TITLE**: Health Conditions, Driving Practice, and Self-Reported Fatigue among Long-Haul Truck Drivers: The National Survey of U.S. Long-Haul Truck Driver Health and Injury**

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ABSTRACT

Driver fatigue and sleepiness may impact driver alertness and performance, which may lead to increased risk of road crashes and poor health. In 2010, NIOSH conducted a nationally representative survey of long-haul truck drivers to help characterize health and safety risk factors in this population. Self-reported health conditions, hours of driving or on-duty, and hours of sleep were collected from 900 truck drivers by interview and through a retrospective Sleep and Activity diary. A multivariable logistic model for high self-reported ratings of fatigue including working/driving character, demographics, and health conditions was developed. Fatigue was defined as a driver being so tired that the driver needed to take a break or sleep, and was determined by ratings on a Likert Scale.

Forty-four percent of drivers indicated self-reported fatigue ratings of 6 or above on the day during the previous week when they felt most fatigued. Model-based standardized marginal risk ratios showed that high self-reported fatigue ratings increased with number of hours driving or on duty, poor quality of sleep, driving alone, and body mass index (BMI). High self-reported fatigue ratings were greater for driver health conditions such as heart disease, back pain, and emphysema. Use of Continuous Positive Air Pressure (CPAP) had a protective effect, as did years worked as a driver in a job requiring a mandatory rest period away from home during each run.

This study suggests that development of trucking policy and programs to minimize long-haul truck driver fatigue should include consideration of working, sleeping, and health conditions.

Keywords: survey, truck driver, health, fatigue, relative risk, work practices

INTRODUCTION

The U.S. economy operates 24 hours per day, 7 days per week, creating a great demand for individuals employed in occupations such as truck driving to work non-standard schedules (1). Long-haul truck drivers often experience long and irregular work hours that may reduce time available to sleep, affect the natural Circadian rhythm, and impact illness, injury, and health behaviors (2,3,4,5,6). In addition, sleep quantity and quality may be impacted by working conditions such as tight delivery schedules and pressure to meet those schedules, as well as individual driver factors such as sleep disorders and other health conditions and behaviors (7).

Insufficient sleep quantity and poor sleep quality may cause fatigue and sleepiness, which may impact driver alertness and performance and result in increased risk of road crashes (8,9,10,11,12,13,14,15,16). Sleep-related fatigue is associated with impaired cognitive performance, slowed reaction times, and decreased overall driver situational awareness (17). Driver sleepiness is associated with a two- and one-half fold increase in near-crash/crashes overall (18), and extreme daytime sleepiness is associated with about a six-fold increase in crashes (19). The Federal Motor Carrier Safety Administration (FMCSA) identified fatigue as being present in 13% of all large-truck-related crashes resulting in a fatality or injury (20). Fatigue was identified as the probable cause, contributing factor, or a finding in 15 (38.5%) of highway crash investigations of commercial vehicles conducted by the National Transportation Safety Board (NTSB) between 1 January 2001 and 31 December 2012 (21).

In 2010, NIOSH conducted a nationally representative survey of long-haul truck drivers to help characterize health and safety risk factors in this population. Results of selected health outcomes are described elsewhere (22). This paper describes the relationship between self-reported driver fatigue and self-reported sleep, working, and health conditions among long haul truck drivers.

METHODS

Data on self-reported fatigue, demographics, driving practices, and work and health conditions were collected in an interview and a Sleep and Activity diary as part of the NIOSH National Survey of Long-Haul Truck Driver Health and Injury (LHTDS) (22). The study was conducted October-December 2010 at 32 truck stops across the 48 contiguous United States.

Self-reported fatigue

To assess fatigue, respondents were asked the following: '*During the past 7 days, what was your level of fatigue on the day you felt most fatigued*?' Fatigue was defined as *being so tired that the driver needed to take a break or obtain sleep* and was rated using an 11-point Likert scale (0=" not at all fatigued" to 10="as fatigued as I could be"). For this analysis, respondent's fatigue rating was dichotomized as low or high based on a rating 6 or more on the day during the previous week when the driver felt most tired. A rating of 6 was determined as the minimum self-reported fatigue rating where more than 50% of drivers reported drowsiness one or more days per week when driving. Sixty-nine percent of drivers who had nodded off or fallen asleep at least once per week while driving during the past 3 months reported fatigue levels of 6 or higher on the day they reported feeling most tired.

