Work And Sleep Among Transport Operators: Disparities And Implications For Safety

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Abstract

The transportation and warehousing sector employs nearly 5 million individuals, many of whom are transport operators. Transport operators have experienced changes in work organization in recent decades; however, little is known about the impacts of these changes and how these impacts differ between operator types. Therefore, using two directly comparable transport operator datasets – one of all transport operator types by the National Sleep Foundation, and another of exclusively long-haul truck drivers called the Trucker Sleep Disorders Survey (TSLDS) – we sought for the first time to evaluate disparities between transport operators' work organization; sleep characteristics; sleep problems and sleep disorders; and safety outcomes. We also explored associations between work organization and sleep characteristics, problems, and disorders with safety outcomes. Many significant differences were found across transport operator sectors. In particular, the TSLDS long-haul truck drivers largely fared worse when compared to other transport operators across a number of characteristics, including shift length, shift work, sleep latency, and the number of safety outcomes due to sleepiness. These cross-sectoral differences suggest the need for tailored interventions to address the unique configurations of demographic, work organization, sleep, and safety characteristics found in different transport operator sectors. However, across all transport operator sectors, latent sleep disorders appeared ubiquitous; thus, universal efforts to screen, diagnose, and treat sleep disorders should be a public health imperative. Differences were found transport operator in patterns of significant associations between work organization and sleep with safety outcomes, further suggesting the need for tailored interventions. However, sleep quality, sleep sufficiency, and whether one's workday schedule allowed adequate sleep were the most strongly associated with safety, suggesting that addressing these issues could benefit many transport operators. Further research, including a national study of transport operators, would help guide future interventions to enhance safety.

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Work and sleep among transport operators: Disparities and implications for safety

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ABSTRACT

The transportation and warehousing sector employs nearly 5 million individuals, many of whom are transport operators. Transport operators have experienced changes in work organization in recent decades; however, little is known about the impacts of these changes and how these impacts differ between operator types. Therefore, using two directly comparable transport operator datasets – one of all transport operator types by the National Sleep Foundation, and another of exclusively long-haul truck drivers called the Trucker Sleep Disorders Survey (TSLDS) – we sought for the first time to evaluate disparities between transport operators' work organization; sleep characteristics; sleep problems and sleep disorders; and safety outcomes. We also explored associations between work organization and sleep characteristics, problems, and disorders with safety outcomes.

Many significant differences were found across transport operator sectors. In particular, the TSLDS long-haul truck drivers largely fared worse when compared to other transport operators across a number of characteristics, including shift length, shift work, sleep latency, and the number of safety outcomes due to sleepiness. These cross-sectoral differences suggest the need for tailored interventions to address the unique configurations of demographic, work organization, sleep, and safety characteristics found in different transport operator sectors. However, across all transport operator sectors, latent sleep disorders appeared ubiquitous; thus, universal efforts to screen, diagnose, and treat sleep disorders should be a public health imperative. Differences were found transport operator in patterns of significant associations between work organization and sleep with safety outcomes, further suggesting the need for tailored interventions. However, sleep quality, sleep sufficiency, and whether one's workday schedule allowed adequate sleep were the most strongly associated with safety, suggesting that addressing these issues could benefit many transport operators. Further research, including a national study of transport operators, would help guide future interventions to enhance safety.

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1. Introduction

The transportation and warehousing sector, which includes transport operators, employs nearly 5 million individuals in the United States (Bureau of Labor Statistics, 2016d). By far the largest segment of transport operators are heavy and tractor-trailer drivers, who number 848,640 (Bureau of Labor Statistics, 2016e). Other transport operators include 71,930 airline pilots, copilots, and flight engineers; 35,860 locomotive engineers; 38,440 railroad conductors and yardmasters; 79,450 taxi drivers and chauffeurs; 230,200 school bus drivers; 66,070 transit and intercity bus drivers; and 51,080 light or delivery service truck drivers (Bureau of Labor Statistics, 2016a, 2016b, 2016c, 2016e). Given the high-stakes nature of work as a transport operator, specifically regarding the safety and well-being of others, safety is paramount in such occupations. However, transportation vehicle operators endure an unequal distribution of risks (Helmkamp et al., 2013), many of which are related to work organization and sleep, that influence safety outcomes.

As is the case with many other occupations, the work organization of transport operators has undergone tremendous changes over the past several decades. Beginning in the mid-1970s, many industries experienced profound changes in business practices (Belzer, 2000). These changes resulted in multiple changes to work organization, including more demanding work, declines in unionization, wage stagnation or decreases, and diminished job security (Landsbergis et al., 2014; Siqueira et al., 2014). Among the most impactful changes have occurred in shift work and work hours. Shift work, defined as any work shift outside the 7 a.m. to 6 p.m. period, or rotating shifts, has become increasingly common (Caruso, 2014; Geiger-Brown et al., 2012). Long working hours, generally defined as working more than 40 h per week, or an extended shift as more than 8 h per day, are also pervasive (Caruso et al., 2004). Among all industrialized nations, the U.S. has the longest working hours on a yearly basis, and the proportion of workers working long hours has increased substantially over the past three decades (Caruso et al., 2006; Johnson and Lipscomb, 2006).

Changes in work organization have detrimentally impacted sleep. This is especially true of transportation workers, who have the highest prevalence of short sleep duration of any occupation (2010). Poor sleep is associated with shift work, long work hours, and job stress, which subsequently result in an increase in performance errors (Caruso and Rosa, 2012; Jackson et al., 2013). Shift work and long work hours disrupt circadian rhythms and are associated with increased sleep problems and sleep disorders and reduced sleep duration and sleep quality (Antunes et al., 2010; Caruso, 2014; Geiger-Brown et al., 2012; Johnson and Lipscomb, 2006; Luckhaupt et al., 2010).

