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Original Article

Surveying the Impact of Work Hours and Schedules on Commercial Motor Vehicle Driver Sleep

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ABSTRACT

Background: Given the long hours on the road involving multiple and interacting work stressors (i.e., delivery pressures, irregular shifts, ergonomic hazards), commercial drivers face a plethora of health and safety risks. Researchers goal was to determine whether and to what extent long-haul trucker work schedules influence sleep duration and quality.
Methods: Survey and biometric data collected from male long-haul truck drivers at a major truckstop in central North Carolina over a six month period.
Results: Daily hours worked (mean = 11 hours, 55 minutes) and frequency of working over government-mandated daily HOS regulations (23.8% "frequently or always") were statistically significant predictors of sleep duration. Miles driven per week (mean = 2,812.61), irregular daily hours worked (63.8%), and frequency of working over the daily hour limit (23.8% "frequently or always") were statistically significant predictors of sleep quality.
Conclusion: Implications of findings suggest a comprehensive review of the regulations and operational conditions for commercial motor vehicle drivers be undertaken.

1. Introduction

The United States (US) transportation sector contributes 8.6% to the country's Gross Domestic Product [1] and employs millions of workers across several occupational categories. Freight haulage is a central component of the transportation sector and commercial drivers who move a variety of goods across the 48 contiguous states are subject to more adverse work conditions than workers in other blue-collar occupations [2,3]. Given the long hours on the road involving multiple and interacting work stressors (i.e., delivery pressures, irregular shifts, ergonomic hazards), commercial drivers face a plethora of health and safety risks. In fact, the work environment of commercial drivers has been linked with a wide range of health afflictions including, among others, musculoskeletal and pulmonary disorders [4–7], cardiometabolic comorbidities [8–11], overweight and obesity disorders [12,13], and fatigue and sleep disorders [14–16]. These comorbidities are particularly pronounced among long-haul truck drivers, who are associated with shorter life expectancies than the general population [6].

Empirical evidence reveals the wide array of challenges for long-haul truck drivers that include long work hours, irregular work schedules, unequal pay structures, and a lack of regular access to quality and affordable health care services [6,17–20]. Truck drivers' work conditions often involve erratic demands and result in inconsistent hours of sleep, short sleep duration, and disrupted sleep patterns, placing long-haul truckers at risk for chronic fatigue [14–16]. A survey by the National Sleep Foundation that investigated the sleep habits of key categories of transport operators reported that 17% of truckers average < 6 hours of sleep on their workdays, compared to 16% of train operators, 10% for bus/taxi/limo drivers, and 9% for airline pilots [21]. The same survey revealed that 44% of truckers get a good night's sleep only on rare occasions or never during their workdays,

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surpassed only by train operators who reported getting a good night's sleep more frequently. Inconsistent sleep patterns of long-haul truckers (i.e., disrupted sleep, irregular sleep, sleep deprivation) may result in overall poor sleep quality that not only influences driver health but also jeopardizes highway safety [14–16,22–24].

With the notion that commercial driving places a tremendous burden on overall morbidity and mortality of transport workers, the purpose of this paper is to determine whether and to what extent work schedules and long and inconsistent work hours of long-haul truckers influence their sleep duration and quality. Study findings are expected to make valuable contributions to research into and preventive interventions for occupational health disparities, and to inform regulatory policy.

2. Materials and methods

2.1. Data collection

Survey and biometric data were collected from male long-haul truck drivers at a major truckstop located in central North Carolina, US over a period of 6 months. This study site was selected due to the consistent high-level trucking activity at the truckstop. Permission to conduct the study was granted by the corporate office of the company and the cooperation of onsite management facilitated data collection; a table was set up in a central location of the truckstop with visible signage around the facility describing the research procedures.

Beginning in October and ending in March, two teams of field researchers spent 3–4 weekdays at the truckstop from 6:00 PM to 10:00 PM. Using intercept techniques, researchers approached drivers and asked targeted screening questions to establish first the status of long-haul trucker (as opposed to short-haul drivers), second that they were laid over that night at the truckstop, and third their willingness to provide fasting blood specimens prior to departing early the following morning. Field researchers explained the voluntary nature of study participation, nature of survey questions, anthropometric and serological data collection, and cash incentives to be paid at the end of the survey data collection and blood draws. Enrolled drivers were then asked to sign an informed consent form, and those who preferred to use aliases to assure a greater degree of confidentiality were allowed to do so. Those drivers who wished to receive the results of their serological tests (e.g., cholesterol) provided either a street or e-mail address, and were later sent their results. In this manner, 260 truck drivers completed the interviewer-administered survey, which took approximately 40 minutes. This paper reports findings based only on survey data.

2.2. Survey instrument

We used the Trucker Sleep Disorders Survey (TSLDS) that was developed from insights gleaned from other key instruments (i.e., Basic Nordic Sleep Questionnaire, Berlin Questionnaire), relevant sleep literature, and our previous work with truckers [25–28]. Initial cognitive testing involved a review of the instrument by public health professionals to assure: (1) appropriateness of language used; (2) that questions conveyed intended meanings and made sense; and (3) optimal question placement and flow. Following necessary revisions, a paper-and-pencil draft of the instrument was pilot tested with a sample of six long-haul truckers in the Piedmont Triad area in central North Carolina. Truckers were monitored and timed as they completed the survey to detect pauses and problems before appropriate revisions were made. This phase was intended to help determine construct validity, identify missing items, clarify scale distributions, help conduct item correlations, and determine reliability.