Sleep and Activity Diary

Participants completed a NIOSH-developed self-administered, retrospective Sleep and Activity diary (23). The format of the diary, modified to be similar to the FMCSA Hours of Service log (24), required truck drivers to record driving or on-duty hours, non-working hours, and sleeping hours. Sleep and Activity diaries were distributed to 900 respondents after they completed the interview to record work and nonwork activities and sleep duration over the two 24-hour periods prior to the interview. Each 24-

hour period was based on the time when driving began. The average duration of driving and sleeping over both periods was used for analysis.

Statistical Analysis

Logistic Regression

A stepwise logistic regression procedure incorporating backwards elimination of health and driving variables was used to develop a multivariable model for presence of fatigue ratings greater than or equal to 6 on the day during the previous week when the driver reported the highest fatigue level. The backwards elimination model was conducted to remove confounding variables at a significance level of $p<0.2$. This approach presents results similar to those obtained from a change-in-estimates approach to variable selection (25).

Driving factors considered were number of hours driving or on-duty, number of years working as a driver with a mandatory rest period away from home on each run, 6 hours or less slept or napping that day, whether sleep was continuous or interrupted, stressful driving situations, and whether driving alone. A stressful driving situation was defined as often having at least one of the following: tight delivery schedules and loading/unloading times, traffic congestion delays, violation of Hours-of-Service rules, or having inadequate compensation. Health conditions included: cancer, diabetes, heart disease, emphysema, obstructive lung disease or lower respiratory disease, use of Continuous Positive Airway Pressure (CPAP) therapy as a potential indication of a diagnosis of sleep disorder, hypertension, elevated cholesterol, lower back pain lasting 1 day or more within the past three months, lack of physical activity, body mass index (BMI), and current smoking (26,27,28,29,30,31,32,33,34). Heart disease was defined as ever having coronary heart disease, angina, or any other heart condition. Lack of physical activity was defined as not meeting HHS guidelines of 150 minutes per week of moderate or vigorous physical activity for at least 30 minutes at a time per day (35). Body mass index (BMI) was calculated as [weight (kg)]/ [height (m)]^2. Demographic variables included race, gender, and age group. A high correlation was found between age and years working as a driver, so for this analysis years working as a long-haul driver was used. Fatigue rating showed a linear relationship with BMI but a quadratic relationship with years working as a long-haul truck driver.

Variables retained in the final model included: 1) driving and working factors – hours driven or on duty that day, number of years driving as a long-haul driver, sleep quality, and driving alone, and 2) demographic and health factors: race, BMI, back pain lasting 1 day or more, heart disease, use of CPAP, and emphysema.

Risk Ratios

Model-based risk ratios were calculated using the method of marginal standardization (36,37). A model-based risk ratio was calculated as the average regression model-based probability of high fatigue rating divided by the average probability of having low fatigue rating. Since averages of predicted probabilities reflect the confounder distribution in the target population, the risk ratio is standardized to the distribution of the variables in the study sample. Risk ratios were calculated for a high self-reported fatigue rating accounting for each variable in the final model.

Descriptive analyses and multivariate regressions were performed using SAS V. 9.3 [38]. Risk ratios were calculated using SUDAAN V. 10 (39,40). Further details on the LHTDS survey procedures and results may be found in Sieber et al. (22). The LHTDS was approved by the Office of Management and Budget (OMB no. 0920-0865) and NIOSH Human Subjects Review Board. A waiver of documentation of informed consent was granted since no personal identifying information was collected and documentation would create a record of individuals that participated in the study.