Sleep patterns, sleep problems and sleep disorders endemic to transportation workers lead to increased fatigue and sleepiness and are a major cause of accidents and injuries (Pack et al., 2006; Smolensky et al., 2011). These connections are particularly well established among transport operators, as operating a vehicle requires continuous attention, and poor performance can generate immediate consequences (Philip and Åkerstedt, 2006). Together, sleepiness, sleep deprivation, and driving at night have been implicated in an estimated 20% of traffic accidents (Philip, 2005). Federal regulatory bodies, including the Federal Aviation Administration, the Federal Transit Administration, and the Federal Railroad Administration (U.S. Federal Motor Carrier Safety Administration, 2015), enact policies to reduce fatigue and improve sleep, with a principal aim of mitigating accidents and injuries. Despite these efforts, the transportation and warehousing sector had an incidence rate of occupational injuries and illnesses of 225.2 per 10,000 full-time workers in 2014, which was the highest rate among all private industries (Bureau of Labor Statistics, 2015b). More specifically, the transportation and material moving occupations had the largest share of fatal injuries (28%) of any occupational group, while transportation incidents accounted for 40 percent of fatal workplace injuries in 2014 (Bureau of Labor Statistics, 2015a,2015b).

1.1. The case of long-haul truck drivers

The largest segment of transport operators – long-haul truck drivers – exemplify many of the patterns of work, sleep, and safety which have unfolded across the transportation and warehousing sector. The trucking industry has undergone substantial changes over the past several decades, many of which have significant implications for the health and safety of drivers (Belzer, 2000). Many of these changes are associated with deregulation following the passage of the Motor Carrier Act of 1980 (Belzer, 2000), which resulted in myriad changes to the structure of the industry and ushered in an era of excessive competition among trucking companies (Belzer, 2000). Multiple elements of the work organization of long-haul trucking were transformed, leading to longer work hours, more frequent shift work, longer periods away from home, and a faster pace of work, all of which have increased job stress and job strain; further, these changes resulted in changes to pay structures which resulted in decreases in unionization, wage declines, along with loss of benefits and more hazardous working conditions (Apostolopoulos et al., 2014, 2016b, 2016c; Belzer, 2000; Lemke et al., 2015; Saltzman and Belzer, 2007).

The work organization of long-haul truck drivers directly affects safety (Belzer, 2009). Cumulatively, long-haul truck drivers' long work hours, fragmented and erratic work shifts, and frequently disrupted circadian rhythms degrade sleep duration and quality and can bring about sleep problems and sleep disorders (Apostolopoulos et al., 2014; Caruso, 2014; Ebrahimi et al., 2015; Geiger-Brown et al., 2012; Hege et al., 2015; Krueger et al., 2007a; Lemke et al., 2015; Philip, 2005). These sleep issues then induce fatigue and excessive sleepiness during working hours (Ingre et al., 2006; Moller et al., 2006; Otmani et al., 2005; Philip, 2005; Philip and Åkerstedt, 2006; Philip et al., 1999). Fatigue and sleepiness have consistently been shown to degrade the ability to safely operate a vehicle and perform other safety-critical job tasks (Ingre et al., 2006; Lemke et al., 2016; Moller et al., 2006; Otmani et al., 2005; Philip and Åkerstedt, 2006; Philip et al., 1999). Thus, sleep issues are associated with accidents and injuries among long-haul truck drivers (Chen et al., 2016; Hanowski et al., 2007; McCartt et al., 2000). Large truck crashes are catastrophic for other motorists and pedestrians and place the public at excessive risks for injury. For example, among large truck crashes in 2012, there were 2813

occupants of other vehicles, 298 pedestrians, and 61 bicyclists killed, compared to 697 large truck occupants – a ratio of nearly 6–1 (Federal Motor Carrier Safety Administration, 2014).

1.2. Rationale and objectives

Surprisingly, relatively little is known about the disparities in work organization; sleep characteristics, problems and disorders; and safety outcomes among transport operators. Further, there is little known regarding the impacts of these disparities on safety outcomes. Recognizing these gaps in knowledge, the National Sleep Foundation (NSF), a leading organization in sleep research in the United States, conducted a national poll of transport operators in 2012 to assess work organization characteristics; sleep characteristics, problems, and disorders; and sleep-related safety outcomes. While the NSF data are compelling, conclusions that can be drawn from these data alone are limited, particularly due to the small number of long-haul truck drivers included in the sample which greatly diminishes statistical power.

Thus, using supplemental and directly comparable data from a larger sample of U.S. long-haul truck drivers titled the "Trucker Sleep Disorders Survey" (TSLDS), which were collected by the current authors, this study sought for the first time to evaluate disparities between transport operators' work organization; sleep characteristics; sleep problems and disorders; and safety outcomes. We also explored associations between work organization and sleep characteristics, problems, and disorders with safety outcomes. We hypothesized that, due to the aforementioned endemic risk which defines the long-haul trucking profession, the TSLDS data would show that long-haul truck drivers' work organization; sleep characteristics, problems, and disorders; and sleep-related safety outcomes are generally more problematic than other transport operators. Further, we hypothesized that these work organization and sleep characteristics, problems, and disorders would correspond with sleep-related safety outcomes, with especially strong connections among the long-haul truck drivers due to the excessive endemic risk speculated in our first hypothesis.

2. Materials and methods

2.1. Study design and procedures

2.1.1. National Sleep Foundation study on transportation workers' sleep

In 2012, the NSF conducted a national study to assess sleep-related issues among transportation workers, which was titled, "2012 Sleep in America Poll: Planes, Trains, Automobiles, and Sleep." (National Sleep Foundation, 2012). With the TSLDS sample (described below) including only males, we only made use of male subjects (N = 809) from the NSF sample (National Sleep Foundation, 2012). This included: 140 bus/taxi/limo drivers; 155 train operators; 190 pilots; 136 short-haul truck drivers; and 42 long-haul truck drivers. All transportation workers included in the sample were at least 25 years old, and 48 were over the age of 65 (National Sleep Foundation, 2012). We made use of only those questions which were identical verbatim in both the NSF and TSLDS surveys.