The TSLDS instrument was organized into five sections and included questions on: (1) trucking work environment such as work hours, workplace factors, job strain, workload, and irregular schedules; (2) truckers' work- and health-related individual factors such as sociodemographics, dietary and physical activity patterns, substance use, prescription medication use, health history, sleep patterns, and psychosocial factors; (3) truckers' self-reported sleep disturbances and disorders such as daytime sleepiness, insomnia, restless leg syndrome, periodic limb movement disorder, sleep fragmentation, sleep deprivation, and diagnosed sleep apnea; (4) truckers' health consequences attributable to sleep-disorders such as concentration lapses, judgment errors, work injuries, highway near misses, accident and crash history, and disability and medical claims; and (5) truckers' self-reported comorbidities associated with chronic sleep disorders such as stroke, hypertension, metabolic syndrome, diabetes, ischemic heart disease, and psychiatric disorders.

2.3. Measures

2.3.1. Sleep patterns and quality

Sleep patterns were assessed with the following five questions: "How many hours of sleep do you feel you need for your highest function?"; "How many hours of sleep do you get on work nights and nonwork nights?" (this can be "days for drivers" depending on the time of day they work), "How long does it take you to fall asleep on workdays and nonworkdays?", "How many naps on average do you take on workdays and nonworkdays?", and "How long are your naps on workdays and nonworkdays?". For each of these questions, participants were given the opportunity to express their sleep length in hours and minutes and to report the number of daily naps and their length in hours and minutes.

Sleep quality was assessed with the following four questions: "How often do you feel you get a good night's sleep on workdays and nonworkdays?" (this can be "days for drivers" depending on the time of day they work); "Over the past 2 weeks, how often have you experienced difficulty falling asleep?"; "Over the past 2 weeks, how often have you experienced waking up during sleep?"; and "Over the past 2 weeks, how often have you experienced waking up too early and being unable to fall back asleep?" Response options included "never", "rarely", "almost every night", and "every night".

2.3.2. Predictors of sleep patterns and quality

Work patterns were measured with the following six questions: "How many miles on average do you drive per week?"; "How many days on average are you on the road per month?" (meaning because of work—we just mean "total" days away from home per month); "How many hours on average do you work each day?"; "Is your schedule the same or different every day?"; "Does the number of hours you work per day remain the same or change each day?"; and "Are the days of the week that you work the same or different each week?". Responses for miles driven per week were the actual weekly average number that drivers reported. For analysis this variable was categorized as "high" ($>$ 3,000 miles), "medium" (2,500–3,000 miles), and "low" ($<$ 2,500 miles). Days on the road were first categorized as $<$ 5 days, 6–10 days, 11–15 days, 16–20 days, 21–25 days, 26–30 days, $>$ 1 month, and $>$ 2 months, then grouped as "high" ($\geq$ 26 days), "medium" (21–25 days), and "low" ($\geq$ 20 days). Hours worked in a day were noted as $<$ 6 hours, 6–7 hours, 7–8 hours, 8–9 hours, 9–10 hours, 10–11 hours, 11–12 hours, 12–13 hours, 13–14 hours, and $>$ 14 hours. For both consistency of schedule and hours worked daily, responses were "different every day" or "same every day". For consistency of the

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weekdays worked, participants responded with either "different each week" or "same each week".

Hours worked, including both driving and nondriving duties, were assessed with the following three questions: "How many hours on average do you work in a day?"; "How often do you work over the 14 hour limit for hours in a day?"; and "How often do you work over the weekly hour limits?" Selections for average hours included: < 6 hours, 6–7 hours, 7–8 hours, 8–9 hours, 9–10 hours, 10–11 hours, 11–12 hours, 12–13 hours, 13–14 hours, and > 14 hours. Responses for the hour-limit questions included: "never", "rarely", "sometimes", "frequently", and "always".

Pace of work was measured with the following question: "How often does your job demand that you work at a fast pace?" with "never", "rarely", "sometimes", "often", and "always" as possible answers. Possible connections between work and sleep patterns were assessed with five questions: "Do you ever experience sleepiness while working but not driving?"; "Have you ever fallen asleep while working but not driving?"; "Over the past month, how many times have you driven sleepy, nodded off, dozed off, or fallen asleep at the wheel?"; "How often does sleepiness impact your concentration?"; and "Due to sleepiness, have you made a serious error? Caused an accident? Had a 'near miss'? or Were involved in a crash?". Responses for sleepiness and falling asleep while working were a simple yes or no. Responses for sleepiness while driving required an actual number of times out of 30. Selections for being awakened by a dispatcher or coworker included: "never", "rarely", "sometimes", "frequently", and "always". In response to the question concerning frequency of sleepiness impacting concentration, drivers were able to indicate "never", "less than once per week", "two or three times per week", "four or five times per week", and "more than five times per week". Finally, responses for sleepiness in relation to errors and accidents included a simple "yes" or "no".

