Sleep Apnea Crash Risk Study

Background

Sleep apnea is a condition in which a narrowing or closure of the upper airway during sleep causes repeated sleep disturbances, and possible complete awakenings, leading to poor sleep quality and excessive daytime sleepiness. This study was completed to assess the risks of commercial motor vehicle (CMV) crashes due to the presence of sleep apnea among truck drivers.

The primary objectives of the study were to:

(1) Obtain additional and more meaningful crash data by linking the University of Pennsylvania (UPenn) sleep apnea database to the FMCSA Motor Carrier Management Information System (MCMIS) crash database,

(2) Understand the impact of sleep apnea and driver impairment on crash involvement, the number of crashes, and the severity of crashes, and

(3) Gain insight into how crash rates are impacted before and after drivers are diagnosed with sleep apnea.

The study used a modeling approach to analyze specific data regarding truck drivers and sleep apnea. The hypothesis tested was that "A driver diagnosed with sleep apnea is more likely to be involved in a motor vehicle crash than a driver with no history or symptoms of sleep apnea, after controlling for differences in the other predictor variables included in the model." The data gained in this study did not support this hypothesis.

Study Design and Methodology

The overall goal of the study was to analyze crash risk due to sleep apnea in CMV drivers. The CMV drivers with sleep apnea were compared to CMV drivers who did not have sleep apnea, looking at the relative crash risks as a function of both the presence and the severity of sleep apnea. To accomplish these analyses, relevant variables from the UPenn sleep apnea database were linked with crash data from the MCMIS crash file, and a specific database was created. The data were analyzed using contingency tables, logistic regression, and a Poisson regression model.

University of Pennsylvania Sleep Apnea Study

From 1996 to 1998, the University of Pennsylvania Center for Sleep and Respiratory Neurobiology collected data for a study on the prevalence and consequences of obstructive sleep apnea among commercial vehicle drivers, and involved the overnight laboratory testing of 406 subjects. The three objectives of the study were to:

(1) Estimate the prevalence of sleep apnea among a sample of commercial truck drivers living in Pennsylvania within 50 miles of the University of Pennsylvania,

(2) Examine the relationship in commercial truck drivers between severity of sleep apnea and decreased function related to driving performance, and

(3) Develop a profile of an overall sample of commercial truck drivers with regard to their sleep apnea-related characteristics and risks.

The subjects were chosen after UPenn sent a multivariable apnea prediction questionnaire to a random sample of 4,826 commercial driver's license (CDL) holders residing in Pennsylvania. From the 1,391 responses that were returned, 406 drivers were selected to participate in the overnight laboratory study. The overall findings from this study revealed that 28 (6.9 percent) of the 406 participants were diagnosed with severe sleep apnea, 32 (7.9 percent) had moderate sleep apnea, 86 (21.2 percent) had mild sleep apnea, and 260 (64 percent) had none.

The results of the study showed that the prevalence rates of sleep apnea among commercial truck drivers are similar to sleep apnea rates found in other general populations. The study also revealed that the prevalence of sleep apnea depends on the relationship between two major factors—age and degree of obesity as measured by body mass index (BMI)—with the prevalence of sleep apnea increasing with increasing age and BMI. Another meaningful study finding showed that the prevalence of sleep apnea depends on the average duration of sleep over consecutive nights at home. Short sleep duration, six hours or less per night, results in an increase in the prevalence of sleep apnea.

Motor Carrier Management Information System (MCMIS) Crash Database

In order to analyze the relationship between sleep apnea and crash risk, researchers compared the sleep apnea information gained from the UPenn study with the crash risk history of each of the 406 commercial drivers who participated in that study. Crash histories for these drivers were obtained from state motor vehicle records for a period of seven years prior to diagnosis in the UPenn sleep study (1989 - 1996) and from the Motor Carrier Management Information System (MCMIS) crash database for a seven year period following diagnosis (1996 - 2003). The MCMIS database was selected as the source of crash data primarily because it is the only database which contains CDL information for each driver involved in a crash. This allowed researchers to link the crash data to the patient data for each of the 406 subjects who underwent in-laboratory testing during the UPenn sleep apnea study.