2.1.2. The trucker sleep disorders survey

Because of the small sample size of long-haul truck drivers in the NSF dataset, a second dataset was utilized to bloster the sample size of this key segment of transport operators and motr meaningfully explore the key research questions in this study. A non-experimental, descriptive, cross-sectional design was employed to collect survey data from 262 U.S. long-haul truck drivers at a large truckstop located in North Carolina, using the Trucker Sleep Disorders Survey (TSLDS). For numerous reasons, including its consistent and high level of trucking activity, its geographic location, and the transient nature of long-haul trucking, this location constituted a representative national truckstop. The TSLDS was developed by our research team using insights gained from other instruments, relevant literature, and our previous work with U.S. long-haul truck drivers (National Sleep Foundation, 2012; Netzer et al., 1999; Philip and Åkerstedt, 2006). Critically, the survey questions in the TSLDS used in this current study are identical verbatim to those in the NSF study. TSLDS characteristics of this survey and a detailed description of the study procedures and cohort characteristics has been described in previous manuscripts which used this same dataset (Apostolopoulos et al., 2016a; Hege et al., 2016, 2015; Lemke et al., 2016, 2015; Wideman et al., 2016). For this study, we filtered our sample by age, and removed those were less than 25 years of age from analyses to match the NSF sample, which resulted in a final TSLDS sample size of 257. This study was approved by the Institutional Review Board (IRB) at a public university in North Carolina, and participants gave written consent.

2.2. Statistical analyses

All statistical analyses were performed using SPSS 23.0 (IBM Corp., 2015). We first conducted descriptive analyses to compare the TSLDS long-haul truck driver sample to the NSF sample for both the entire sample and specific transport operator types. This included all variables related to demographics (age and race), work organization (work hours, scheduling practices), sleep characteristics (duration, quality, schedule allowing for adequate sleep, and lack of alertness to perform job safely), and sleep problems (waking up, snoring, difficulty falling asleep, and diagnosis with a sleep disorder). Work hours were categorized in the following fashion: less than 6 h = 1; 6 h to less than 8 h = 2; 8 h to less than 9 h = 3; 9 h to less than 12 h = 4; and 12 h or more = 5. We categorized sleep duration based on NSF recommendations, with 7–9 h considered "sufficient". For sleep duration comparisons, we used the NSF survey response selections, with incremental categories ranging from 5 h of sleep or less = 1, to more than 10 h of sleep = 22. We then grouped the sleep duration variable in quartiles to display the differences and similarities across the samples. Several of the descriptive statistics for the TSLDS have been reported in previous manuscripts (Hege et al., 2016, 2015; Lemke et al., 2016, 2015;

Wideman et al., 2016); however, these analyses represent the first comparisons of the TSLDS findings with other transport occupations.

We performed chi square (χ^2) tests to compare proportions for categorical variables across the groups and summary independent-sample *t*-tests to compare means of the groups for continuous variables. With seven comparison groups against the TSLDS sample, we used Bonferroni-adjusted *p*-values to avoid Type II errors; therefore, 0.007 (0.05/7) was the criterion for statistical significance of $p < 0.05$, and 0.001 (0.01/7) was the criterion for statistical significance of $p < 0.01$. We conducted Kruskal-Wallis tests to examine for differences across the ordinal categorical variables.

We next calculated a measure of daytime sleepiness experienced by individuals – the Epworth Sleepiness Scale (ESS). ESS scores range from 0 to 24 for the groups and were calculated by making use of a set of questions which queried transport operators' likelihoods of dozing off or falling asleep while engaging in various tasks. To accumulate the scores, each of these tasks were weighted 0–3 based on the following criteria: Would never doze = 0; slight change = 1; 2 = moderate chance; and 3 = high chance. ESS scores were categorized in the following manner: Unlikely that the individual is abnormally sleepy = 0–7; individual has an average amount of daytime sleepiness = 8–9; individual may be excessively sleepy depending on situation = 10–15; and individual has excessive sleepiness and should consider medical attention = 16–24 (Talk About Sleep). We calculated the means and performed summary independent-sample *t*-tests to make comparisons across groups. We then examined differences in the impact of sleepiness on job performance and being involved in incidents at work, again making use of χ^2 tests to compare proportions across groups. These variables have been reported in a descriptive form a previous manuscript (Lemke et al., 2016); however, as stated previously, these analyses represent the first comparisons of the TSLDS findings to other transport occupations.

Lastly, we were interested in the associations between work organization characteristics and sleep characteristics, problems, and disorders with the three sleep-related safety outcome variables (ESS score, the impact of sleepiness on job performance, and having a safety incident or accident on the job). To examine patterns of associations across the groups, we used partial correlation analyses. We controlled for age and race in these analyses, as these two demographic characteristics represent potential confounding factors that could potentially influence the patterns of these associations.

Table 1
Comparison of demographic and work organization characteristics of TSLDS long-haul truck driver sample and NSF sample data.

	TSLDS long-haul truck drivers (N = 257)	**NSF long-haul truck drivers** (N = 42)	**NSF short-haul truck drivers** (N = 136)	**NSF pilots** (N = 190)	**NSF train operators** (N = 155)	**NSF bus/taxi/limo drivers** (N = 140)
Age (Mean (SD))	46.90 (10.29)	51.43 (9.15)**	51.39 (10.05)**	46.43 (10.13)**	46.30 (9.52)**	56.83 (9.48)**
Race/Ethnicity (%)						
White	57.2	92.5	93.2	92.0	89.6	86.2
Non-White	42.8	7.5	6.8	8.0	10.4	13.0
Length of Shift (Mean (SD))	4.46 (0.69)	4.07 (0.56)**	3.48 (1.00)**	3.75 (1.05)**	3.61 (0.84)**	2.61 (1.20)**
Less than 6 hours (1) (%)	0.4	0	3.7	3.7	0.6	22.9
6–8 h (2)	0.8	0	14.0	12.1	11.0	25.7
8–9 h (3)	2.3	11.9	25.7	15.3	25.8	23.6
9–12 h (4)	43.0	69.0	44.1	47.9	52.3	23.6
12 or more hours (5)	53.1	19.0	12.5	21.1	10.3	4.3
Schedule Regularity (%)						
Same Daily Schedule	17.5	21.4	61.0**	6.8*	45.2**	56.4**
Same Daily # of Hours	36.6	14.3**	30.9	5.3**	29.0	50.7
Same Days each Week	67.6	0.5**	77.9	10.5**	51.6	71.4
Time Begin Work (%)						
Midnight – Before 6 a.m.	37.3	33.3	22.9	23.1	15.7*	26.6
6 a.m. to Before 9 a.m.	57.3	44.4	56.6	30.8*	57.1	55.7
9 a.m. to Before 12 p.m.	3.6	11.1	2.4	7.7	2.9	3.8
12 p.m. to Before 6 p.m.	0.9	11.1	8.4	15.4	12.9	11.4
6 p.m. to Before Midnight	0.9	0	9.6	23.1*	11.4	2.5
Time End Work (%)						
Midnight – Before 6 a.m.	3.0	22.2*	7.2	0	5.8	6.3
6 a.m. to Before 9 a.m.	1.0	11.1	7.2	27.3	10.1	3.8
9 a.m. to Before 12 p.m.	0	0	3.6	0	1.4	2.5
12 p.m. to Before 6 p.m.	25.3	22.2	60.2*	36.4	50.7*	74.7**
6 p.m. to Before Midnight	70.7	44.4**	21.7**	36.4**	31.9**	12.7**