2.4. Statistical analyses

Descriptive statistics and multivariate analyses were performed. Multinomial logistic regression modeling was employed to identify the variables that could effectively predict the sleep duration and quality of study participants. Initially stepwise regression modeling was conducted to select a subset of potential crucial predictors. In the stepwise variable selection process Akaike Information Criterion was adopted for optimizing the size of the model (the number of variables). Additionally, odds ratios were reported to indicate the magnitude of the influence of variables on the outcomes.

Table 1
Demographic and employment profile of truck drivers ($n = 260$)

	Mean	SD	%
Age (y)	46.57	10.525	
Race			
Caucasian			58.3
African American			31.6
Latino/Hispanic			7.5
Native American			0.8
Asian			0.7
Other			1.1
Education			
Some high school			12.4
High school diploma/GED			42.9
Some trade school			1.5
Trade school			3.1
Some college			25.9
College degree			12.7
Some grad/professional degree			0.4
Grad/professional degree			1.2
Driving experience (y)	14.97	11.528	
Driver type			
Company driver			41.2
For-hire			23.8
Owner–operator: own authority			6.5
Owner–operator: lease			26.2
Other			2.3
Pay structure			
By the mile			70.3
By the load			13.5
Percentage of revenue			14.7
Other			1.5
Health insurance coverage			
No insurance			33.5
Private insurance			56.5
Government insurance			9.6
Other			0.4
Health insurance premiums			
Driver alone pays			22.3
Driver and employer share			29.2
Spouse's employer pays			9.2
Government			9.2
Other			30.0

3. Results

3.1. Demographic profile of truckers

The age of study participants ranged from 23 years to 72 years with a mean age of 46.57 years [standard deviation (SD) = 10.525]. Respondents were primarily Caucasian (58.3%), African American (31.6%), or Latino (7.5%), with a small representation of Native Americans (0.8%), Asians (0.7%), and other racial/ethnic groups (1.1%). Most truckers had a high school diploma or General Educational Diploma (GED) (42.9%), with fewer reporting some college (25.9%), or a college degree (12.7%). A small percentage went to trade school (3.1%) or had a professional or graduate degree (1.2%; Table 1).

3.2. Employment profile of truckers

Interviewed truckers' driving experience ranged from 1 year to 56 years, with a mean of approximately 15 years (SD = 11.528). Respondents mostly identified themselves as company drivers (41.2%), owner–operators that lease their services to companies or to motor carriers (26.2%), or for-hire drivers (23.8%), with a smaller group working as owner–operators on their own authority (6.5%). Most truckers were paid for their work by the mile (70.3%), the rest were paid either by the load (13.5%) or received a percentage of the trucking company's revenues (14.7%). Health insurance emerged as a concern with over a third (33.5%) of drivers having no health insurance coverage of any sort. Of those drivers with private insurance (56.5%), premiums are paid either by drivers themselves (22.3%), drivers share the cost with their employers (29.2%), or they are paid by the spouse's employer (9.2%).

3.3. Work demands and patterns of truckers

Long and irregular work schedules were commonplace among study participants. The number of miles driven ranged from a very low 500 miles/wk to an extremely high 7,000 miles/wk, with the mean approaching 3,000 miles/wk (2,812.61; SD = 810.11). Over three quarters of the respondents indicated driving over 2,500 miles/wk (75.6%). Drivers reported being away from their homes

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Table 2
Work demands and patterns of truck drivers

	Mean	SD	%
Miles driven per week			
Long (> 3,000)	2,812.61	810.11	22.2
Medium (2,500–3,000)			53.4
Short (< 2,500)			25.4
Days on road/mo			
Long (≥ 26)	27.0	0.812	43.4
Medium (21–25)			41.2
Short (≤ 20)			15.4
Total h worked/d	11 h, 55 min		
< 6			0.4
7–8			0.7
8–9			2.2
9–10			9.3
10–11			15.6
11–12			16.3
12–13			14.4
13–14			22.2
> 14			14.4
Job demands fast pace			
Never			16.9
Rarely			15.0
Sometimes			21.5
Often			17.3
Always			28.8
Irregular schedule			
Irregular shifts			82.7
Irregular total daily hours			63.8
Irregular days of week			32.3
Government regulations			
Work over 14-h daily limit			
Never			39.2
Rarely			16.9
Sometimes			20.0
Frequently			12.3
Always			11.5
Work over 70-h 8-d limit			
Never			56.4
Rarely			16.6
Sometimes			10.0
Frequently			12.4
Always			4.6

for long stretches at a time; most drivers (84.6%) reported spending over 21 total d/mo on the road and away from home due to work, with a mean of 27 days (SD = 0.812). While not detailed in Table 2, some of our respondents indicated they were away from home for several months at a time, with a few indicating they do not keep residences because they are on the move so much and thus live in their trucks. In addition to being on the road for such lengthy periods, the majority of drivers (82.9%) reported working on average ≥ 10 h/d (mean = 11 hours, 55 minutes), which included both driving and nondriving duties.