RESULTS

Demographic and Self-Reported Sleep Health Characteristics

The LHTDS collected interview, health and driving information from a nationally representative sample of 1265 long haul truck drivers. The present analysis is based on 900 drivers who completed both the interview and a sleep and activity diary. Demographic and sleep characteristics from the interview are presented in Table I. Not included in this analysis are an additional 365 drivers who completed the interview but either did not complete the diary fully, did not complete it correctly, or who did not drive during at least one 24-hour period immediately prior to the interview. No statistically significant difference was found between prevalence of a fatigue rating of 6 or greater in the 900 drivers completing both diary and interview, and the 365 drivers who did not ($p=0.10$).

The sample of 900 drivers was mostly male (94%) drivers between 30 and 59 years old (84%), with an average age of 46.7 years. Seventy-four percent of drivers were white, 17% were Black or African-American, and 7% reported other or multiple races. Eight percent were of Hispanic ethnicity. Forty-eight percent reported feeling very drowsy when driving one or more times per week, while eight percent reported feeling very drowsy while driving almost every day. Fourteen percent reported they had nodded off or fell asleep while driving at least once during the previous 3 months, while almost four percent indicated nodding off or falling asleep while driving at least once per week. Forty-four percent of the drivers reported fatigue rating of 6 or higher on the day when they felt most tired, but only 1 % reported ratings 6 or more on days when they felt least tired. Six percent reported average fatigue ratings 6 or higher throughout the previous 7 days.

Driving/On-Duty and Sleep Duration

The average number of hours driving or on-duty (driving, securing the load, truck maintenance, etc.) and sleeping duration recorded in the Sleep and Activity diary are shown in Table II. Respondents who drove or were on-duty during the two 24-hour periods prior to the interview worked an average 10.0 hours per 24-hour period; reported an average 5.3 non-working hours (eating, doing laundry, etc.); and recorded sleeping/napping an average 8.7 hours per day. Thirteen percent of drivers averaged 6 hours or less of sleep time during the 24-hour period. Most drivers (86%) began their driving shift between 0000 and 1200 hours.

Standardized Marginal Risk Ratios

Standardized marginal risk ratios for self-reported fatigue ratings greater than 6 are shown in Table III. Risk ratios for high self-reported fatigue ratings by number of hours driving are presented relative to levels expected if not driving. After driving 1 hour, the risk of a fatigue rating over 6 increases 10%, after 2 hours to 20% after 2 hours, and doubles after driving 10 hours. Risk of self-reported fatigue rating increases 20% if the driver's sleep is interrupted compared to having continuous sleep, and increases 10% if driving alone. The risk for high self-reported fatigue ratings decreases 10% after more than 10 years of working in a long-haul driving job. In this population, risks for high self-reported fatigue ratings were increased 20% or more for self-reported heart disease, back pain, emphysema and higher BMI. However, risk of high self-reported fatigue ratings is reduced with use of CPAP.

Risk ratios for high self-reported fatigue ratings by time period when starting driving are shown in Table IV. Risk ratios in each time period are presented relative to ratings for drivers starting between 1801 and 2400 hours, when prevalence of high self-reported fatigue ratings was lowest. The greatest risk for high ratings of self-reported fatigue was for drivers starting driving between 0001 and 0600 hours.

Characteristic	Percent of Drivers	Number of Drivers
Gender:		
Male	93.8	844
Female	6.2	56
Age Range (Years)		
20-29	5.1	46
30-39	21.8	196
40-49	32.0	288
50-59	30.4	274
60-69	9.9	89
70-80	.8	7
Hispanic or Latino[1]	7.9	71
Race		
White	74.8	673
African American	14.2	227
Other or multiple race[2]	11.0	99
Felt very drowsy when driving		
Once per month or less	51.9	467
About once per week	21.8	196
2-5 times per week	18.2	164
Almost every day	8.1	73
Nodded off or fell asleep while driving in the last 3 months		
Never	86.2	776
1-2 times	10,2	92
Once per week	1.8	15
2-3 times per week	1.2	11
More than 3 times per week	0.8	6
Self-Reported Fatigue Rating $\geq$ 6 in Past 7 Days[3]		
On the Day Driver Felt Most Fatigued	44.2	398
On the Day Driver Felt Least Fatigued	1.3	12
Average Level of Fatigue	6.4	58

[1]Hispanic ethnicity includes Spanish, Mexican, Mexican American, Chicano, Puerto-Rican, Cuban, Dominican (Republic), Central or South American, Other Latin American, or another Hispanic/Latino.