* $p < 0.05$.
** $p < 0.01$.

Table 2
Comparison of sleep characteristics of TSLDS long-haul truck driver and NSF samples.

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (N = 42)	NSF short-haul truck drivers (N = 136)	NSF pilots (N = 190)	NSF Train operators (N = 155)	NSF bus/taxi/ limo drivers (N = 140)
Workday Sleep Sufficiency (%)		*				
More Sleep than Needed	9.0	14.3	1.5	0.5	0.6	0.7
Sufficient	44.9	71.4	44.1	59.0	48.7	57.9
Less Sleep than Needed	46.1	14.3	54.4	40.4	50.6	41.4
Non-Workday Sleep Sufficiency (%)		*	**	**	**	**
More Sleep than Needed	33.9	22.0	9.6	10.1	14.3	8.6
Sufficient	44.4	68.3	71.3	78.3	71.4	80.0
Less Sleep than Needed	21.8	9.8	19.1	11.6	14.3	11.4
Sleep Duration (Quartiles)						
Workdays						
25	5.0	9.0	5.0	6.0	5.0	6.0
50 (Median)	9.0	12.5	8.0	9.0	8.0	9.0
75	13.0	16.25	10.0	12.0	11.0	12.75
Non-Workdays						
25	9.0	12.0	9.0	11.0	9.0	9.0
50 (Median)	12.0	13.0	12.5	13.0	13.0	13.0
75	15.0	17.0	15.0	16.0	17.0	16.0
Workday Sleep Quality (%)			*	*	*	**
Every Night	18.5	11.9	5.9	3.2	4.5	9.3
Almost Every Night	44.1	52.4	48.5	43.7	38.7	64.3
Rarely/Never	37.4	33.4	44.1	51.6	56.1	25.7
Non-Workday Sleep Quality (%)		**	**	**	**	**
Every Night	46.5	26.2	14.7	8.4	11.6	17.1
Almost Every Night	37.4	42.9	54.4	68.4	58.7	62.9
Rarely/Never	16.1	28.6	30.1	22.1	38.4	20.3
Workday Schedule Allows Adequate Sleep (%)	55.7	71.4**	67.6*	61.6	54.2	78.6**
Ever told your superior that you were not alert enough to perform your job safely (%)	7.4	1.0	7.4	* 21.6	7.1	1.0

* $p < 0.05$.
** $p < 0.01$.

3. Results

Demographic and work organization characteristics for the TSLDS and NSF samples are available in Table 1. The mean age of the TSLDS sample was 46.9 years of age, which was significantly younger than the NSF long-haul truck drivers, short-haul truck drivers, and bus/taxi/limo drivers, as well as the control group and the total sample. The TSLDS sample was significantly more diverse (42.8% non-white) than all the NSF groups. For work hours, the mean score for the TSLDS sample was 4.46 out of 5, which represented significantly longer work hours than all of the NSF groups. The TSLDS sample experienced the same daily schedule 17.5% of the time, the same number of daily hours 36.6% of the time, and the same days each week 67.6% of the time. There were several statistically significant proportional differences with NSF groups, particularly for daily schedules. Among the TSLDS sample, 37.3% reported beginning work between the hours of midnight and before 6:00 a.m., which was higher than any of the NSF groups. Over 70% of the TSLDS sample reported finishing work between 6:00 p.m. and midnight, which was significantly more common than every NSF group.

A complete description of sleep characteristics for the TSLDS and NSF samples are available in Table 2. Not surprisingly, the TSLDS and NSF samples universally reported getting more sufficient sleep on non-workdays than on workdays. The TSLDS sample was significantly different than all NSF groups on non-workday sleep sufficiency, with only 44.4% reporting “sufficient” sleep during these days, with much higher rates of drivers getting too much or too little sleep. Overall, the TSLDS sample was similar to the NSF groups with regard to sleep duration. Similar to sleep sufficiency, participants reported better sleep quality on their non-workdays. The TSLDS sample reported disproportionately better sleep quality on non-workdays than all other NSF groups. Among the TSLDS sample, 55.7% reported that they felt their schedule allows them to get enough sleep, which was significantly lower than the NSF long-haul, short-haul, and bus/taxi/limo drivers, as well as the control group. Finally, NSF pilots were significantly more likely to report having told their superior of not being alert enough to perform their job safely.

A complete description of sleep problem characteristics for the TSLDS and NSF samples are available in Table 3. Sleep problems and disorders were commonplace across both samples. For example, among the TSLDS long-haul truck drivers, over half reported waking up during the night (68.1%), waking up feeling unrefreshed (55.7%), snoring (64.2%), or waking up too early and not being able to get back to sleep (51.6%) in the most severe category (“Every Night/Almost Every Night”). Among the TSLDS sample, 13.8% having been diagnosed with a sleep disorder, which was a higher rate than any of the NSF groups although statistically non-

Table 3
Comparison of sleep problems of TSLDS long-haul truck driver sample and NSF sample data.