When describing their work pace, nearly half (46.1%) of drivers indicated that their pace was often or always fast and 21.5% experienced this pace sometimes. At the same time, drivers' work schedules are irregular in a number of ways: 82.7% reported irregular shifts, which is disruptive for their sleep patterns, 63.8% reported irregular total daily hours, meaning they cannot predict from one day to the next how many hours they will work, and 32.3% reported that the days of the week they are expected to work also varies.

When drivers were asked about working over 14 consecutive hours in a day (this includes up to 11 hours max of driving and 3 hours for other duties; however, hours can vary in terms of duties), following 10 consecutive hours off, as per the US Department of Transportation's [29] (DOT) regulations, 43.8% reported violating the 14-hour rule sometimes, frequently, or always. Current DOT regulations also mandate that drivers do not exceed a maximum of 70 work hours over an 8-day period [29]; in response to questions on their compliance, 56.4% of drivers indicated never violating this rule, while the rest (43.6%) reported doing so to some extent, with 17% frequently or always working beyond these hours (see Table 2).

3.4. Sleep patterns of truckers

3.4.1. Hours of sleep

Drivers varied in reporting needed hours of sleep, which ranged from 1 hour to 14 hours (SD = 1.532), with the majority reporting needing slightly less than 7 hours of sleep to function at their best. When asked about the number of hours drivers actually slept, they reported getting about 6 hours, 55 minutes of sleep per night on workdays with 46.5% reporting < 7 hours, 45.7% between 7 hours and 9 hours, and 7.8% getting > 9 hours of sleep. This is equivalent to the general population and concurs with a previous study using objective measures, which suggested that drivers are obtaining more sleep as a result of 2003 modifications to the hours-of-service (HOS) regulations [30]. However, it is also plausible that due to self-reported data, some truckers may have given answers that they considered desirable. On nonworkdays, truckers reported sleeping 8 hours, 16 minutes on average, with a range of 4–16 hours (SD = 2.122). In addition, 16.9% reported getting < 7 hours, 54.2% 7–9 hours, and 28.9% > 9 hours on nonworkdays (see Table 3).

3.5. Number and length of naps

To factor in compensation sleep in the form of naps, drivers were asked about the number and length of their naps during their workdays and nonworkdays. Truckers reported averaging less than one nap per workday (mean = 0.53; SD = 0.818), with the average length of the nap being 1 hour, 13 minutes. Further, they reported one and a half naps (mean = 1.59; SD = 3.390) on nonworkdays, with an average length of 1 hour, 29 minutes. While there was a statistically significant difference between the number of naps on workdays and nonworkdays ($t = 4.33$; $p < 0.0001$), there was no significant difference between the duration of these naps (t-Ratio = 0.314; Prob > t = 0.3775; Table 3).

3.5.1. Sleep quality

Regarding the amount of time it takes drivers to fall asleep once they go to bed, respondents reported an average time of 32 minutes, which was a couple of minutes shorter than the 30minutes on nonworkdays; this difference was not statistically significant ($t = 1.04$; $p = 0.1489$). In terms of their sleep quality, 39.5% of truckers reported never or rarely getting a good night's sleep and 42.6% reported sleeping well almost every night and 17.9% doing so every night. On nonworkdays, 16.8% reported never or rarely getting a good night's sleep, which was frequently explained by family obligations, attention needed for children and household tasks. Overall, drivers indicated they sleep better during nonworkdays; 83.2% reported sleeping well every or almost every night. Study participants were also questioned about difficulties falling asleep in the previous 2 weeks, to which 31.6% indicated they sometimes, frequently, or always had some type of difficulty. Drivers also sometimes, frequently, or always experienced disruptions to their sleep (68%) and reported waking up too early and being unable to fall back asleep (52.8%) with the same frequency (Table 3).

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Table 3
Sleep patterns of truck drivers

	%	Mean	SD	Time (min)
Sleep duration				
Perceived hours needed for highest function		6 h, 45 min	1.532	
Actual hours slept		6 h, 55 min		
Workday			1.672	
< 7 h	46.5			
7–9 h	45.7			
> 9 h	7.8	8 h, 16 min		
Actual hours slept			2.122	
Nonworkday				
< 7 h	16.9			
7–9 h	54.2			
> 9 h	28.9			
Number and length of naps				
Daily naps		0.53	0.818	1 h, 13 min
Workday		1.59	3.390	1 h. 29 min
Nonworkday		*t-Ratio; Prob > t*		*t-Ratio; Prob > t*
		4.33; < 0.0001		0.314; 0.3775
Sleep quality				
Time to fall asleep (min)		32.01		
Workday		30.03		
Nonworkday		*t-Ratio; Prob > t*		
		1.04; 0.1489		
Good quality sleep				
Workday				
Never	9.1			
Rarely	30.4			
Almost every night	42.6			
Every night	17.9			
Nonworkday				
Never	4.7			
Rarely	12.1			
Almost every night	37.3			
Every night	45.9			
Difficulty falling asleep (previous 2 wk)				
Never	44.4			
Rarely	24.0			
Sometimes	21.1			
Frequently	7.5			
Always	3.0			
Waking up during sleep (previous 2 wk)				
Never	14.3			
Rarely	17.7			
Sometimes	28.2			
Frequently	15.8			
Always	24.0			
Waking up too early/Unable to fall back asleep (previous 2 wk)				
Never	26.0			
Rarely	21.2			
Sometimes	27.9			
Frequently	13.2			
Always	11.7			