[2] Other race Includes Asian, Native American, Native Hawaiian or Pacific Islander, and unknown.

[3] Self-reported fatigue was defined as being so tired that the driver needed to take a break or sleep. Elevated self-reported fatigue level is fatigue level reported greater than or equal to 6.

Table I. Demographic and Self-Reported Driving Characteristics from Personal Interview, Survey of U.S. Long-haul Truck Drivers, Fall 2010

Characteristic	Mean or Percent of Drivers	Number of Drivers
Total number driving[1]	900	900
Number of hours Driving or on-duty (SD)[2]	10.0 (2,8)	900
Number of hours Off duty or not working (SD)	5.3 (3.0)	900
Number of hours Sleeping or napping (SD)	8.7 (2.5)	900
Number of drivers averaging 6 or less hours of sleep in a work day	12.6%	113
Number of Drivers beginning driving shift between:		
0001 - 0600	32.0%	288
0601 - 1200	54.0%	486
1201 - 1800	11.2%	101
1801 - 2400	2.8%	25

[1] Entries are for those driving 24-hour periods prior to interview.

[2] Abbreviation SD = Standard Deviation.

Table II. Self-Reported Driving and Sleep Characteristics from Sleep and Activity Diary, Survey of Long-Haul Truck Drivers, Fall 2010

Factor	Risk Ratio	
	Estimate (SE)[1]	95% Confidence Interval
Working/Driving Factors:		
Number of Hours driving or on duty[2]:		
1	1.1 (0.03)	(1.0, 1.1)
2	1.2 (0.06)	(1.1, 1.3)
4	1.4 (0.12)	(1.1, 1.6)
6	1.6 (0.20)	(1.2, 2.0)
8	1.8 (0.30)	(1.3, 2.4)
10	2.0 (0.39)	(1.3, 2.9)
11	2.1 (0.44)	(1.4, 3.2)
Interrupted vs. continuous sleep	1.2 (0.09).	(1.0, 1.3)
Driving alone vs. having passenger	1.1 (0.11)	(0.9, 1.4)
Years worked in job as a long-haul driver[3]		
5	1.0 (0.0)	(1.0, 1.0)
10	1.0 (0.01)	(1.0, 1.0)
15	0.9 (0.02)	(0.9, 1.0)
20	0.9 (0.03)	(0.8, 0.9)
Health/Demographic Factors:		
Heart Disease[4]	1.4 (0.16)	(1.1, 1.7)
Back pain lasting all day	1.2 (0.10)	(1.0, 1.4)
Emphysema	1.5 (0.30)	(1.0, 2.18)
Use of Continuous Positive Air Pressure (CPAP)	0.6 (0.14)	(0.4, 1.0)
Body Mass Index (kg/m^2)[5]		
25	1.1 (0.03)	(1.0, 1.1)
30	1.1 (0.07)	(1.0, 1.3)
35	1.2 (0.10)	(1.0, 1.4)
40	1.3 (0.1)	(1.0, 1.6)
45	1.4 (0.18)	(1.0, 1.7)
Race[6]	1.2 (0.13)	(1.0, 1.5)

Abbreviation SE=Standard Error.

[2] Predicted marginal risk compared to that from no driving.

[3] Predicted marginal risk compared to that from 1-year driving experience.

[4] Heart disease was defined as having coronary heart disease, angina, or any other heart condition.

[5] Predicted marginal risk compared that at BMI=20 kg/m^2.

[6] Predicted marginal risk for race=white vs. other race.