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (n = 42)	NSF short-haul truck drivers (n = 136)	NSF pilots (n = 190)	NSF train operators (n = 155)	NSF bus/taxi/ limo drivers (n = 140)
Woke Up During the Night (%)						
Every Night/Almost Every Night	68.1	69.0	74.3	77.9	70.3	72.9
At Least a Few Times a Week	17.3	21.4	22.1	20.0	21.9	22.9
Rarely/Never	14.6	7.1	3.7	2.1	7.7	4.3
Woke Up Feeling Unrefreshed (%)						
Every Night/Almost Every Night	55.7	45.2	50.7	63.7	64.5	40.0
At Least a Few Times a Week	21.5	40.5	42.6	32.6	28.4	49.3
Rarely/Never	22.3	14.3	4.4	3.7	6.5	10.0
Snored (%)						
Every Night/Almost Every Night	64.2	66.7	58.8	46.3	54.2	52.1
At Least a Few Times a Week	4.6	19.0	19.9	26.8	14.8	21.4
Rarely/Never	21.2	2.4	5.9	11.1	14.8	7.9
Had Difficulty Falling Asleep (%)						
Every Night/Almost Every Night	30.8	21.4	32.4	34.7	36.8	25.7
At Least a Few Times a Week	24.6	57.1	55.9	57.9	47.1	55.7
Rarely/Never	44.6	21.4	11.0	7.4	16.1	18.6
Woke Up Too Early and Could Not Get Back to Sleep (%)						
Every Night/Almost Every Night	51.6	31.0	36.0	43.7	46.5	36.4
At Least a Few Times a Week	21.5	40.5	48.5	44.2	38.7	51.4
Rarely/Never	26.5	28.6	14.0	11.6	14.2	12.1
Sleep Disorders (%)						
Any Sleep Disorder	13.8	7.1	13.2	4.7	13.5	12.1

significant. The long-haul truck drivers from both samples had the highest frequencies of snoring, while the TSLDS sample had the highest frequency of waking up too early and not being able to get back to sleep.

A complete description of safety outcomes is available in Table 4. The range of ESS scores was 5.18–6.36. There were no significant differences between the TSLDS sample and any of the NSF groups across ESS scores or the frequency of sleepiness impacting job performance. However, there were several statistically significant differences across the two samples when reporting having any incident at work, making a serious error, or having a "near miss" due to sleepiness. TSLDS sample had a statistically significant higher frequency of any incident at work, making a serious error, and experiencing a near-miss due to sleepiness than all NSF groups.

Table 4
Comparison of safety outcomes of TSLDS long-haul truck driver sample and NSF sample data.

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (n = 42)	NSF short-haul truck drivers (n = 136)	NSF pilots (n = 190)	NSF train operators (n = 155)	NSF bus/taxi/ limo drivers (n = 140)
ESS (Mean (SD))	5.52 (4.10)	5.56 (5.05)	5.32 (4.27)	6.36 (4.72)	6.12 (4.45)	5.45 (4.39)
Unlikely abnormally sleepy (ESS = 0–7) (%)	70.8	66.7	73.4	63.8	68.8	75.2
Average amount of sleepiness (ESS = 8–9)	13.2	19.4	12.9	12.6	11.1	10.1
Depending on situation (ESS = 10–15)	14.0	8.3	9.7	18.4	16.0	13.2
Excessively sleepy (ESS = 16–24)	2.0	5.6	4.0	5.2	4.2	1.6
Impact of Sleepiness on Job Performance (%)						
5 or More Times Per Week	0.8	2.4	3.7	2.1	0.6	0.7
3–4 Times Per Week	3.1	4.8	0	3.7	4.5	0.7
1–2 Times Per Week	13.7	2.4	11.0	17.9	18.7	7.1
Less than 1 Time Per Week	20.2	16.7	14.7	30.0	28.4	15.7
Never	62.0	71.4	69.1	42.6	45.2	75.7
Due to Sleepiness… (%)						
Any Incident at Work	59.2	14.3**	16.4**	24.9	21.6**	14.2**
Made a Serious Error	32.4	7.1**	5.9**	20.5	9.7*	5.7**
Had an Accident	18.7	2.4	2.2	1.6	0.6	2.9
Had a "Near Miss"	52.3	14.3**	14.7	11.1**	16.8**	10.7**

* $p < 0.05$.
** $p < 0.01$.

Table 5
Associations between sleep-related safety outcomes, work organization characteristics, and sleep characteristics, problems and disorders with excessive daytime sleepiness (controlling for age and race).

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (n = 42)	NSF short-haul truck drivers (n = 136)	NSF pilots (n = 190)	NSF train operators (n = 155)	NSF bus/taxi/limo drivers (n = 140)
Impact of Sleepiness on Job Performance	0.18**	0.12	0.03	0.05	-0.08	0.18*
Due to Sleepiness, Had Any Incident at Work	0.20**	0.30	0.02	0.11	-0.03	0.10
Length of Shift	-0.03	-0.04	-0.01	0.01	0.12	0.00
Shift Work	0.13	-0.07	-0.02	-0.13	0.03	-0.04
Workday Sleep Sufficiency	0.16*	0.17	0.13	0.24**	0.24**	0.26**
Workday Sleep Duration	-0.20**	-0.30	-0.16	-0.20*	-0.19*	-0.25**
Workday Sleep Quality	-0.28**	-0.47**	-0.06	-0.03	-0.38**	-0.23**
Workday Schedule Allows Adequate Sleep	-0.15*	0.03	-0.03	-0.03	0.00	-0.06
Sleep Problems	0.29**	-0.05	-0.15	0.01	-0.03	-0.19*
Sleep Disorders	0.07	0.11	0.02	0.41**	0.25**	-0.07

* $p < 0.05$.
** $p < 0.01$.

However, the TSLDS sample reported more frequent accidents due to sleepiness than all NSF groups, although these differences were not statistically significant.

