Long Distance Driving and Self–Induced Sleep Deprivation among Automobile Drivers

Philip P.[1,2], Taillard J.[1], Guilleminault C.[2], Quera Salva M.A.[3], Bioulac B.[1], Ohayon M.[4]

[1]Clinique du Sommeil, Bordeaux, France; [2]Stanford University Sleep disorders Center, USA; [3]Laboratoire du Sommeil, Garches, France; [4]Institut de Recherche Pinel de Montreal, Canada

Objective: To evaluate the sleep hygiene and prevalence of sleep deprivation among a large sample of automobile drivers.
Design: From the 15th of June to the 4th of August 1996, with the help of the French highway patrol, we randomly stopped automobile drivers at the toll booths of Bordeaux and Biarritz. All subjects completed a validated questionnaire on sleep/wake habits during the year. After answering the questionnaire, subjects completed a graphic travel and sleep log of the three days preceding the interview.
Participants: We randomly stopped 2196 automobile drivers. Ninety–one percent of the sample (mean age 43 ± 13 years) agreed to participate in the survey.
Results: Fifty percent of the drivers decreased their total sleep time in the 24 hours before the interview compared with their regular self–reported sleep time. 12.5% presented a sleep debt >180 minutes, and 2.7% presented a sleep debt >300 minutes. Being young, commuting to work, driving long distances, starting the trip at night, being an "evening" person, being a long sleeper during the week, and sleeping in on the week–end were risk factors significantly associated with sleep debt.
Conclusion: The results of the study highlight variables (long–distance driving, youth, sleep restriction) that are frequently associated with sleep–related accidents.

INTRODUCTION

AUTOMOBILE ACCIDENTS ARE A MAJOR CAUSE of premature death in western societies.[1] Alcohol has been identified as a risk factor for these deadly crashes, but sleepiness, another risk factor, has been ignored for many years and has only recently been considered a significant risk factor. Twenty to thirty–one percent of automobile accidents[2] and fatal–to–the–driver truck crashes[3] have been attributed to drivers falling asleep at the wheel. Over the past few years, investigators have also demonstrated that sleep disorders, specifically obstructive sleep apnea syndrome and narcolepsy, may result in higher accident rates.[4,5,6,7] Treatment of these sleep disorders improves daytime alertness and performance.[8,9] Acute sleep restriction also leads to daytime sleepiness and may be a factor involved in automobile accidents.

Preliminary studies were conducted on one of the major freeways of Western Europe during the peak summer vacation season. Performed at busy rest stops, these studies indicated that sleep deprivation was common among vacationing drivers and was associated with sleepiness.[10,11] These findings are important in light of the report by Coren et al[12] that shows a significant relationship between sleep restriction and the rate of driving accidents. The prevalence of sleep–deprived automobile drivers on the road, however, is unknown.

A limitation of our earlier studies was that we interviewed drivers at a rest area, which could have led to a selection bias in favor of more "fatigued" drivers. We also only interviewed holiday drivers and eliminated work days from our study schedule.

To avoid the same shortcomings in this study, we randomly collected and surveyed a large sample of automobile drivers during peak driving periods on both weekdays and week–ends. We also chose a time period that began prior to the beginning of the vacation season (i.e. involving mostly commuting) and continued into the summer vacation season.

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Reprint requests: Dr. Pierre Philip, Clinique Du Sommeil, Hopital Pellegrin, Place Amelie Raba-Leon, F-33076 Bordeaux, FRANCE

Table 1

Hour of interview	Mean Sleep debt	SD
08:00-10:00	74.6	125
10:01-12:00	40.2	127
11:01-14:00	26.6	127
14:01-16:00	22.2	117
16:01-18:00	12.6	113
18:01-20:00	12.5	115

Hour of interview	Traffic mean	No. of cars selected	%
08:00-10:00	1687.9	237	14
10:01-12:00	2146.8	514	23.9
11:01-14:00	1627.6	339	20.8
14:01-16:00	1773.8	475	26.8
16:01-18:00	1770.9	446	25.1
18:01-20:00	1706.1	185	10.8

