is largely the result of how much sleep a person has received, and that time-on-task is not likely to impact performance significantly as long as individuals obtain an adequate amount of sleep (7-to-8 hours per day). He also noted that this sort of approach is consistent with the approach that the Federal Aviation Administration (FAA) has taken recently with regard to pilot duty-time rules. Additionally, Boeing, in its turn-key risk management system, is integrating a sleep-prediction model into scheduling software that runs the airlines, and includes factors relevant to workload and work time. Boeing has created a two-process model that optimizes schedules to make them fatigue friendly.

Dr. Belenky noted that the most important determinant of scheduling drivers or any other risk-assuming professional is human biology, such as circadian cycles. Accordingly, he believes that successful programs in other transport professions are applicable to motorcoach drivers, for whom there is little direct evidence on fatigue and scheduling.

The expert panel strongly advocated that FMCSA have rules for bus/motorcoach drivers that revolve around a fixed 24 hour work period. It was noted that for passenger-carrying drivers, unlike truck drivers, the current hours-of-service (HOS) rule allows drivers to extend their work day with breaks from driving. They are not established over a fixed time frame. The panel noted that over time, extension of the work time will likely infringe on sleep time, and that this type of schedule is going to result in the accumulation of sleep reductions which will impact on work performance. Evidence is clear that extended wake time amplifies the negative effects of time-on-task on performance. They argued that the HOS rules for drivers (both truck and bus/motorcoach drivers) should follow human physiology.

The Expert Panel also discussed how to regulate work-time cycles within a 24-hour day. One suggestion was to limit work start times during a particular time frame so that schedules are relatively consistent day-to-day within that period and therefore less likely to result in disruptions to sleep and consequent accumulation of sleep loss. For example, if a driver begins the first day of service during a particular work interval at 8 am, the HOS rules could limit the start-time during the remainder of the work interval to plus or minus 1-2 hours of that same start time (e.g., 6 am to 10 am). This will ensure that drivers have an opportunity for a consolidated sleep.

It was noted however, that the challenge with prescriptive rules such as the HOS rules for driving which aim to mitigate fatigue, is that it is not possible for FMCSA to regulate how much sleep a person obtains. Nor is it possible to regulate when they sleep. This led to discussion about the possible use of performance-based approaches.

Dr. Hanowski described a study (Hanowski, et al., 2008) in which in-vehicle devices objectively measure real-time performance and decrements in performance due to drowsiness. For example, if a driver has a certain number of lane departures, this might signal fatigue or drowsiness within the driver. He noted that technology directed at identifying drowsiness in real-time driving is currently available and is being used by some vehicle manufacturers (e.g., http://media.ford.com/article_display.cfm?article_id=18041; http://blog.sfgate.com/topdown/2009/07/05/mercedes-tackles-drowsiness/). Performance-based approaches for ensuring safety are consistent with the direction that is being taken in other industries such as those regulated by the Occupational Safety and Health Administration (OSHA).

Another point of discussion revolved about the possibility of allowing motorcoach companies' risk management as alternative means of demonstrating compliance which is currently proposed for the aviation industry.

5. Recommendations for Future Research

The panel members noted that a key limitation to being able to draw evidence-based conclusions regarding the effect of fatigue in motorcoach/bus driver safety, and the specific factors important in contributing to fatigue in motorcoach/bus drivers, is the limited availability of empirical research in the domain of motorcoach drivers in general, and more specifically in the areas of fatigue and sleepiness research. The panel acknowledged that the small number of motorcoach crashes per year is the main limiting factor in performing research on cause of motorcoach crash and motorcoach driver safety in general. Additional research needs identified by the expert panel during the course of the meeting are identified below.

1. There is a lack of information characterizing motorcoach driving patterns. What are typical duty cycles for motorcoach drivers? The literature doesn't provide reliable data

about duty and driving times for this driver type. Convening one or more focus groups may inform this and real-world issues with motorcoach scheduling.

Additional information of interest includes a better understanding of driver and industry problem-solving strategies and methods to cope with driver fatigue. This formative research should ideally be performed before new studies are planned. Focus groups could also inform the feasibility of implementing any proposed regulations.

2. Naturalistic studies on motorcoach drivers have not been performed but might inform real-world driving hours and patterns, and real-time exposure data.

3. Studies that follow drivers through 24-hour cycles instead of just driving shift time would provide the most comprehensive information about fatigue and hours of service and contextual non-shift factors.

4. Existing but unpublished data, such as insurance database actuarial data, might provide new information relatively inexpensively if made accessible to FMCSA or other investigators.