3.6. *Effects of sleep quality on truckers' work performance*

Poor sleep quality was found to negatively impact drivers' job performance. When asked about this, 37.7% of study participants reported experiencing sleepiness during the day while working but not driving, and 36.3% reported falling asleep while working but not driving. Over half of the sample, 54.9% of drivers, reported having driven while sleepy, nodded off, dozed off, or fallen asleep at the wheel of their truck an average of 3.8 times during the previous month. Drivers who reported getting a good night's sleep every night or almost every night had a 0.7323 probability of not falling asleep while working, which dipped to 0.5188 when they reported rarely or never getting a good night's sleep, clearly pointing to the positive impact sleep quality has on reducing the likelihood of falling asleep during work hours (Table 4).

One fifth of truckers (19.8%) reported sometimes, frequently, or always being awakened during their statutory rest period by a dispatcher; the 53.4% who indicated that this never happens also

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Table 4
Effects of sleep quality on truck drivers' work performance

	%	Response probability
Sleepiness while working (not driving)	37.7	
Falling asleep while working (not driving)	36.3	
Good night's sleep		
Every or almost every night		0.7323
Rarely or never		0.5188
Drove truck sleepy, dozed off, or fell asleep (average 3.8 times in previous mo)	54.9	
Awakened during statutory rest period		
Never	53.4	
Rarely	25.8	
Sometimes	12.9	
Frequently	4.1	
Always	3.8	
Sleepiness impacts concentration		
Never	55.6	
< 1 time/wk	22.9	
2 or 3 times/wk	14.3	
3 or 4 times/wk	2.7	
4 or 5 times/wk	1.1	
> 5 times/wk	3.4	
Due to sleepiness		
Made serious error	32.8	
Caused an accident	7.5	
Had "near miss"	53.2	
Had crash	19.9	

reported turning off their radio during sleep to prevent interruption by their dispatcher. When asked if sleepiness impacts their concentration during the workday, 44.4% of drivers reported an occurrence of this at least once per week, with 3.4% reporting more than five times per week (nearly daily). Finally, nearly one third of drivers (32.8%) reported making a serious error at work due to sleepiness, 53.2% experienced a near miss because of sleepiness, 19.9% had been involved in a crash due to sleepiness, and 7.5% had caused an accident due to sleepiness (Table 4). This particular question appeared to make some drivers uncomfortable; while some indicated that every driver has had a near miss at one time or another, others appeared to downplay the role of fatigue and sleepiness in their driving.

3.7. *Effects of work on truckers' sleep duration and quality*

Based on foregoing findings, we identified nine work related variables as potential explanatory factors of truckers' sleep duration: miles driven per week; number of days on the road per month; total daily hours worked; the fast pace of work; irregular shifts (time of day); irregular number of daily hours worked; irregular days of the week worked; working over the daily hour limit; and working over the weekly hour limit (per DOT regulations). Using multinomial logistic regression modeling, we found total daily hours worked (mean = 11 hours, 55 minutes) and the frequency with which drivers worked over the government-mandated HOS regulations (23.8% "frequently" or "always") to be statistically significant predictors of sleep duration. Further, we also calculated odds ratios to examine the influence (association) of these two variables on sleep duration (Tables 5 and 6).

Table 6
Odds ratio estimates of significant predictors (sleep duration)

Effect	Point estimate	95%	Wald confidence limits
Total daily hours worked			
Short sleep (< 7 h)	1.248	0.808	1.060
Optimal sleep (7–9 h)	1.849	0.715	1.062
Long sleep (reference)			
Work over 14-h day:			
Short sleep (< 7 h)	3.619	0.985	2.804
Optimal sleep (7–9 h)	0.644	0.732	2.103
Long sleep (reference)			

The same nine work-related variables were used as potential explanatory factors of sleep quality, beginning with stepwise regression modeling to select a subset of predictors from among these nine variables in order to narrow down the potential predictors (Table 7). When there are too many predictors and thus too many parameters to be estimated, the model tends to be unstable because it lacks degrees of freedom, and thus preliminary screening is essential. Unlike the conventional stepwise procedure in which the result is affected by the order of variable entry, in JMP is statistical software from SAS Institute different combinations were considered by swapping variables in and out. At the end of this exploratory process, miles driven per week, total daily hours worked, fast pace of work, irregular daily hours worked, and working over the DOT daily hour limit were retained in the model (Table 8). Subsequently, using multinomial logistic regression modeling as a verification procedure (all remaining variables are entered instead of swapping them in and out), we found that miles driven per week (mean = 2,812.61 miles/wk), irregular daily hours worked (63.8%), and working over the daily hour limit (23.8% "frequently" or "always") were statistically significant predictors of sleep quality. This logistic regression model was operated in a descending fashion, which means it targeted the highest category ("almost every night") of the sleep quality variable. Finally, Table 9 indicates that if drivers' daily hours constantly change the odds of being in the higher categories of sleep quality decreases by a factor of 0.604. In other words, the driver is 60.4% less likely to enjoy high