Hour of interview	Sleep debt ± SD	Mean Traffic	Mean no. of cars selected	%
08:00-10:00	74.6 ± 125	1687.9	237	14
10:01-12:00	40.2 ± 127	2146.8	514	23.9
11:01-14:00	26.6 ± 127	1627.6	339	20.8
14:01-16:00	22.2 ± 117	1773.8	475	26.8
16:01-18:00	12.6 ± 113	1770.9	446	25.1
18:01-20:00	12.5 ± 115	1706.1	185	10.8

table 1 : traffic on the freeway according to the hour of interview

METHOD

Location

The survey was co–ordinated with different highway authorities involved in the maintenance of safe driving, including the highway patrol. It was conducted from the 15th of June to the 4th of August 1996 at two toll booths located at Bordeaux and Biarritz on the French segment of the interstate highway that links Sweden and Morocco.

Subject selection

From 8:00 a.m. to 8:00 p.m., drivers who stopped at the toll booths when one of the interviewers was available were systematically approached by the highway patrol and asked to participate in the study. Interviewers always followed the same script. After introducing themselves, they explained the survey. Drivers were told that the study was independent of the highway patrol and that they could refuse to participate if they wished. If they agreed to participate, they were told that they would remain anonymous and that the survey would take no more than fifteen minutes.

Design

Each driver, with the help of the interviewers, filled out an 8–point scale evaluating overall daytime alertness, the Epworth sleepiness scale,[13] and a validated questionnaire exploring the usual sleep schedule of the drivers as well as the presence of sleep disorders.[14] This tool, the Basic nordic sleep questionnaire,[14] was validated by a group of epidemiologists in 1988 and has since been used in two different studies where it proved to be a valid tool.[15,16] In addition, a morning–evening type questionnaire[17] and three visual analog scales investigating fatigue, anxiety, and sleepiness at the time of the interview were included.

Once this part of the survey was over, subjects completed a sleep log covering the three days preceding the interview and a graphic travel log. These logs outlined the total driving time since departure and during the previous 24 hours, the number of stops, and their respective duration. They also outlined the total wake and sleep times during the previous 24 hours. A question on the travel log also evaluated the level of sleepiness at the wheel during the trip (from 0="never" to 5="near miss accident").

Data analysis

We looked at all our sleep variables including the onset of sleep during the week and weekends, the wake–up time during the week and weekends, the duration of naps during the day, and the ideal amount of sleep needed (in the absence of unusual social stressors).

Total wake time and total sleep time in the 24 hours just preceding the interview were calculated based on the sleep logs. We also calculated usual total sleep time (night sleep plus naps) during the year on week days and on weekends and what subjects considered to be the ideal amount of sleep they needed.

Statistical analysis

Calculations were performed with the SPSS statistical software package. Significance was considered when $p < 0.05$. Spearman coefficients were calculated first to evaluate relationship between factors; a stepwise multiple regression analysis was applied to investigate the relationship of the sleep debt to the other collected variables. Colinearity of variables was tested by the Belsey–Khu–Welsh test with Conditioning Index <15. The relationship between hour of driving and sleep debt was analysed by the Kruskal–Wallis test followed by a Mann Whitney U test (post hoc analysis).

RESULTS

Sample

Two thousand one hundred ninety–six (2,196) automobile drivers were randomly stopped by the highway patrol out of a total of 214,263 cars that went through the toll booths during the study. Hour by hour details are provided in table 1. Ninety–one percent of those stopped (n=2007; mean age 43 ± 13 years; 78.2% male) agreed to answer the survey. The 9% of subjects who did not participate did not differ significantly in sex, age (45±13 years vs. 42.7±13 years, p=0.02), BMI, socio–professional status, and horsepower of the car's engine.

Ten percent of the sample were between 16 and 25 years of age, 54% were between 26 and 50 years of age, and 36% were 51 years and older. Close to 20% (actually 18.8%) of the sample were single drivers; 31.3% were drivers with one adult passenger in the car; and the rest of the sample was composed of families with children or several adults.

Drivers on vacation represented 81.3% of the sample. There was, thus, a large under–representation of individuals driving to work (18.7%) reflecting the time of year selected for the study.

Driving variables

The mean driving distance was 377 ± 297 Km. One–third (33.8%) of the sample had driven more than 500 Km. The mean total duration of driving time was 230 ± 190 minutes, but 10% of drivers had driven more than 8 hours. The journey began between 2:00 a.m. and 6:00 a.m. for 14.6% of the subjects and between 8:00 p.m. and midnight for 2.3% of the subjects.