Tables 5–7 provide the complete results from the partial correlation analyses across the transport operator samples between work organization characteristics and sleep characteristics, problems, and disorders with: ESS, reporting that sleepiness impacted job performance, and reporting having any type of safety incident at work due to sleepiness, respectively. While controlling for age and race, there were significant positive associations between ESS score, impact of sleepiness on job performance, and having a safety incident or accident while on the job among the TSLDS sample. Additionally, there were negative associations between sleep quality and sleep duration and ESS score, the impact of sleepiness on job performance, and having a safety incident or accident while on the job. There were also positive correlations between the number of sleep problems experienced and ESS score, the impact of sleepiness on job performance, and having a safety incident or accident while on the job. Across the sample there were significant correlations but without the robustness of the relationships found in the TSLDS sample.

4. Discussion

4.1. Cross-sectoral comparisons

Previous studies have shown that workers in the same sector experience disparities in work organization, safety, and other characteristics (Helmkamp et al., 2013; Jackson et al., 2013). The findings from the current study confirm this to indeed be the case with regard to transportation vehicle operators.

Table 6
Associations between associations between sleep-related safety outcomes, work organization characteristics, and sleep characteristics, problems and disorders with sleepiness impacting job performance (controlling for age and race).

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (n = 42)	NSF short-haul truck drivers (n = 136)	NSF pilots (n = 190)	NSF train operators (n = 155)	NSF bus/taxi/limo drivers (n = 140)
ESS	0.18**	0.12	0.03	0.05	-0.07	0.18*
Due to Sleepiness, Had Any Incident at Work	0.39**	-0.04	0.01	0.16*	-0.03	-0.05
Length of Shift	0.12	-0.05	0.15	-0.02	0.00	-0.06
Shift Work	0.10	0.12	0.08	-0.01	0.09	0.06
Workday Sleep Sufficiency	0.04	0.02	0.08	0.15*	0.01	0.09
Workday Sleep Duration	-0.05	0.13	-0.07	-0.14	0.01	-0.14
Workday Sleep Quality	-0.20**	0.03	-0.04	-0.33**	-0.02	-0.20*
Workday Schedule Allows Adequate Sleep	-0.33**	-0.70**	-0.03	-0.33**	-0.02	0.04
Sleep Problems	0.30**	0.49**	-0.04	-0.07	-0.06	-0.13
Sleep Disorders	0.15*	-0.03	-0.04	0.15*	-0.05	0.14

* $p < 0.05$.
** $p < 0.01$.

Table 7
Associations between sleep-related safety outcomes, work organization characteristics, and sleep characteristics, problems and disorders with having any type of safety incident at work (controlling for age and race).

	TSLDS long-haul truck drivers (N = 257)	NSF long-haul truck drivers (n = 42)	NSF short-haul truck drivers (n = 136)	NSF pilots (n = 190)	NSF train operators (n = 155)	NSF bus/taxi/limo drivers (n = 140)
ESS	0.20**	0.30	0.02	0.11	-0.03	0.10
Impact of Sleepiness on Job Performance	0.39**	-0.04	0.01	0.16*	-0.03	-0.05
Length of Shift	0.20**	0.23	0.25**	-0.03	0.17*	0.09
Shift Work	0.17*	-0.04	0.11	-0.13	-0.03	0.13
Workday Sleep Sufficiency	0.10	0.30	0.01	0.05	0.14	0.23**
Workday Sleep Duration	-0.10	-0.33	0.01	-0.10	-0.13	-0.18*
Workday Sleep Quality	-0.16*	-0.53**	-0.02	-0.03	0.03	0.07
Workday Schedule Allows Adequate Sleep	-0.17*	-0.44**	-0.03	-0.02	-0.03	-0.03
Sleep Problems	0.27**	-0.08	-0.05	0.07	-0.06	0.07
Sleep Disorders	-0.01	0.02	-0.07	0.20**	0.06	-0.07

* $p < 0.05$.
** $p < 0.01$.

4.1.1. Demographics and work organization

The TSLDS and NSF samples were different with regard to race/ethnicity. Differences in these demographic characteristics have serious implications for safety. For example, Asian-American and African-American ethnicity have been established as major risk factors for sleep disorders, especially obstructive sleep apnea (OSA) restless legs syndrome (RLS), and insomnia (Kales and Straubel, 2014; Krueger et al., 2007a; Villaneuva et al., 2005). The overall advanced age of these transport operators across both samples may indicate a need for screening efforts to identify and treat those who may have comorbid conditions associated with advancing age.

The TSLDS sample worked longer shifts than any NSF group. It also appears that weekly work hours have continued to rise in recent years for long-haul truck drivers, up nearly 2 hours a week between 2006 and 2016 (Bureau of Labor Statistics, 2016e). Other studies have found that these drivers work over 60 hours per week and are home very rarely, typically spending six or fewer days at home per month (Sieber et al., 2014). Similar patterns in work hours have been found in long-haul truck drivers in other nations, including Brazil, Argentina, Japan, and Australia (Kanazawa et al., 2006; Perez-Chada et al., 2005; Sharwood et al., 2012; Souza et al., 2005). Shift work was also rampant among long-haul truck drivers: With the exception of the NSF pilots, the TSLDS and NSF long-haul truck driver samples had the least consistent daily schedules; further, both long-haul truck driver samples had the highest prevalence of starting work between midnight and before 6 AM. These scheduling patterns suggest that long-haul truck drivers' work organization is fundamentally different from other transport operators across factors which are associated with negative health and safety outcomes, including cardiometabolic comorbidities, sleep issues, and fatigue (Drake, 2010; Ebrahimi et al., 2015; Hege et al., 2016; Kanazawa et al., 2006; Krueger et al., 2007a; Lemke et al., 2015; Smolensky et al., 2011). The federal regulations which dictate long-haul truck drivers' driving hours should be revisited, and potential policy changes should include considerations for shift work as well as work and sleep hours.