The MCMIS crash database contains a census of trucks and buses involved in fatal, injury, and tow-away crashes. It is maintained by FMCSA and contains data on trucks and buses in crashes that meet the uniform crash data standards developed through the National Governors Association (NGA). An NGA-reportable crash involves a truck (a vehicle that is designed, used, or maintained primarily for carrying property and has at least two axles and six tires) or a bus (a vehicle with a seating capacity of at least nine people, including the driver). The crash must result in either at least one fatality, at least one injury for which the injured person was taken to a medical facility for immediate medical attention, or at least one vehicle that was towed from the crash scene as a result of disabling crash damage. The crashes are reported by the individual states and transmitted to FMCSA through a microcomputer-based software system called SAFETYNET. While some states do not report all NGA-eligible crashes and the MCMIS crash file captures only approximately 60 percent of all NGA-reportable crashes per year, it was confirmed that Pennsylvania, the state in which the majority of crashes occurred involving the drivers used in this study, commonly reports about 96 percent of all truck crashes to MCMIS.

Study Database

After confirmation of databases to combine, data requirements were defined and a new database was created to support the analysis of crash risk due to sleep apnea in commercial drivers. This involved merging selected data elements collected by UPenn during the sleep apnea study with crash information contained in the MCMIS crash file. Some of the data elements collected using the UPenn study survey questionnaires included driver demographic information, medical histories, information about sleeping habits, and job-related driving data, including monthly/yearly miles driven, years of commercial driving experience, driving schedule, and types of vehicles driven. Data elements from the MCMIS crash file included the date and time of the crash, number of injuries and fatalities, and the state in which the crash occurred. These were just a few of the data elements combined to create the database to be analyzed regarding sleep apnea and crash risk.

Methods of Analysis

After choosing specific data elements to include in the database created for this study, the data were analyzed using three different methods. The first method was Contingency Table Analysis, a statistical method used for exploring multivariate but discrete data distributed into tables. In general, the rows of a contingency table represent alternate outcomes, and the columns denote exposure (or lack of exposure) to a treatment or risk factor.

The data were also analyzed using logistic regression, which is a mathematical modeling approach that can be used to describe the relationship of several independent or predictor variables to a binary or dichotomous dependent variable, such as crash or no crash. Logistic regression models identify factors that affect the likelihood of an outcome and can be used to predict the outcome of an event. Because the outcome of interest for this study is a heavy truck-related crash, logistic regression models were used to predict the occurrence of a crash event based on a set of predictor variables, which included such driver characteristics as the presence and severity of sleep apnea, age, gender, alcohol and drug use, and annual miles driven.

Finally, crash rates were normalized by the number of miles driven annually for each driver, and a Poisson regression model was estimated. Poisson regression analysis is a regression technique used for modeling dependent variables that describe discrete data. The methodology of Poisson regression analysis assumes that

the underlying distribution of the dependent variable under consideration is Poisson. The Poisson distribution is often used to model the occurrence of rare events, such as the number of motor vehicle crashes occurring either over time or as a function of the number of miles driven. Thus, Poisson regression is an appropriate statistical technique for analyzing crash rates.

Results

As mentioned previously, age and body mass index were the two major factors that are linked to the prevalence of sleep apnea. However, only age was found to be associated with both sleep apnea and the occurrence of crashes during the pre-diagnosis period. The mean age of subjects with some degree of sleep apnea was 48.7 years compared to an average age of 45.5 years for those who were not diagnosed with sleep apnea. On the other hand, while older drivers are at higher risk for sleep apnea, younger drivers with fewer years of commercial driving experience have an increased likelihood of motor vehicle crashes.

Looking at the seven year period following participation in the UPenn sleep study (1996 - 2003) in Table 1, crash involvement among sleep apnea patients was shown to be higher than in the comparison group—14.4 percent vs. 11.2 percent. But the chi-square statistic, used in this case to test an association between crashes and sleep apnea, was not significant ($p = 0.3$). The results for all crashes over the entire 14 year period can be similarly interpreted. Therefore, there is no statistical evidence in these data to suggest that the presence of sleep apnea significantly increases the likelihood or the risk of motor vehicle crashes.

Looking at the results in a logistic regression model, with odds ratios adjusted for potential confounding effects of various factors by including them as independent variables, the same results are revealed. Various factors included age, gender, alcohol use, body mass index, self-reported daytime sleepiness, presence or absence of high blood pressure, use or nonuse of medications causing drowsiness, unusual work/sleep schedule, and miles driven per year. The odds ratios included 95 percent confidence intervals, which indicated that the relationship between sleep apnea severity and motor vehicle crashes is not statistically significant. The null hypothesis being tested in the logistic regression analysis is that the two possible outcomes, crash or no crash, are equally likely (odds ratio = 1). Since the value of 1 is contained in every confidence interval at a 95 percent level of significance in this model, the null hypothesis of no association cannot be rejected, and, therefore, it was concluded that there is no statistical evidence in the data to suggest that drivers with sleep apnea are more likely than drivers without sleep apnea to have a commercial vehicle crash.