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Appendix A: Evidence Report Summary

Introduction

More than 124,000 large trucks and buses were involved in crashes on America's roadways in 2009, resulting in 3,619 deaths and 75,141 injuries. The effects of non-pathologic or acute fatigue can impair the ability of professional drivers, who drive long distances for hours at a time, to drive effectively and safely. Although fatigue has been well researched, its effect on transportation drivers, in particular motorcoach drivers, is of particular interest. Motorcoach drivers face extended workdays that require non-driving duties, intermittent non-working periods, and lengthy contact with passengers. The Federal Motor Carrier Safety Administration (FMCSA) – tasked with preventing related injuries and fatalities related to trucks, busses, motorcoaches and other commercial vehicles in the United States – seeks to identify motorcoach drivers' risk for crash as a result of acute fatigue and given the differences between motorcoach drivers and interstate truck drivers, all of which are explored in this evidence review.

Purpose and Scope of Evidence Report

This purpose of this report is to assess and characterize the relationship between crash and fatigue in generally healthy motorcoach drivers. Non-pathologic fatigue can be caused by factors such as insufficient sleep, disrupted circadian cycles, stress, and monotony. Fatigue or sleepiness caused by medical or sleep conditions is outside the scope of this report and has been previously assessed by the Federal Motor Carrier Safety Administration (FMCSA) in other evidence reports.

This evidence report addresses four key questions developed by the FMCSA to inform evaluation of current medical examination guidelines:

Key Question 1: What impact does non-pathologic fatigue have on crash incidence and driving ability?

Key Question 2: How much rest does a fatigued professional driver need to resume driving unimpaired?

Key Question 3: How do motorcoach drivers differ from truck drivers in terms of the following attributes:

E. Demographics (gender, age, race, etc.)?
F. Job function (pre-trip preparations, roads and distances travelled, opportunities for rest, etc.)?
G. Work environment (interactions with passengers, cabin ergonomics, schedules, shift cycles, etc.)?
H. Health-related behaviors and disease characteristics (body mass index, caffeine and alcohol use, depression, cancer, etc.)?

Key Question 4: Do identified differences between motorcoach and truck drivers increase (or decrease) the risks for acute non-pathologic fatigue?

The first two key questions assess the impact of non-pathologic fatigue on crash incidence and driving ability in motorcoach drivers and how much rest motorcoach drivers need to recover from this type of fatigue, also referred to as acute fatigue. Evidence on optimal shift and rest patterns also are identified.

Key Question 3 identifies quantitative differences between motorcoach and truck drivers in terms of demographics, job functions, work environments, and health-related behaviors and disease characteristics. Key Question 4 assesses whether the differences identified in Key Question 3 increase or decrease the risk of non-pathologic fatigue in motorcoach drivers. To inform assessment of hours-of-service rules for motorcoach drivers, the Agency wants to identify differences between interstate truck drivers, in general, and motorcoach drivers.

Identification of Evidence

We identified publications using a multistage process: We (1) searched the literature using electronic and manual methods; (2) applied retrieval criteria to titles and abstracts of identified studies to select articles for review; and (3) applied full inclusion criteria to full-length articles to determine which to include. Retrieval and inclusion criteria were designed with the FMCSA to ensure systematic selection of relevant studies that address the key questions and outcomes of interest.

Rating the Strength of Evidence

We critically appraised the risk of bias of individual studies using standard instruments to inform the quality of the overall evidence base and then considered this along with consistency, robustness, and amount of evidence to render strength of evidence ratings. The strength of evidence ratings are defined in Table 3.

Table 3. Strength-of-Evidence Ratings

Strength of Evidence	Interpretation
Strong	Evidence supporting the conclusion is convincing. It is highly unlikely that new evidence will lead to a change in this conclusion.
Moderate	Evidence supporting the conclusion is somewhat convincing. There is a small chance that new evidence will overturn or strengthen our conclusion. Regular monitoring of the relevant literature for moderate-strength conclusions is recommended.
Minimally acceptable	Although some evidence exists to support the conclusion, this evidence is tentative and perishable. There is a reasonable chance that new evidence will either overturn or strengthen our conclusions. Frequent monitoring of the relevant literature is recommended.
Insufficient	Although some evidence exists, the evidence is insufficient to warrant drawing an evidence-based conclusion. Frequent monitoring of the relevant literature is recommended.

Findings

Key Question 1: What impact does non-pathologic fatigue have on crash incidence and driving ability?