4.1.2. Sleep characteristics

Given the overall superior sleep characteristics on non-workdays compared to workdays, it appears that the work organization of transport operators has a broad effect on sleep, although, surprisingly, the majority of transport operators across all segments indicated that their workday schedule allows adequate sleep. These differences in workday and non-workday sleep may be explained by a number of factors, including work schedule-induced circadian misalignment (e.g., shift work) (Drake et al., 2004), poor sleep hygiene (Stepanski and Wyatt, 2003), work-related or other stressors (Åkerstedt, 2006), or substance use (e.g., caffeine consumption) (Kelly et al., 1997). However, issues related to sleep quality may be particularly important here. For example, for long-haul truck drivers, workday sleep is often obtained in uncomfortable sleeper berths of truck cabs, often while parked at truck stops. These locations are notorious for high levels of noise and air pollution (Doraiswamy et al., 2005). Factors which are associated with poor sleep quality may also decrease sleep duration and sufficiency among transport operators, and therefore represent potential high-leverage intervention points.

4.1.3. Sleep problems and disorders

Broadly, the transport operators in these two samples demonstrated a high frequency of sleep problems across the array of sleep problems addressed in the two surveys. For several of these, including waking up during the night, waking up feeling unrefreshed, and snoring, the majority of nearly every transport operator group responded in the most severe category. Several of these sleep problems are directly associated with sleep disorders. In the case of OSA, the most common sleep-related breathing disorder (Jackson and Howard, 2011), symptoms include snoring, waking up during the night, and unrefreshing sleep (Park et al., 2011).

Perhaps the most important implications of the sleep problems data are in light of the low rate of sleep disorder diagnosis in both the TSLDS and NSF samples. Sleep disorders are notoriously underdiagnosed in many individuals (Park et al., 2011), including

transport operators, and these data suggest that this may be the case across a large segment of such workers. For example, although the prevalence of *any* sleep disorder was below 14% for the TSLDS sample, and 11% for the NSF long-haul truck driver sample, a conservative estimate for the prevalence of OSA alone within this population is 21% (Berger et al., 2012). Further, in the TSLDS and NSF samples as a whole, prevalence figures for any sleep disorder ranged from 5–14%; however, the estimate of prevalence of OSA alone among U.S. commercial drivers is between 17% and 28% (Kales and Straubel, 2014). Sleep disorders impair sleep quantity and quality and cause cognitive deficits, fatigue, and excessive daytime sleepiness (Jackson and Howard, 2011; Kales and Straubel, 2014; Smolensky et al., 2011), negatively impacting a drivers' ability to safely operate a vehicle. Further, sleep disorders are independent risk factors for cardiovascular and other morbidities (Krueger et al., 2007a; Park et al., 2011). Other relevant sleep disorders for transport operators include shift work disorder (SWD), insomnia, RLS, phase delay syndrome, and narcolepsy (Drake, 2010; Krueger et al., 2007a). Many of these remain poorly understood, especially in the context of transport operators.

Sleep problems and disorders warrant further attention and, due to their health and safety implications, should be diagnosed and treated with vigor (Kales and Straubel, 2014). Fortunately, sleep disorders are considered to be diagnosable, treatable, and manageable among transport operators (Krueger et al., 2007a). Adequate policies and regulations are needed to curb sleep problems and disorders (Kales and Straubel, 2014); however, these often lag behind the current state of the science (Krueger, 2013). Closing these gaps should be an occupational and public health priority.

4.1.4. Sleep-related safety outcomes

Overall, the TSLDS and NSF samples scored low on the ESS. However, sleepiness scores may be underreported. For example, in a study of 595 U.S. long haul truck drivers, over 20% reported falling asleep at stoplights (Smith and Phillips, 2011). In another study of public transport operators, daytime hypersomnolence occurred in 26% of participants (Karimi et al., 2013). Further, as stated previously, transport operators are often hesitant to accurately report sleep-related issues. As these individuals are believed to have relatively high rates of sleep disorders, which are known to induce excessive daytime sleepiness and hypersomnolence (Kales and Straubel, 2014), it is possible that ESS were underreported in both samples.

The TSLDS and NSF long-haul truck driver samples presented significant discordance in sleep-related safety outcomes due to sleepiness, with the former far worse, and the latter far better, than the other NSF groups. This may also be attributed to weak operational definitions in the terminology used in the surveys. A known issue in many studies evaluating fatigue and sleep-related safety outcomes is a lack of consensus in how these terms are conceptualized and defined, and this has led to varying estimates of the impacts of fatigue-related issues on safety (Smolensky et al., 2011). To better understand the sleep-related safety outcomes of transport operators, efforts must be made among researchers to resolve these issues and provide more insightful research findings.

4.1.5. Associations between work organization characteristics with safety outcomes

Work organization, including long work hours and shift work, has been shown to directly impact safety among commercial drivers (Belzer, 2009). However, among the transportation operators in our samples, these connections were not especially strong. For example, long driving hours and shift work have been shown in other studies to be especially important predictors of daytime sleepiness (de Pinho et al., 2006; Kanazawa et al., 2006). In contrast, in our data none of these factors were significantly associated with ESS score. The data from the TSLDS and NSF groups are more in agreement with other studies regarding the connections between length of shift and shift work with having any time of safety incident at work, as other studies have shown that long work hours are associated with fatigue and increased safety risk (Belman and Monaco, 2001; Benstowe, 2008; McCartt et al., 2000; Morrow and Crum, 2004) and that shift work, especially driving at night, is associated with poorer safety outcomes (McCartt et al., 2000; Morrow and Crum, 2004; Philip, 2005; Stevenson et al., 2013). Among the work organization variables included in the partial correlation analyses, the question of whether workday schedule allowed adequate sleep most consistently was significantly associated with safety outcomes other than ESS. As scheduling issues have been associated in other studies with safety outcomes (e.g., falling asleep behind the wheel (McCartt et al., 2000)), these findings point to the vital importance of transport operators' schedules in their safety-relevant performance. Scheduling issues should be addressed by transportation companies and at the federal policy level, as long work hours and other scheduling issues are jointly influenced by drivers' behaviors, pressures placed upon them by their employers, and federal regulations.