Table III. Standardized Marginal Risk Ratios for Variables Associated with High Self-Reported Fatigue Ratings, Survey of Long-Haul Truck Drivers, Fall 2010

	Risk Ratio	
Start of drive time[1]	Estimate (SE)[2]	95% Confidence Interval
Between 0001 and 0600	1.2 (0.35)	(0.7, 2.2)
Between 0601 and 1200	1.1 (0.31)	(0.6, 2.0)
Between 1201 and 1800	1.1 (0.33)	(0.6, 2.0)
Between 1801 and 2400	Reference	

[1] Predicted marginal risk compared to that if driving begun between 1801 and 2400 hours
[2] Abbreviation S.E. – Standard Error.

Table IV. Standardized Marginal Risk Ratios for High Self-Reported Fatigue Ratings by Time when Driving Begins, Survey of Long-Haul Truck Drivers, Fall 2010

DISCUSSION

Our analysis combines self-reported health data with daily Sleep and Activity logs to examine the extent to which work and health conditions of. long-haul truck drivers influence self-reported driver fatigue ratings.

Fatigue is a subjective term often used to describe the experience of being 'tired' or 'exhausted' (41, 12). In this study self-reported fatigue was characterized using a 10-point Likert scale. Subjective assessment of fatigue was used in this study to collect both health and driving data from a large number of long-haul truck drivers during work times (42).

Objective measures to assess fatigue and sleepiness while driving include: physiologic measures of brain activity or cardiac activity, ocular measures such as Percent Eye Closure (PERCLOS) (43), vigilance attention tests such as the Psychomotor Vigilance Test (PVT) (44,45), or driver performance tests such as lane departures while driving (46). Subjective and objective measures of individual fatigue may not necessarily agree although they may correlate at a group level (16,42). Since some objective methods may require specialized equipment, subjective assessments of sleepiness have been advocated as indicators of potential fatigue (47).

Environmental and health factors may contribute to fatigue among long haul truck drivers. Driving at night, driving for long duration, and organizational factors may impact fatigue (48,49,50). The linkage between fatigue and health conditions such as sleep apnea, obesity, and heart disease has been recognized (10). Fatigue management programs have been developed in some cases to address some of the factors indicated above (10,51,52,53).

Self-Reported Fatigue and Driving

Driver fatigue and sleepiness have been shown to play a significant role in increasing the risk of road crashes (9,11,13). In this study, high self-reported fatigue ratings increased 10% for each hour driven or on duty. Those driving or on duty during 24-hour periods prior to the LHTDS interview reported an average of 10.0 hours driving or on duty. Driving 10 hours continuously would represent a 2-fold increase in high self-reported fatigue rating. Current FMCSA regulations limit maximum driving time to 11 hours within a 14-hour duty period, after 10 consecutive hours off duty (54). It should be noted that driving time alone (time on task) has not been found to be a consistent predictor of fatigue (16).

About half of drivers in the LHTDS study (48%) reported stopping for a break or fuel at least every 4 hours, 44% reported stopping between 5 and 8 hours and 9% over 8 hours (data not shown). Rest breaks might help to limit the increase in higher ratings of self-reported fatigue with driving times. Two rest breaks of 30 minutes each during a 10-hour trip have been reported to be adequate to reduce crash risk with fatigue involvement (55). Bunn et al., (56) found an association between distance from rest havens/truck stop locations and commercial vehicle driver at-fault crashes involving sleepiness/fatigue.

Risk of high self-reported fatigue ratings increased when driving alone, but decreased with more years working in a long-haul driving job. This effect of years may be attributed to older, more experienced drivers who may have developed coping strategies such as smoking or taking caffeine, taking breaks and driving during daytime hours to reduce the effects of fatigue, or to a healthy worker survival bias, where drivers who could not cope with fatigue or other aspects of the job, self-selected out of the industry. In this study years worked was used as a surrogate for age of driver. Other studies have not found significant or consistent relationships between age and fatigue (57,16).

Fatigue may not necessarily lead to loss of driving performance. Many truck drivers report that they are able to cope with fatigue while driving, even though acknowledging some level of fatigue. Risk ratios for increased ratings of self-reported fatigue less than 2.0, and in many cases near to 1.0, were found in this study. In a study on perception of fatigue by truck drivers, 60% of drivers and 88% of managers

reported that fatigue is rarely or never a problem for the drivers (58). It should be noted that, given the many factors affecting self-reported fatigue levels, truck drivers do not experience higher levels of fatigue. Only 44% of drivers interviewed indicated high fatigue ratings even on the day when they felt most fatigued. It is remarkable how drivers are able to cope with fatigue given the many contributing factors to it in their working environment.