A. Crash

We examined the impact of non-pathologic fatigue on real-world crash by summarizing important previous work, assessing the literature, and highlighting gaps in the information. Previous work, including a 2009 FMCSA-commissioned systematic review, points to an association between fatigue and/or sleepiness and crash. However, in these previous works, drivers were not selected for healthfulness, and the influence of sleep disorders or health issues on these statistics is unknown. To address gaps in the identified previous work, we conducted two new assessments. First, we investigated the association between crash and fatigue or sleepiness in healthy drivers only. Then, we assessed the association between driving patterns, which can be fatiguing, and crash in professional drivers.

Crash and Fatigue or Sleepiness in Healthy Drivers

This analysis was intended to provide information on the impact of non-pathologic fatigue on crash, and to be free from the potentially confounding influence of fatigue or sleepiness consequent to a health or medical issue. We searched for relevant literature on fatigue or sleepiness and crash in healthy individuals only. No studies assessing the impact of fatigue or sleepiness on healthy drivers on crash incidence were identified.

Crash and Driving Patterns in Other Commercial Motor Vehicle Drivers

We also assessed the influence of driving patterns on crash among professional drivers. Demanding driving patterns could potentially fatigue drivers. Driving patterns for the purposes of this assessment include anything related to driving schedule, such as time-of-day driving, hours driven per day and week, and duration of breaks and rest.

Motorcoach Drivers

No studies that assessed driving patterns and motorcoach drivers were identified.

Other Commercial Motor Vehicle Drivers

Evidence primarily on truck drivers suggests that the incidence of crash increases after 5 or 6 hours of driving and continues to increase through the end of driving time at 8 to 11 hours. *(Strength of Evidence: Moderate)* Kaneko et al., 1991[1], found crash risk was highest during the first hour of driving, which was not replicated in other studies. After this initial elevated risk, the crash risk rose after hour 5 driving. Park et al., 2005[2], similarly found crash risk rose after the first 5 hours of continuous driving, and Jovanis et al., 2011[3, 4], found it increased after 6 hours.

After the first 5 to 7 hours of driving, studies generally found the crash incidence continued to rise. Park et al. found crash incidence rose significantly after 5 hours of continuous driving, as did Kaneko et al. Jovanis et al., 2011[3], found that in less-than-truckload trucks, crash incidence increased after the 6th hour of driving, and in truckload loads it increased after the 7th.

With one exception, the rest of the studies found greater crash incidence with even longer driving duration. Park et al. reported that crash incidence did not continue to significantly increase during continuous driving hours 5 through 10. Jones and Stein, 1987[5], found drivers who drove more than 8 hours were more likely to be in a multiple-car accident and had a higher crash incidence than drivers driving only 2 hours. Kaneko et al. noted, though, that it found crash risk continued to increase up to the 9th hour of continuous driving. McCartt et al., 1998[6], found that drivers who drove more than 10 consecutive hours were more likely to have been in a crash in the preceding 5 years. Jovanis et al. found that crash increased up to the 11th hour of driving, with the highest odds of crash at the 11th hour.

Crash incidence is generally highest during overnight and early morning hours, and increased in the afternoon. *(Strength of Evidence: Minimally Acceptable)* Nine studies assessed the relative frequency of crash by time of day, as described in the following text. Six studies (Hickman et al., 2005[7]; Park et al. 2005 [2]Jones and Stein, 1987[5]; Jovanis et al., 2011[8]; Massie et al., 1997[9]; and NTSB, 1996[10]) observed greater crash incidence in overnight to early morning hours, generally between midnight and 8 a.m. (with some variation in time frame assessed among studies). Massie et al. also observed another peak in crash between 3 p.m. and 5 p.m. Two studies had contrary findings. Kaneko at al. observed higher crash incidence among drivers who operated their vehicles in the afternoon and evening, and suggested this could be due to greater traffic congestion during those time. Sando et al.[11] found transit bus crash incidence was lowest between midnight and 4 a.m. and highest between 1 p.m. and 7 p.m. It attributed this to greater routes and risk exposure in the afternoon and evening.

B. Driving Ability

In this section, we examine the impact of non-pathologic fatigue or sleepiness on driving performance, measured by real-world driving and driving simulator studies. Real-word driving studies measure driving ability using special vehicles with instruments that measure driving performance and/or an expert passenger who assesses driving performance, or video monitoring or driver and vehicle. Driving simulator studies collect driving ability measures in a computer-generated driving environment.

Although this question is intended to assess driving ability in healthy drivers, we did not exclude drivers for whom health status was not reported, because previous FMCSA-supported systematic review work does not address the impact of fatigue or sleepiness on driving ability (as was the case for crash). However, we did exclude drivers who clearly had a health or sleep issue that could impact driving, such as obstructive sleep apnea.