Table 5
Effects of work on truck drivers' sleep duration

	Likelihood-ratio Chi-square	*p*
Miles driven/wk	1.460	0.482
Days on road/mo	3.657	0.161
Total daily h worked	7.221	0.027*
Fast pace of work	3.351	0.187
Irregular shifts (time of day)	0.800	0.670
Irregular daily hours worked	4.998	0.082
Irregular days of week worked	1.752	0.416
Working over the daily h limit	6.995	0.030*
Working over the 8-d h weekly limit	1.111	0.574

Table 7
Effects of work on truck drivers' sleep quality

	Likelihood-ratio Chi-square	*p*
Miles driven/wk	6.219	0.101
Days on road/mo	4.163	0.244
Total daily h worked	0.606	0.895
Fast pace of work	3.1609	0.366
Irregular shifts (time of d)	2.659	0.447
Irregular daily hours worked	5.656	0.130
Irregular d of wk worked	2.721	0.437
Working over the daily h limit	5.786	0.122
Working over the 8-d h limit	6.402	0.094

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Table 8
Effects of work on truck drivers' sleep quality

	Likelihood-ratio Chi-square	*p*
Miles driven/wk	5.639	0.018*
Total daily h worked	10.318	0.243
Fast pace of work	7.789	0.100
Irregular daily h worked	4.555	0.033*
Working over the daily h limit	17.192	0.002*

*Significant at $p < 0.05$.

quality sleep as a result of constantly fluctuating workdays. If the driver always (instead of "sometimes") works over the daily HOS set, the odds of getting better sleep quality declines by a factor of 0.64 or 64%. However, if the driver never works over the set HOS hours, the odds of getting better sleep quality increase by a factor of 1.903. In other words, the driver is almost twice as likely to sleep better. At first glance, the odds ratio of miles/wk is puzzling because at the odds ratio of 1 it seems that miles of driving per week has no impact on sleep quality, yet the *p* value is significant. It is important to point out that the odds ratio for a continuous independent variable tends to be close to 1, but it does not necessarily imply that the coefficient is not significant. Specifically, a significant *p* value implies a departure from 0 even though the difference is very small. In this case, when the odds ratio equals 1, it indicates a 50/50 chance that sleep quality will change due to a small change in the independent variable (Tables 7–9) [31].

4. Discussion

Our findings indicate that long-haul truck drivers' sleep duration and quality are significantly influenced by several key work-related factors and suggest that longer work hours and more miles driven lead to less sleep. It is important to point out that compared with other studies of truck drivers in the US, Europe, Asia, or South America [15–17,22,24,32–34], participating truckers in this study reported getting more hours of nightly sleep than researchers anticipated. Our findings align with recent results that suggest that drivers may be getting more sleep due to modified HOS regulations [30], but that the key issue in terms of cognitive attention and awareness could be in relation to the time of day in which the sleep occurs [35–37]. When comparing the sleep in relation to HOS and work hours, it is noteworthy that the regulations differ in other countries when compared to the US; for instance, drivers in Australia are allowed 14 hours total (12 hours driving time) daily, Canada 14 hours (13 hours driving time) daily, while in Europe it drops to 9 hours daily of driving time [38]. Meanwhile, in Brazil there are no HOS specific to drivers, but labor laws mandate that employees have 11 hours off between their shifts [39]. In our study, longer work hours, highly irregular shift patterns, high number of miles driven, and frequency with which drivers exceeded the DOT mandated HOS [29] had a critical bearing on their sleep patterns. Specifically, when our sample reported working even 1 hour longer per day their odds of getting < 7 hours of sleep increased. The likelihood of sleeping for shorter durations further increased to parallel the increasing frequency with which drivers worked over the mandated 14 hours of work per day. Ultimately, the drivers who never violated the 14-hour mandate increased their odds of getting a good night's sleep on work nights. Those drivers who saw the most variation in work shifts were the most likely to not get a good night's sleep.

Table 9
Odds ratio estimates of significant predictors (sleep quality)

Effect	Point estimate	95%	Wald confidence limits
Miles/wk	1.000	0.999	1.000
Daily h: different vs. same	0.604	0.372	0.980
Work overtime: always vs. sometimes	0.640	0.266	1.541
Work overtime: frequently vs. sometimes	0.355	0.153	0.820
Work overtime: never vs. sometimes	1.903	1.014	3.572
Work overtime: rarely vs. sometimes	1.547	0.730	3.282