4.1.6. Associations between sleep characteristics with safety outcomes

Sleep issues – especially disordered sleep, short sleep duration, and sleepiness due to long work hours and shift work – are associated with increased risk of safety-related job performance and accident risk (Chen et al., 2016; Krueger et al., 2007b). Short sleep duration has been associated with degradation in safety-related job performance among transport operators across multiple studies (Chen et al., 2016; Filiatrault et al., 2002; Lemke et al., 2016; McCartt et al., 2000; Morrow and Crum, 2004; Pack et al., 2006; Philip, 2005; Philip and Åkerstedt, 2006). Among the TSLDS and NSF samples, sleep duration was most strongly associated with ESS. Diminished sleep quality has also been associated with safety-related job performance among transport operators, as well as leading to poorer decisions related to fatigue management (Filiatrault et al., 2002; Lemke et al., 2016; McCartt et al., 2000; Philip and Åkerstedt, 2006). Sleep quality was the most prevalent factor associated with safety outcomes among the factors included in the partial correlation analyses.

Improving sleep sufficiency should be an objective for interventions to improve safety. For example, other studies have found that poor sleep habits are especially important predictors of daytime sleepiness (de Pinho et al., 2006; Kanazawa et al., 2006). Thus, improving sleep habits should be a goal when addressing sleep sufficiency. A principal objective of improving sleep habits should be to enhancing the quality of sleep obtained. Others have advocated for an increased emphasis on sleep quality when addressing safety

outcomes among transport operators (Braeckman et al., 2011; Filiatrault et al., 2002; Lemke et al., 2016). To improve sleep habits and sleep quality, transport operator stakeholders should engage in comprehensive efforts which focus on: Scheduling which promotes better sleep characteristics; work environments which are lower in stress and, for transport operators who sleep in their vehicles, are more conducive to high quality sleep; and providing sleep disorder screening campaigns to diagnose and treat extant sleep disorders.

4.1.7. Associations between sleep problems and disorders with safety outcomes

Sleep problems and disordered sleep are associated with poorer safety outcomes among transport operators (Chen et al., 2016; Krueger et al., 2007b). Sleep disorders, and especially OSA, has been associated with increased ESS scores; further, excessive daytime sleepiness may be the most important safety-related consequence of OSA (Kales and Straubel, 2014; Karimi et al., 2013; Zhang et al., 2012). Sleep problems and sleep disorders were significantly associated with ESS among several of the transport operator groups in the TSLDS and NSF samples. Sleep disorders, including OSA, SWD, and having multiple sleep disorders simultaneously, have been associated with increased accident risk in previous transport operator studies (Braeckman et al., 2011; Drake et al., 2004; Jackson and Howard, 2011; Krueger, 2013; Krueger et al., 2007a; McCartt et al., 2000; Perez-Chada et al., 2005; Smolensky et al., 2011; Zhang et al., 2012). Among the TSLDS and NSF samples, these were both moderately associated with safety outcomes, although – similar to many of the partial correlation analyses – these patterns varied across transport operator segments. As mentioned previously, it appears that sleep disorders are underdiagnosed among the transport operators in the TSLDS and NSF datasets. Given the strong connections between sleep problems and disorders with safety outcomes found in these data, diagnoses and corresponding treatment should be foci of safety initiatives among these occupational segments.

4.2. Limitations

There are four limitations of the current study. First, both the TSLDS and NSF samples are cross-sectional and represent a "snapshot" in time. To further explicate work organization, sleep, and sleep problems and disorders and their roles in safety among transport operators, a longitudinal design is required. However, given the methodological barriers to conducting longitudinal studies among transport operators, the cross-sectional data here provide valuable insights. Second, the overall sample sizes for both the TSLDS and NSF samples are relatively small, which hindered the power of statistical analyses. This was especially problematic for more "rare" events, where the raw data showed differences between the groups but the analyses were not powerful enough to establish a statistically significant relationship. Nonetheless, given the novelty of these findings, these data provide important information which can be useful for interventions. Third, potential barriers to participation in both samples, may have resulted in selection bias. However, potential barriers to participation were relatively few in both samples, and it is unlikely that they meaningfully impacted the representativeness of these data. Finally, transport operators are reluctant to truthfully report certain issues, especially those related to sleep disorders (Smith and Phillips, 2011). This weakness is mitigated by the thoroughness of questions which dynamically addressed key topics; for example, for sleep disorders, participants were queried both about subjective sleep problems and objective sleep disorder diagnoses (Table 4).

5. Conclusions

Given the safety-critical nature of transport operators' occupations, work organization, sleep, and sleep problems and disorders have significant implications for safety. For the first time, these findings delved into how the primary segments of transport operators are differentially burdened across work organization and sleep factors, with varying potential impacts on individual and public safety. As expected, the long-haul truck drivers in the TSLDS sample were disproportionately impacted across several factors, including long work hours, frequent shift work, and having an incident at work due to sleepiness. This suggests that long-haul truck drivers represent a uniquely vulnerable subgroup of transport operators that requires urgent attention and action. More broadly, patterns of cross-sectoral differences suggests to the need for tailored interventions to address the unique configurations of demographic, work organization, sleep, and sleep-related safety characteristics found in different transport operator sectors. However, cross-sectoral findings indicate that latent sleep disorders are pervasive among transport operators, and screening, diagnosis, and treatment of sleep disorders are imperative for transport operators in general. Regarding the patterns of associations among work and sleep characteristics with safety outcomes, our second hypothesis was generally supported, which indicates a sense of urgency to implement tailored interventions for long-haul truck drivers is imperative. The variation found among the transport operator groups again suggests the need for tailored interventions across all transport operator groups; however, several of these work and sleep characteristics were more broadly associated with safety outcomes across groups and may represent especially important avenues for safety promotion. A national study of transport operators, which capitalizes on the key factors studied here and avoids limitations evident in both studies, would more fully elucidate disparities in work and sleep and the impacts of these disparities on safety and would help elucidate optimal intervention points.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jth.2017.08.006.

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