Motorcoach Drivers

No included studies address the role of non-pathologic fatigue on driving ability in motorcoach drivers.

Other Commercial Motor Vehicle Drivers

Evidence suggests critical event rates increase over 11-hour driving shifts, which represented driving task-related fatigue for the purpose of this analysis. *(Strength of Evidence: Minimally Acceptable)* Two naturalistic studies of commercial truck drivers, the Drowsy Driver Warning System Study (n=99)[12, 13] and the Naturalistic Truck Driving Study (n=97)[14, 15] assessed the critical event rate (events per opportunity) over 11 hours of driving. The Drowsy Driver Warning System Study found that the rate was statistically significantly higher at hours 2 through 11, compared to the first hour of driving. The Naturalistic Truck Driving Study found the safety critical event increased by the hour, and the authors concluded this represented a time-on-task effect. Neither study found a statistically significant increase in event rate between the 10th and 11th hour.

No other specific conclusions are possible because each of the studies report different outcomes for the same general area of fatigue assessment; however, in general, the studies suggest fatigue impairs driving ability.

Non-professional Drivers

Evidence suggests insufficient sleep leads to greater incidence of simulated crash *(Strength of Evidence: Moderate)*, and that it is associated with decreased ability to drive within lane *(Strength of Evidence: Strong)*. Other measures of driving ability were addressed by fewer studies with less consistent findings; this evidence was insufficient to support evidence-based conclusions.

Three studies assessed the influence of insufficient sleep on simulated crash in healthy adults, and all found that with less sleep or longer duration since last sleep, crash was more common. Baulk et al., 2008[16], kept 15 adults up for 26 hours of supervised wakefulness, and they had only one or two collisions per simulated drive except for between hours 24 and 26, when they had 25. The other two studies subjected the volunteers to sleep restriction and then measured crash frequency during driving simulation at the afternoon circadian nadir, starting at 2 p.m. Peters et al., 1999[17], found the mean crash incidence was higher after only 4 hours in bed the previous night than after non-deprived sleep the preceding day. Vakulin et al., 2007[18], and colleagues found that significantly more of their 21 drivers crashed after 4 hours in bed than after 8.5 hours in bed.

Seven studies assessed the relationship between insufficient sleep and lane deviation in healthy adult volunteers. Insufficient sleep was experimentally induced by either prolonging wakefulness or assigning reduced time in bed. These studies consistently found that increased wakefulness or time in bed restricted to less than four hours was associated with greater lane deviation.

Among studies that kept drivers up for prolonged wakefulness and repeatedly measured lane deviation, all found deterioration. Baulk et al. kept 15 adults awake for 26 hours and found that lane drifting increased significantly with duration of wakefulness and was higher at each time the drive was repeated during increasingly extended wakefulness. Matthews et al., kept 14 young men awake for 22 hours and found that during 10-minute drives taken between 2 and 22 hours of wakefulness, lane drifting was not significantly different.[19] However, the number of times the center of the car left the road or struck a vehicle it was passing significantly increased over time. Arnedt et al. measured performance over 30-minute drives at 2:30 a.m., 5 a.m., and 7:30 a.m. after a normal day among 29 young healthy college students, and found that with increased time awake, lane deviation increased at each session, and increased faster during later sessions.[20].

The four studies that restricted time in bed to four hours or less found impairment in lane tracking, which was most pronounced at durations of time in bed of less than four hours. Philip et al., assigned 14 healthy young men to 2 hours in bed one night and 8 another night, finding that during real or simulated drives of over 100 miles repeated throughout the following day, there were more inappropriate line crossings after 2 hours in bed but that performance did not deteriorate throughout the day for either group.[21] Park et al., assigned 14 healthy young adults to 0, 4, and 8 hours of sleep before a 60-minute simulation drive and found lane deviation was worse when the participants had no sleep, but it was not significantly different when they had 4 hours compared to 8 hours.[22] Otmani et al., tested healthy men in a 90-minute simulation between 2 p.m. and 4 p.m. after no sleep deprivation or only 4 hours in bed. They did not find a significant difference between groups at any one time point, but did find a significant difference overall in a repeated measures analysis.[23] Lenne et al., 1998[24], compared performance after sleep deprivation or normal night's sleep in 24 college students at 8 a.m., 11 a.m., 2 p.m., 5 p.m., and 8 p.m., and found that sleep-deprived drivers drove more laterally, but within acceptable boundaries. They noted that changes during the day or within sessions were not significant.