4.1. Sleep hours

Although survey question sequences were carefully separated, the TSLDS asked drivers about their sleep patterns as well as history of highway near misses and accidents, among a number of other sensitive questions. Because drivers are often concerned that any participation in such studies might jeopardize their commercial drivers' licenses, despite assurances that collected data will be de-identified, it has been our experience that they exercise some level of care in formulating their responses. Researchers believe that this might have played a role in this study sample's reported nightly sleep hours on workdays, which were higher than expected. Other previous studies have reported significantly fewer number of sleep hours for truckers during work days but relatively similar numbers during nonworkdays [23,25]. Drivers who participated in this study reported sleeping 1 hour, 21 minutes longer during nonworkdays, which implies that they may not get sufficient sleep during workdays. Additionally, our sample's obesity patterns and elevated body mass index—usually associated with insufficient sleep, among other factors—are high. The authors suggest that interviewed drivers may have overstated the number of hours they sleep during work days and understated disturbances to their sleep in order to distance themselves from driving risks associated with insufficient sleep. Discrepancies can be seen in some of their responses; more specifically, over a third of interviewed drivers reported sleepiness: 37.7% reported feeling sleepy while working but not driving, 36.3% reported actually falling asleep while working but not driving, 54.9% reported feeling sleepy or nodding off while behind the wheel, and reported averaging one and a half naps (of 1 hour, 29 minute duration) during nonworkdays. These can be considered high in view of the reported number of hours that study participants claimed that they slept.

4.2. Work hours

The hours worked in the trucking industry have been consistently associated with a higher rate of excessive daytime sleepiness in conjunction with poor sleep quality [17]. Our findings support previous work that has established that the transportation sector, including long-haul trucking, has the highest rate of employees working > 48 h/wk; additionally those employees who consistently work > 50 h/wk have a greater chance of driving while sleepy [40]. Among working Americans, 63.9% report getting 6–8 hours of sleep each night; among truckers from a recent large national survey, only 51% report the same, with a little more than one in four drivers getting ≤ 6 hours [41]. As a result, many truckers, including those in our study, may try to nap throughout the day to compensate for sleep on their off-days, but it is not possible to reverse chronic sleep debt by sleeping longer on days off [42,43]. Sleepy drivers or those experiencing poor sleep put themselves and all other vehicles on the road at risk, as excessive daytime sleepiness among truck drivers are a primary risk factor for road-traffic accidents [32,44]. This was true in our study, with 53.2% having had a near miss and

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7.5% having caused an accident due to sleepiness. This is much greater than the 2% of working Americans reporting an accident or near miss due to driving while sleepy [40]. Based on field studies showing that the 34 hours restart provision in the 2003 HOS regulations is most helpful to drivers driving during the day and sleeping at night during the optimal circadian sleeping time, new provisions in 2013 were added mandating that drivers have two consecutive nights off to sleep during the 1–5 AM period to help to further mitigate fatigue and help to cut down on accident risks [35–37].

Both the trucking industry and federal regulations impact the long number of hours worked. Proposed DOT rule changes that went into effect on July 1, 2013 require that drivers must include a 30-minute rest break over an 8-hour period and kept the maximum number of hours worked at 70 hours after 8 days [29]. However, with the previously mentioned 34-hour restart provision, drivers can still accumulate up to 84 h/wk legally. The American Transportation Research Institute [45] reported that following the July 1, 2013 implementation of the new HOS rule, 67% of drivers reported a decrease in pay and 80% of motor carriers experienced productivity loss since the rules took effect, with nearly half stating that they require more drivers to haul the same amount of freight, which could incentivize drivers to push more miles and ultimately work more hours. With the increasing lack of accessible and affordable healthcare resources for truckers [19] (33.5% of our sample had no insurance), drivers may not have the means to seek medical assistance or consider the health effects of their long and irregular hours [46–49], including sleep consequences.

Even with the newest HOS rules, almost a quarter of our sample frequently or always violated this mandate, which corroborates the work of McCartt et al [50], which found that drivers violated the HOS rules between a quarter to a third of the time over a 3-year period. This potentially is due to the nondriving duties that drivers must perform, which is unpaid and often performed while logged as “off duty”, and as such is not recorded as working time. As a result, US drivers are on the road while sleepy more often than their European Union counterparts, who lead the world in highway safety [51]. European Union drivers are mandated to take a longer break of at least 45 minutes after driving for 4.5 hours and a minimum 11 hour rest period within 24 hours after the end of the previous rest period as compared to the 30 minute break requirement during the first 8 hours of a shift for American drivers.

