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The influence of daily sleep patterns of commercial truck drivers on driving performance

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ABSTRACT

Fatigued and drowsy driving has been found to be a major cause of truck crashes. Lack of sleep is the number one cause of fatigue and drowsiness. However, there are limited data on the sleep patterns (sleep duration, sleep percentage in the duration of non-work period, and the time when sleep occurred) of truck drivers in non-work periods and the impact on driving performance. This paper examined sleep patterns of 96 commercial truck drivers during non-work periods and evaluated the influence these sleep patterns had on truck driving performance. Data were from the Naturalistic Truck Driving Study. Each driver participated in the study for approximately four weeks. A shift was defined as a non-work period followed by a work period. A total of 1397 shifts were identified. Four distinct sleep patterns were identified based on sleep duration, sleep start/end point in a non-work period, and the percentage of sleep with reference to the duration of non-work period. Driving performance was measured by safety-critical events, which included crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations. Negative binomial regression was used to evaluate the association between the sleep patterns and driving performance, adjusted for driver demographic information. The results showed that the sleep pattern with the highest safety-critical event rate was associated with shorter sleep, sleep in the early stage of a non-work period, and less sleep between 1 a.m. and 5 a.m. This study also found that male drivers, with fewer years of commercial vehicle driving experience and higher body mass index, were associated with deteriorated driving performance and increased driving risk. The results of this study could inform hours-of-service policy-making and benefit safety management in the trucking industry.

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1. Introduction

According to the Bureau of Labor Statistics (BLS), about 1,701,500 people were employed as heavy and tractor-trailer truck drivers in the United States in 2012 (Bureau of Labor Statistics, 2014). These workers are at an increased risk of occupational fatalities. They were 12 times more likely to die on the job than the U.S. general worker population (Chen et al., 2014). In 2012, 695 heavy and tractor-trailer truck drivers died on the job, the largest number of occupational fatalities in any occupation (Bureau of Labor Statistics, 2013). The majority (488 out of 695, or 70%) of these fatalities were caused by motor vehicle crashes.

Truck driver safety is not only a national occupational safety priority (National Institute for Occupational Safety and Health, 2009), but also a general public health concern because of the high death toll for truck crashes among drivers and occupants of other vehicles and the economic burden of truck crashes on society. In 2012, 3464 large trucks were involved in fatal crashes, 73,000 were involved in injury crashes, and 241,000 were involved in property-damage-only crashes (Federal Motor Carrier Safety Administration, 2014b). In the aggregate, for each large truck driver death, six other persons (persons in other vehicles, pedestrians, or cyclists) died in truck crashes (Federal Motor Carrier Safety Administration, 2014a). Motor vehicle crashes involving large trucks and buses cost the U.S. economy an estimated $99 billion in 2012 (Federal Motor Carrier Safety Administration, 2014b). These costs included productivity

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Table 1
Classification of activities and periods from activity register data.

Activity code	Activity type	Period based on Blanco et al. (2011)	Revised period
1	Driving truck	On-duty work period	Work period
2	Heavy work (loading/unloading)		
6	Light work (waiting, paperwork, vehicle maintenance)		
3	Sleep	On-duty rest period	Non-work period
4	Rest (not asleep)		
5	Eating		
7	Sleep	Off-duty period	
8	Rest (not asleep, watching TV, resting)		
9	Eating		
10	Light housework (dishes)		
11	Heavy housework (mowing lawn)		
12	Light leisure activity (walking, Internet)		
13	Heavy leisure activity (running, sports)		
14	Driving other vehicle (not work-related)		
15	Other		

losses, property damage, medical costs, rehabilitation costs, travel delays, legal and court costs, cost of emergency services (such as ambulance, police, and fire services), insurance administration costs, and the costs to employers (Blincoe et al., 2002).