Truck crashes and accidents are more prevalent during the period 0001-0600 (59,60,61). In this study, drivers who begin driving between 0001 and 0600 had a greater risk for high self-reported fatigue ratings compared to drivers who started driving during later periods of the day. Available light and visibility between the pre-dawn and later starting times may be factors in this finding.

Sleep

Those driving or on duty for at least one 24-hour period reported sleeping or napping an average 8.7 hours per 24-hour interval. The average number of hours of sleeping or napping per 24-hour interval in this study was more than the 6.6 hours per night reported by Ursin et al. (62) and the 6.3 hours per 24-hour interval reported by Hanowski et al. (63), and almost 4 hours longer than 4.8 hours per sleep period in a study by Mitler et al. (64). Most drivers in the LHTDS slept within the recommended 7-9 hours by the National Sleep Foundation (22,65). However, 13% of LHTDS drivers reported averaging six hours or less of sleep, compared to 30% reported by all workers in the 2010 National Health Interview Survey (NHIS) ($p<0.001$) and 33% among all workers in the transportation and warehousing sector (6,22). Prevalence of short sleep duration of less than 7 hours among workers in transportation and material moving occupations has increased from 32.0% in 2010 to 41.0% in 2018 (66). Short sleep duration is also associated with increased mortality prevalence, diabetes mellitus, cardiovascular disease, coronary heart disease, sleep disorders, depression, and obesity (67,68).

Drivers in this study reported high ratings of fatigue when sleep was interrupted compared to drivers who reported continuous sleep. Short-term consequences of sleep disruption include increased stress responsivity, somatic pain, reduced quality of life, emotional distress and mood disorders, and cognitive, memory, and performance deficits. Long-term consequences may include hypertension, dyslipidemia, cardiovascular disease, weight issues, metabolic syndrome, diabetes mellitus, and certain cancers (69). Sleep loss from sleep disruption has been found to be more detrimental to positive mood than sleep loss from delaying bedtime (70).

Health Conditions

Our regression model included conditions reported to be associated with fatigue and sleepiness: heart disease, emphysema, back pain, BMI, and use of CPAP therapy as a potential indicator of diagnosis of a sleep disorder (26,27,28,29,30,31,32,33,34). Risks for high fatigue ratings for drivers with reported heart disease or emphysema are both comparable to those who reported 4 or more hours of driving or on duty time. Certain heart conditions and respiratory disorders may also compromise the ability to drive safely and result in medical disqualification for commercial driving licensure (71). In a review of obstructive sleep apnea (OSA)-related motor vehicle crashes, Tregear et al. found that drivers with OSA are at increased risk for crash compared to drivers without OSA (10,14). OSA may result in excessive daytime sleepiness and may be treated by use of CPAP. In this study high ratings of self-reported fatigue decreased for drivers using CPAP.

Lower back pain is reported to be associated with fatigue (72), and in this study risk of high self-reported fatigue for drivers experiencing lower back pain lasting an entire day or more during the previous 3 months was increased. Back pain among drivers may be minimized with proper seat design and ergonomic considerations in truck cab design and adoption of safe lifting and material handling guidelines while loading and unloading. Anthropometric considerations in truck cabs have been discussed by Guan

(73), and recommended weight limits on manual material handling and lifting are available in the revised NIOSH lifting equation (74).

Self-reported fatigue has been associated with higher BMI (75). In this study, risk for high self-reported fatigue ratings increased with BMI. The average BMI of drivers in this study was 32.1 kg/m^2. Since both fatigue and obesity have been associated with crash risk (76), these findings and the known relationship between obesity and other adverse health conditions may provide additional impetus for public health efforts to reduce the prevalence of obesity among truck drivers.