Five of the studies described above, Matthews et al., [19], Arnedt et al.[20], Otmani et al., [23], Park et al.[22], and Lenne et al.[24], also assessed lane deviation variability, defined as the standard deviation of lane position. All found that experimentally induced insufficient sleep significantly increased lane deviation variability.

Key Question 2: How much rest does a fatigued professional driver need to resume driving unimpaired?

The intent of this key question was to determine the optimal rest duration and pattern required for a fatigued motorcoach driver to adequately recover functioning to a level consistent with safe driving. For this question, we define the "amount of rest" as any period of time spent not working. This period may, or may not, include sleep. Rest could take place during a shift break, before a shift (eg, overnight sleep), or between shifts (eg, reset). Breaks could be planned or taken in response to fatigue. In addition to coach drivers, commercial truck and bus drivers were assessed.

Motorcoach Drivers

No studies were identified that addressed rest and functional recovery in motorcoach drivers.

Other Commercial Motor Vehicle Drivers

Evidence suggests resting or napping for 30 minutes during a work break may reduce the incidence of crash, near crash, or other safety critical events, but there is an insufficient quantity of evidence from which to determine what the minimal duration is, and other studies inconsistently suggest that napping for any duration does not improve feelings of fatigue or sleepiness. *(Strength of Evidence: Minimally Acceptable)*

Perez-Chada, 2005[25], and the Naturalistic Truck Driving Study, 2011[26], assessed the impact of rest during shift on driving function. Perez-Chada compared the incidence of safety critical events in long-haul truck drivers who did and did not leave the road to take a 30- to 40-minute rest break in response to sleepiness, and found that those who napped had a significantly lower incidence of crash or near crash. In the Naturalistic Truck Driving Study, safety critical event incidence was compared in truck drivers before and after a 30-minute rest break, during which drivers did not work and did not necessarily sleep. The study found the safety critical event incidence was 28 percent lower after the break. Boivin et al.[27], which compared self-reported fatigue among truck drivers based upon their reported duration and frequency of rest, did not find an association between fatigue and time napping on or after shifts. Wylie et al., 1998[28], compared objective measures of sleepiness (eg, droopy eyelids, repeated blinks, as recorded on video and reviewed by investigators) and self-reported sleepiness in truck drivers before and after they took naps. The authors reported wide variation within and between drivers in signs and symptoms of sleepiness before and after naps. Their analysis could not link duration of nap sleep time with post-rest alertness; the authors postulated this might be due to the wide variation among individuals.

Evidence suggests a minimum of 4 to 6.7 hours is needed in the 24 hours before driving, and that at least 8 to 12 hours is needed in the 48 hours before driving to function well. One study emphasized that sleep in the 24 hours prior to shift start, as well as total sleep during the 48 hours before, were important for function. *(Strength of Evidence: Minimally Acceptable)*

Four studies, listed below, addressed the association between duration of sleep before shift and crash, safety critical event, or driving-related psychomotor vigilance. Two of those studies assessed crash. Dorrian and Dawson,[29], analyzed the amount of sleep before a crash among truck drivers with fatigue-related crash and those with crash due to other causes (eg, weather, speeding), finding that crash was less likely to be due to fatigue if the driver slept more than 6.5 hours in the preceding 24 hours *and* at least 8 hours total in the preceding 48 hours. The authors emphasized that these factors are most predictive of fatigue-related crash when considered together. Hertz et al.[30], compared fatal crash incidence in tractor-trailer drivers, who slept in two four-hour shifts in the sleeper berth, to those who slept eight hours continuously, finding the adjusted odds ratio of fatal crash was about three times higher in the broken rest group.

Hanowski et al.[31] assessed safety critical events, including crash and near-crash. The study reported the mean duration of sleep the night before a critical incident during the 10th or 11th hour of driving was 5.28 (SD 2.03) hours. The overall study period mean was 6.63 (SD 1.47) hours. The findings were similar whether or not drivers were at fault.

The remaining study addressing function assessed driving-related psychomotor vigilance. Belenky et al. [32], and Balkin et al. [33], conducted an experimental laboratory study in which truck and bus drivers were assigned to three, five, seven, or nine hours in bed overnight for a week, and the duration of sleep was physiologically monitored. Psychomotor vigilance task performance declined for all groups except the nine-hour group. Impairment was seen starting on day two for the three-hour group, and starting on day three for the five-hour group. The sleep-deprived groups then were assigned to a three-day recovery period with eight-hour nights, and psychomotor task recovery was observed for the three-hour group on the first day, but not at all for the five-hour group. The study authors concluded that at least four hours of sleep per night is required to maintain daytime alertness and performance.