Count Column % Row %	Sleep Apnea	No Sleep Apnea	TOTAL
Crash	21 14.38 42.00	29 11.15 58.00	50
No Crash	125 85.62 35.11	231 88.85 64.89	356
TOTAL	146	260	406

Table 1. 2x2 Contingency Table: Presence of Sleep Apnea vs. Crash Involvement (Post-Diagnosis)

If the presence of sleep apnea in commercial drivers does not significantly influence the crash risk, the question arises as to whether the severity of sleep disturbances contributes to crashes. However, once again, the data lacked statistical evidence of a positive association between sleep apnea severity and post-diagnosis crash involvement, as indicated by an insignificant chi-square test ($p = 0.7$). Similar findings of no association of sleep apnea severity were obtained for pre-diagnosis crashes and all crashes, as well.

Next, the hypothesis that drivers with various degrees of sleep apnea had a greater likelihood of being involved in multiple crashes over the 14 year period was investigated. No association was found between sleep apnea presence or severity and multiple crashes. This suggests that the commercial drivers in this study who were diagnosed with sleep apnea were not at increased risk for having more than one crash over the 14 year period prior to and following diagnosis.

In the final logistic regression analysis, the relationship between sleep apnea severity and the severity of motor vehicle crashes was assessed. In this analysis, a significant relationship was found between severe sleep apnea and severe crashes (those which include multiple injuries and vehicle towed from accident scene). Drivers with severe sleep apnea were 4.6 times more likely to be involved in a severe crash in the seven year period than drivers with no sleep apnea. However, it was also found that drivers with severe sleep apnea were no more likely to involved in moderate/minor crashes than those without sleep apnea. Moreover, no statistically significant relationship was found between either moderate or mild sleep apnea and crash severity.

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A Poisson regression model was estimated to explore the impact of sleep apnea on crash rates, or crashes as a function of miles driven. The results indicated that none of the sleep apnea severity categories had a significant impact on whether or not a driver had a crash.

Conclusions

In summary, the presence and severity of obstructive sleep apnea among a population of 406 commercial truck drivers was analyzed as a risk factor for CMV crashes. Contingency tables and logistic regression models were developed to determine the likelihood of crash involvement, crash severity, and multiple crashes among commercial drivers before and after being diagnosed with sleep apnea. In addition, crashes were normalized by mileage driven, and Poisson regression models were developed to determine the effect of sleep apnea on crash rates. With the exception of a significant positive relationship between severe sleep apnea and severe crashes, results from this study showed that the presence and severity of sleep apnea in commercial truck drivers are not good predictors of motor vehicle crash involvement. In other words, no compelling statistical evidence was found that supports the hypothesis that sleep apnea increases crash risk among commercial drivers. Furthermore, there was no evidence from the data used in this study to suggest that crash risk is impacted before and after drivers are diagnosed with sleep apnea.

The results of this study contradict those found in several previous studies, which found a strong positive relationship between sleep apnea and motor vehicle crashes. While it appears that sleep apnea is not a risk factor for vehicular crashes among this sample of CMV drivers, the limitations of the data must be acknowledged, and these results must be interpreted with caution. For example, the data includes many confounding variables, which were based on self-reported information, and many drivers may have misinterpreted some survey questions. Incomplete crash and driving records add to the limitations of the study, as well. Finally, the large majority of subjects analyzed in this study were short-haul drivers who operated local routes, generally driving in dense urban environments requiring a higher level of alertness than long-haul truckers, who drive long stretches on interstate highways under monotonous driving conditions and who are more susceptible to fatigue and daytime sleepiness. These are just a few of the limitations of the data included this study.

Given the limitations in the data and the results of these analyses, some recommendations for future research are suggested. These include:

(1) Obtain complete and accurate crash records for every subject in the study population.

(2) To the extent possible, obtain prospective information regarding treatments advised and actually administered to the study subjects for the sleep disorders diagnosed during clinical testing. These data should include the recommended treatment, if any, and follow up on treatment receipt and effectiveness.

(3) Future studies should target long-haul commercial truck drivers who operate heavy tractor-trailer vehicles. In over-the-road highway driving, the longer distances and monotonous routine may contribute to drowsiness, and the higher speeds may increase the danger to drivers.

With these additions, a more reliable database can be created and a stronger case can be made from the results of a future study.

References

Pack, A.I., Dinges, D.F., and Maislin, G. *A Study of Prevalence of Sleep Apnea Among Commercial Truck Drivers.* Report No. DOT-RT-02-030. Federal Motor Carrier Safety Administration, U.S. Department of Transportation, May 2002.