Strengths and Limitations

Study population

This analysis is based on results from the NIOSH LHTDS, a representative national survey. Results from the 1265 drivers completing the LHTDS interview are applicable to the U.S. long-haul truck driver population. However, the 900 respondents who completed both the interview and sleep and activity diary may not be nationally representative. No statistically significant difference was found between prevalence of self-reported fatigue ratings of 6 or greater in the 900 drivers completing both diary and interview and the 365 drivers who did not ($p=0.10$).

Fatigue Measures

This analysis was limited to health and working/driving factors affecting the extent of self-reported driver fatigue on the day when the driver felt most tired during the previous 7 days. In this study it was assumed that high ratings of self-reported fatigue resulted from the effects of short-term sleep loss or periods of overwork. Extreme fatigue over time not relieved by rest, or chronic fatigue syndrome, was not assessed in the LHTDS. Prevalence of self-reported chronic fatigue syndrome has been found to be relatively low at 3.28% (77). Factors such as condition of the roadway or time of day were also not considered. Current Hours of Service (HOS) regulations are meant to minimize the type of drowsiness that can lead to crashes (54).

The presence and rating of self-reported fatigue to the extent that it affected work was determined using questions included in the subjective Fatigue Symptom Inventory (FSI) (78,79), which was administered as part of the LHTDS interview. A Likert scale for levels of self-reported fatigue between 0 and 10 was used. Self-reported fatigue levels may not be consistent with objective measures of fatigue,

Collecting self-reported fatigue data enabled collection on both health and working conditions from a large sample of truck drivers. Self-reported ratings at which at least 50% of drivers reported feeling drowsiness while driving a truck, and where 69% of drivers reported nodding off or falling asleep more than once per week while driving a truck were used to determine the fatigue rating of 6 or higher to indicate higher levels of self-reported fatigue. Drowsiness and nodding off frequencies were collected by questionnaire. The cutoff rating of 6 was further checked against a validated index of daytime sleepiness, the Epworth Sleepiness Scale (ESS) (80). The ESS is a self-assessment tool for measuring the likelihood of the respondent falling asleep in different situations, and is accepted as reliable, internally consistent which has been externally validated in different populations and with other measures of sleepiness (81). Sixty-six percent of drivers with elevated levels of self-reported fatigue showed high Epworth values above 10 (indicating excessive daytime sleepiness), for a sensitivity of 66% and specificity of 60%. Since fatigue levels are subjective and not uniform across respondents, the analysis was limited to the logistic analysis using cutoff values to indicate the presence or absence of higher ratings of self-reported fatigue.

Since the LHTDS was a cross-sectional study, causality cannot be determined. Results can best be used to examine associations between health and working conditions, and self-reported fatigue.

Respondents to this cross-sectional survey were drivers on the road who visited truck stops during the fall of 2010.

Self-reported data collected in this study were subject to recall and interviewer bias. Bias was limited using standard interview protocols and survey-specific training, including use of probes. The format of the Sleep and Activity diary was similar to that of the FMCSA Hours of Service log (24) for easier completion by drivers. It is possible, however, that some drivers might have reported total time in a sleeper berth rather than actual time sleeping or napping.

CONCLUSION

This study documents the association between long-haul truck drivers' self-reported fatigue, work and driving factors, and health conditions. Higher ratings of self-reported fatigue increase with number of hours driving or on duty, poor quality of sleep, driving alone, and BMI. Risks for higher ratings of self-reported fatigue were greater for driver health conditions such as heart disease, back pain, and emphysema. Use of CPAP had a protective effect, as did years worked as a driver in a job requiring a mandatory rest period away from home during each run. Many of the factors found here to influence high ratings of self-reported fatigue can be addressed by work organization changes such as engineering controls, fatigue management and health programs, or other administrative practices. This study suggests that development of trucking policy and programs to minimize long-haul truck driver fatigue should include consideration of working, sleeping, and health conditions.

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AUTHOR CONTRIBUTIONS

All authors confirm contribution to the paper as follows: study conception and design, data collection, draft manuscript preparation. Dr. Sieber prepared analysis and interpretation of results. All authors reviewed the results and approved the final version of the manuscript.

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