Two studies assessed pre-shift rest or sleep and sleepiness. Belenky et al. [32], and Balkin et al., [33], described above, also reported objective sleepiness outcomes (ie, time to fall asleep at night) and self-reported sleepiness. They found the group assigned to three hours of rest in bed per night reported statistically significantly greater sleepiness after the first night, but the groups with five, seven, or nine hours in bed per night did not. They reported the time to fall asleep significantly shortened for the three- and five-hour groups, and that recovery on this outcome was not observed after the participants were reassigned to the three-day recovery period with eight hours of bedtime per night. No changes were observed in the seven- and nine-hour rest groups throughout the study. As noted above, the authors concluded at least four hours of sleep per night is necessary to maintain alertness and performance.

Barr et al.,[34], found that drivers judged drowsy by analysts watching videos of them, slept significantly less prior to driving than drivers who did not appear drowsy; however, the mean difference was small (285 minutes vs. 298 minutes, or 14 minutes mean difference). The authors did not find a relationship between time in bed and drowsiness, or the duration of sleep two or three days prior and drowsiness.

Key Question 3: How do motorcoach drivers differ from truck drivers in terms of the following attributes:

A. Demographics (gender, age, race/ethnicity, and other demographic characteristics)?

In this section, we assessed the prevalence of gender, race/ethnicity, age, education level, income, marital status, and job tenure among truck drivers and motormotorcoach/bus drivers. Our examination of data from the Bureau of Labor Statistics (BLS) and 23 studies – two focusing on bus and one on coach drivers – revealed several likely differences. They are:

- **Gender**. The majority of truck and motorcoach/bus drivers are male. Additionally, the percentage of women who drive motorcoach/bus (22.2 percent, data based on only three studies) appears to be higher than women who drive trucks (4.5 percent). Although more females appear to drive motorcoach/bus, the estimated range is broad (12 to 24.5 percent), according to data obtained from only three motorcoach/bus studies. A more precise estimate is not possible with the available data. *(Strength of Evidence: Moderate)*
- **Age**. Based on data from 17 studies, the weighted mean age of truck drivers is 43.7 years. Data from three motorcoach/bus driver studies suggest the average age of this driver group is 48 years. This is consistent with estimates from the BLS for the more broadly defined groups of bus and truck drivers with median ages of 44.3 and 49.46 years, respectively. *(Strength of Evidence: Moderate)*
- **Income**. Motor coach drivers tend to have lower incomes than commercial truck drivers, but this disparity in income is reducing. *(Strength of Evidence: Moderate)*
- **Job tenure**: Motorcoach/bus drivers tend to have more years on the job than commercial truck drivers. *(Strength of Evidence: Minimally Acceptable)*

Limited data precluded us from drawing a conclusion on the following attributes. However, BLS data – containing more broadly defined groups of bus and truck drivers – showed the following:

- **Race/Ethnicity.** More white and Hispanic drivers drive truck (82.8 and 16.6 percent, respectively) than motorcoach/bus (69.5 and 12 percent, respectively). More black drivers drive motorcoach/bus (26.6 percent) than truck (13.7 percent). Based on data from eight studies, the mean percent of white truck drivers (82 percent) is similar to the BLS data. However, data was retrieved from only one study (Escoto and French, 2012) of transit bus drivers in a Midwestern U.S. city, with limited generalizability across different geographical locations. The study showed 59 percent of its participants were white and 41 percent non-white.
- **Education level.** A slightly larger proportion of truck drivers (17.6 percent) than motorcoach/bus drivers (10.6 percent), on average, do not have a high school diploma. The percentage of truck drivers (53 percent) and motorcoach/bus drivers (50.7 percent) who finished high school but did not attend college was statistically close. Data from three truck driver studies showed 20 percent did not finish high school and 40.8 percent had a high school diploma. One bus driver study (Escoto and French, 2012) found that 45.8 percent of its participants had a high school diploma and 39.8 percent had some college.

A paucity of literature for truck and motorcoach/bus drivers regarding marital status precludes conclusions about difference between the two driver groups.