4.3. Irregular work schedules

While there is a great deal of ambiguity in what we refer to as shiftwork, we are generally referring to an inconsistency in the time of day that someone begins and ends work, but it can also relate to the inconsistency of weekly schedules and the number of hours worked in a day. For instance, a typical daytime shift is a $\leq$ 8-hour period between the hours of 6:00 AM and 6:00 PM, with at least 8 hours of rest allowed between shifts [48]. Shiftwork and irregularity of work schedules currently affects one in seven US workers [48]. In our sample, 82.7% of drivers reported that their daily schedules were irregular, 63.8% had irregularities in the number of hours they worked from one day to the next, and 32.3% experienced differences in their week-to-week schedule. The unpredictability in scheduling made drivers in this study susceptible to sleep challenges, which concurs with reports depicting linkages between drivers’ frequent shiftwork and sleeping $<$ 6 hours on workdays [48]. In a study with long-haul truckers in Brazil, where there are no HOS for truck drivers but where national labor laws require all workers to have 11 hours off between work shifts [39], researchers found similar results: drivers who worked irregular schedules slept for a shorter time and experienced more sleep disruptions when compared to those with fixed schedules [33]. Shift workers are also prone to working more daily hours and driving while they are drowsy [48]. This also emerged in our findings with the number of hours truckers reported working but also in relation to their level of concentration while working and involvement in accidents or near misses due to their drowsiness. Meanwhile, sleep research has shown that much of the fatigue experienced by those working irregular shifts could be attributed to a misalignment of one’s circadian rhythm, or the 24-hour period that determines when we sleep [52]. With long-haul truckers frequently driving during nighttime (often to avoid traffic or due to scheduling), it is reasonable to expect that their circadian rhythms would be disrupted, thereby influencing the quality of their sleep. In effect, the aforementioned 2013 HOS modifications were instituted as a method to counter this and help to prevent excessive fatigue among drivers and allow them to get two consecutive nights of sleep during the optimal circadian time period. Napping has been considered a method of overcoming complications from shiftwork, but will not make up missed sleep, while naps of $>$ 20 minutes can lead to drowsiness when getting back on the road again immediately following a nap [43]. With truck drivers, research has shown that napping can help to overcome fatigue and increase alertness and ultimately help to decrease the risk of traffic accidents [35]. The concerns with long-haul truckers and the irregularity of their schedules should not be restricted to just sleep duration and quality, since prolonged shiftwork has been associated with a number of other comorbidities such as cardiovascular disease [49], metabolic disturbances [49], gastrointestinal ailments [53], and mood and anxiety disorders [54]. Although unintended consequences such as higher traffic times and more interaction with vehicles on the road cannot be controlled for, the improved predictability of work has the potential to not only increase safety on US highways, but also to play an enormous role in improving the overall health of a significant occupational segment of commercial vehicle drivers.

4.4. Miles driven

Compared to the average American automobile driver who drives 13,000 miles/y [55], three out of every four of sampled drivers (75.6%) in our study reported driving at least 2,500 miles/wk (equivalent to 130,000 miles/y) or 10 times the national average. A recent survey with a representative sample of American long-haul truck drivers averaged 107,668 miles/y [56], whereas, our sample’s mean weekly mileage was much higher at 2,812.61 miles (equivalent to 146,255.72 miles/y). For most drivers, the number of miles they drive over the road represents earned income; according to the Bureau of Labor Statistics, the median pay for drivers is $38,200/y, with a wide variety of per-mile rates [57]. It is difficult to imagine anyone spending more time behind the wheel than long-haul truck drivers. Even with new regulations mandating more breaks and less total time driving, truck drivers emerge as the population at greatest risk based on miles driven for sleep-related accidents. With the majority of drivers (70.3% in our sample) receiving mile-based compensation, it is understandable that they would drive as many miles daily as possible, regardless of the risks involved in driving while sleep deprived. This may contrast with another pay structure such as by the hour or a set salary. Although long-haul truckers have been instrumental to the national economy for many decades, it remains a challenge to balance the need for employee productivity while eliminating the sleep debt commonly experienced in the profession as was found in our study. In doing so, we must consider the individual health of drivers along with the risks associated with driving performance on the highways.

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4.5. Limitations

As a result of our cross-sectional study design, we by no means claim causal connections for any of the established associations, as sleep duration and sleep quality could have been adversely affected by other (individual or combined) factors of multiple origins, as is often the case. Some of the key challenges still remaining in transport worker sleep research include the lack of prospective studies, studies with pre-driving sleep estimates, as well as the presence of adequate control groups. It should be also noted that randomized control trials in occupational health and safety are oftentimes not feasible due to practical, ethical, legal, or other constraints. In addition, due to driver selection and retention biases, as well as extensive use of relevant medications, and drivers' self-reported estimates of their sleep, these findings may underrepresent the true scale of sleep challenges of truckers. Finally, a profound lack of research using similar work-related measures and how they may influence sleep renders these findings somehow difficult to compare with other findings. Future studies of work-related factors in relation to the sleep of long-haul truckers should seek to utilize larger and more representative samples. With our findings being self-reported and subjective, the authors suggest that this type of study be replicated with objective findings such as found in previous naturalistic studies of drivers. Lastly, the findings in relation to previous literature indicate that the work environment, including work hours and schedules, of long-haul truck drivers should be examined in relation to other health and safety measures.

5. Conclusion

As a result of the 1980 industry deregulation, trucking has gradually evolved into what is considered a stressogenic, obesogenic, and often pathogenic work environment [58,59]. In this context, long-haul truckers are afflicted by a plethora of syndemic comorbidities with not only ramifications for their own health but as well for the safety of the driving public [60]. Our findings corroborate that fatigue-inducing factors such as long work hours, irregular work shifts, high number of miles driven, and violation of HOS regulations have had a critical bearing on truckers' sleep patterns. Despite recent changes in HOS legislation, the implications of these findings suggest that a comprehensive review of the regulations and operational conditions for commercial motor vehicle drivers should be undertaken.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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