Fatigued or drowsy driving has been identified as a major cause of truck crashes (Morrow and Crum 2004; Federal Motor Carrier Safety Administration, 2006, Advocates for Highway and Auto Safety, 2011). The National Transportation Safety Board found fatigue to be the most frequently cited probable cause (31%) in fatal-to-the-truck-driver crashes (National Transportation Safety Board, 1990). A primary reason for occupational fatigue is incompatible timing of duty schedules relative to circadian (i.e., 24-h) rhythm and the need for sleep (Satterfield and Van Dongen, 2013). In addition, age and body mass index (BMI) are also contributing factors to fatigue (Schur et al., 2007). A number of studies examined the association between sleep duration and fatigue-related crashes or driving performance. Sweeney et al. (1995) examined 107 single-vehicle heavy truck crashes and classified these crashes as either fatigue-related or non-fatigue-related. The results suggested that drivers who slept less during their last sleep period in the past 24 h and who experienced split sleep periods were more likely to be involved in fatigue-related crashes. Hanowski et al. (2007) reported that drivers who received significantly less sleep than their usual amount prior to trips were more likely to be involved in safety-critical events (SCEs), which include crashes, near-crashes, or crash-relevant conflicts. Blanco et al. (2011) and Soccolich et al. (2013) suggested that breaks (including sleep) preceding driving are beneficial in reducing SCEs, and mitigate the negative effects of time-on-task (i.e. driving performance in the later stage of a work period can be decreased due to tasks occurred earlier in the work period (Soccolich et al., 2013)).

According to circadian rhythm, the time period from 1 a.m. to 5 a.m. is an important natural sleep time (National Sleep Foundation, Butkov and Lee-Chiong 2007; Department of Transportation, 2014, National Institute for Occupational Safety and Health, 2014). In 2013, the Federal Motor Carrier Safety Administration revised the hours-of-service regulations. The revised hours-of-service regulations require the restarting period to cover two night periods occurring between 1 a.m. and 5 a.m. There is a need for examining the association between sleep in the period of 1–5 a.m. and truck drivers' driving performance or driving risk.

The objectives of this study were two fold: (1) to examine truck drivers' sleep patterns in non-work periods, and (2) to evaluate the associations between sleep patterns in the non-work period and driving performance and risk in the immediate subsequent work period adjusted for years of employment, drivers' age, gender, and BMI.

2. Data

2.1. Naturalistic truck driving study data

This study used the Naturalistic Truck Driving Study that recorded approximately 735,000 miles of truck driving by 96 commercial truck drivers (75 long-haul and 21 line-haul truck drivers) (Blanco et al., 2011; Soccolich et al., 2013). Each driver drove a commercial truck equipped with a comprehensive data acquisition system that gathered data from the vehicle network, multiple video cameras, radar, a three-dimensional accelerometer, and a Global Positioning System (GPS). Driving data were collected continuously from ignition-on to ignition-off for approximately one month for each driver. The data were downloaded to a secure data center for analysis after data collection. The project was approved by the Virginia Tech Institutional Review Board.

Abnormal driving events were identified via a combination of kinematic triggers such as longitudinal and lateral acceleration rates and yaw rate, followed by confirmation via visual inspection of videos by trained data analysts. The analysis in this study included the same four types of SCEs used in Blanco et al. (2011): crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations. Because crashes are rare events, non-crash events are often included in traffic safety analyses to increase sample size and statistical power (Dingus et al., 2006; Fitch et al., 2013; Klauer et al., 2014; Ouimet et al., 2014). It has been illustrated that near-crashes provide useful information on driving risk evaluation (Guo et al., 2010). Crash-relevant conflicts, also known as critical incidents, have been shown to be associated with crash and near-crash risk (Guo and Fang 2013). Unintentional lane deviation events are a measure of driving performance decrement (Van Dongen et al., 2010) and driver fatigue (Hanowski et al., 2008).

The participant drivers recorded their 24-h work and non-work activities using an activity register. As shown in Table 1, drivers' daily activities were subsequently classified using 15 activity codes and divided into three types of periods based on the legal regulations for on- and off-duty driving, working times, and resting times (Blanco et al., 2011). The user recorded activities were cross-referenced with the objectively recorded naturalistic driving data to produce a hybrid register with precise driving period.

2.2. Data processing

To evaluate the impact of sleep on the immediate subsequent driving period, we reclassified the activities into two revised periods: the non-work period and the work period. The classification of the revised periods was based solely on the nature of the daily