B. Job Function (Loading requirements, light work duties, driving time, etc.)?

In this section, we assessed roads travelled, distance travelled, driving time, total time worked, loading requirements, light work duties, pre-trip operations, and opportunities for rest among truck and motorcoach/bus drivers. Our examination of 16 studies, four of which focus on motorcoach/bus drivers, offers three differences in job function characteristics. They are:

- **Roads travelled**: Based on available data from two studies, long-haul truck drivers spend most of their driving time on the interstate and transit bus drivers spend most of their driving time in the city; however, one in three bus drivers spends half his/her time equally in the city and suburbs. Few spend most of their time in the suburbs. No data was available for coach drivers. *(Strength of Evidence: Minimally Acceptable)*
- **Distance travelled**: Based on data from seven studies, truck drivers drive more miles per trip and per week. The average length per trip for truck drivers (557.8 miles) is longer than the average travelled by coach drivers (250 to 300 miles), with a mean difference of at least 257.8 miles. On average, coach drivers drive nearly half as many miles per week than truck drivers: 1,200 miles vs. 2,449 miles. *(Strength of Evidence: Minimally acceptable)*
- **Driving time:** Based on data from six studies, bus drivers drive slightly fewer hours than truck drivers, on average. About 60 percent of long-haul truck drivers drive 10 hours or less per day compared to bus drivers, who average between 8 and 9 hours of driving per day. One study reported a mean driving time of 9.4 hours for truck drivers, and another reported 8.58 for bus drivers. Data was not available for coach drivers. *(Strength of Evidence: Insufficient)*

A paucity of literature for truck and motorcoach/bus drivers regarding the following topics precludes conclusions about difference between these two driver groups:

- Loading requirements
- Light work duties
- Pre-trip operations
- Opportunities for rest

C. Work Environment (Interaction with passengers, access to health care, scheduling/shift cycles, etc.)?

In this section, we assessed control over trips, interactions with passengers, cabin ergonomics, scheduling/shift cycles, access to health care, employment/industry culture, potential exposure to harmful substances, quality of rest/sleep, and opportunity for exercise among truck drivers and motorcoach/bus drivers. Our examination of 20 studies, four of which are motorcoach/bus driver studies, provided two differences in work environment characteristics. They are:

- **Employment/industry culture:** Based on data from one study, both truck and coach drivers feel pressure to bend driving rules because of dispatchers. On a scale of 1 to 7 (7 meaning a lot of pressure), both driver groups scored in the 3 range, with truck drivers reporting a mean number of 3.98 and coach drivers a 3.13. A significant difference was found between truck and coach drivers on personal motivations to continue driving when tired. Truck drivers reported a mean score of 6.59 on the 1 to 7 scale, meaning to a very large extent, whereas coach drivers reported a mean score of 2.63, meaning to a lesser extent. *(Strength of Evidence: Minimally acceptable)*

- **Scheduling/shift cycles:** Based on data from five studies, bus drivers have a more consistent schedule than truck drivers. *(Strength of Evidence: Insufficient)*

A paucity of literature for truck and motorcoach/bus drivers regarding the following topics precludes conclusions about difference between these two driver groups:

- Control over trips
- Interactions with passengers
- Cabin ergonomics
- Access to health care
- Potential exposure to harmful substances
- Quality of rest/sleep
- Opportunity for exercise

D. Health-Related Behaviors/Disease Characteristics (Smoking Status, BMI, etc.)?

In this section, we assessed smoking status, BMI, physical activity, stimulant use, alcohol use, general health, HIV/AIDS, cancer, cardiovascular disease, cerebrovascular disease, respiratory conditions, renal/CKD, endocrine disease, neurological disease, musculoskeletal disorders, mental health/suicide, and vision and hearing disorders among truck drivers and motorcoach/bus drivers. Our examination of 28 studies offers only one similarity in health characteristics of the two driver groups.

Based on data from nine truck driver studies and one bus driver study, the majority of truck and bus drivers are overweight or obese. The mean BMI for bus drivers is 32.7 kg/m^2 and 32.30 kg/m^2 for truck drivers. *(Strength of Evidence: Minimally Acceptable)*

A paucity of literature for truck and motorcoach/bus drivers regarding the following topics precludes conclusions about difference between these two driver groups:

- Smoking status
- Physical activity
- Stimulant use
- Alcohol use
- General health
- HIV/AIDS
- Cancer
- Cardiovascular disease
- Cerebrovascular disease
- Respiratory conditions.

- Renal/CKD
- Endocrine disease
- Neurological disease
- Musculoskeletal disorders
- Mental health/suicide
- Vision and hearing disorders

Key Question 4: Do identified differences between motorcoach and truck drivers increase (or decrease) the risks for acute non-pathologic fatigue?

Demographics

Based on comparisons between coach/coach and truck drivers in Key Question 3A, our review found that motorcoach/bus drivers are more likely to be older, female, comprising more nonwhite drivers, earning less money, and having more experience.

The literature suggests that two key variables are likely to increase the risk for acute fatigue, placing motorcoach/bus drivers more at an increased risk:

- **Older age:** (Di Milia et al., 2011[35]; Muecke, 2004[36]; and Nicholson, 1999[37])
- **Female gender:** (Tiesinga et al., 1999[38]; and Di Milia et al., 2011[35])

No other demographic variables were identified that would either increase or decrease the risk for acute fatigue for motorcoach/bus drivers when compared with truck drivers.

Job Function

Based on comparisons between motorcoach/bus and truck drivers in Key Question 3B, our review found that motorcoach/bus drivers are more likely to drive on city roads, fewer miles, and for slightly fewer hours. Despite these results, only one attribute (miles per day) represents coach drivers.

The literature suggests that exposure to three key variables is likely to increase the risk for acute fatigue, placing motorcoach/bus drivers at a decreased risk for acute fatigue when compared to truck drivers:

- **Monotonous driving conditions** (Eskandarian et al., 2007[39]; Lal and Craig, 2001[40]; and Williamson et al., 2011[41])
- **Long driving hours** (Caruso et al., 2004[42]; Duke et al., 2010[43]; Horne and Reyner, 1999[44]; and Lal and Craig, 2001[40])
- **Long work hours** (Eskandarian et al., 2007[39]; Lal and Craig, 2001[40]; Morrow and Crum, 2004[45]; Nicholson, 1999[37]; and Van der Hulst, 2003[46])

Work Environment

Based on comparisons between motorcoach/bus and truck drivers in Key Question 3C, our review found that motorcoach/bus drivers are more likely to have more consistent scheduling and feel slightly less pressure from dispatchers to bend driving rules. Despite these results, only one attribute (dispatcher pressure) represents coach drivers.

Our literature review of fatigue risk factors in this section suggests that exposure to three key variables is likely to place motorcoach/bus drivers at a decreased risk for acute fatigue:

- **The pressure of making deliveries on time** (Morrow and Crum, 2004[45]).

Other work environment characteristics that are consistently associated with increased risk for acute fatigue include:

- **Shift work** (night work/irregular work hours, both of which interfere with the circadian rhythm) (Akerstedt et al., 2003[47]; Apostolopoulos et al., 2010[48]; Lal and Craig, 2001[40]; Leibowitz et al., 2006[49]; Morrow and Crum, 2004[45]; Muecke, 2004[36]; and Nicholson, 1999[37])
- **Sleep debt/cumulative sleep loss** (Akerstedt et al., 2003[47]; Apostolopoulos et al., 2010[48]; Duke et al., 2010[43]; Eskandarian et al., 2007[39]; Leibowitz et al., 2006[49]; Muecke, 2004[36]; Nicholson, 1999[37]; Niu et al., 2011[50]; Smolensky et al., 2011[51]; and Williamson et al., 2011[41])

Health-Related Behaviors and Disease Characteristics

Based on comparisons between motorcoach/bus and truck drivers in Key Question 3D, our review found that motorcoach/bus drivers are as likely to be overweight or obese as truck drivers.

The literature suggests that obesity is a key variable to increase the risk for acute fatigue:

- **Obesity** (Duke et al., 2010[43]; Smolensky et al., 2011[51]; and Vgontzas et al., 2006[52])

The only health-related data available for both motorcoach/bus and truck drivers pertain to obesity. On average, both motorcoach/bus and truck drivers are overweight and/or obese, with an average BMI of 32.7 kg/m^2 (based on a single study) and 32.3 in kg/m^2 (based on eight studies), respectively, placing both groups at an increased risk for acute fatigue based on their BMI.

Other health-related characteristics that are consistently associated with increased risk for acute fatigue include:

- **Sleep apnea/Sleep-disordered breathing (**Duke et al., 2010[43]; Eskandarian et al., 2007[39]; Leibowitz et al., 2006[49]; Smolensky et al., 2011[51]; and Vgontzas et al., 2006[52])
- **Restless legs syndrome** (Leibowitz et al., 2006[49]; and Smolensky et al., 2011[51])
- **Diabetes** (Smolensky et al., 2011[51]; and Vgontzas et al., 2006[52])
- **Depression and/or anxiety** (Leibowitz et al., 2006[49]; Smolensky et al., 2011[51]; Tiesinga et al., 1999[38]; and Vgontzas et al., 2006[52])

A paucity of data for motorcoach/bus drivers, however, makes it difficult to examine whether they are at an increased (or decreased) risk for acute fatigue based on differences between these health-related variables.

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