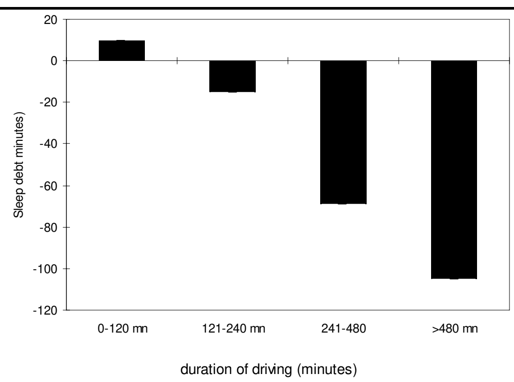

Figure 1 : Relationship between the sleep debt in the 24 hours before the interview and the duration of driving

Sleep duration during the 24 hours prior to the interview vs. the yearly regular sleep schedule

In the 24 hours prior to the interview, subjects slept a mean of 460 ± 115 minutes, but 4.4% of the sample acknowledged sleeping less than four hours and 10% less than five hours. The reported regular sleep duration during the year was 483 ± 69 minutes with 0.2% of subjects sleeping less than 4 hours and 1.3% less than five hours. Table 1 shows the sleep debt of our drivers at the time of the interview.

Our drivers declared they ideally needed a mean of 458 ±73 minutes of sleep per night. According to the questionnaires, however, they actually slept a mean of 490 ± 72 minutes during the week and 557 ± 90 minutes on the weekend.

We then looked at sleep duration three days prior (TST–3) to the interview, which could be considered as representative of a usual night's sleep. TST–3 correlated very strongly (Pearson correlation coefficient, Rho=0.426, p<0.001) with our calculation of usual total sleep time. TST–3 correlated less significantly with what subjects perceived to be their ideal sleep duration (Pearson correlation coefficient, Rho=0.207, p<0.001). We therefore chose to calculate the sleep debt or gain using the usual total sleep time of the subjects rather than their perceived ideal sleep duration. Sleep debt or gain was calculated by subtracting the usual total sleep time of the drivers over the previous year from the total sleep time in the 24 hours preceding the interview.

Fifty percent of the drivers had less sleep in the 24 hours prior to the interview than their reported mean regular sleep duration. 12.5% had a sleep debt >180 minutes, and 2.7% had a sleep debt >300 minutes.

Duration of driving and sleep debt

Figure 1 presents the strong relationship existing between the amount of time spent driving in the previous 24 hours and the magnitude of the sleep debt. Single occupancy (one driver alone in the car) was not a risk factor for sleep deprivation.

Self perception of fatigue and somnolence during the trip

Sleep deprivation was best correlated with sleepiness at the wheel (Pearson correlation, Rho=0.2, p<0.01). 5.6% of our sample declared that they had to stop because they could not drive anymore due to severe daytime somnolence and 0.2% of our sample reported to have been victim of a "near–miss accident" during this trip.

Sleep deprivation was also correlated with sleepiness, as reported on a visual analog scale during the interview (Pearson correlation, Rho=0.145, p<0.01), and fatigue, as reported on a visual analog scale during the interview

(Pearson correlation, Rho=0.138, p<0.01). At a lower level of significance (Pearson correlation, Rho=0.6, p<0.01), anxiety reported on a visual analog scale during the interview was also correlated to the sleep debt.

Sleepiness, as reported on a visual analog scale during the interview, was best correlated with fatigue, as reported on a visual analog scale during the interview (Pearson correlation, Rho=0.6, p<0.01).

Determinants of the sleep deprivation

The "sleep debt" was selected as the dependant variable in the stepwise multiple regression analysis. Overall 14 variables were introduced into the model. They were chosen for their possible effect on sleep debt: restorative function of sleep in the year preceding the interview; daytime sleepiness in the year preceding the interview; frequency of snoring; frequency of breathing pauses during sleep; frequency of nocturnal awakening; stability of sleep–wake schedule; morningness–eveningness; duration of driving (square root transformation); departure hour; discrepancy between total sleep time needed and total sleep time during week days; discrepancy between weekend and week day total sleep time; purpose of the travel (holiday or work); age and gender.

Results of evaluation of assumptions led to transformation of some variables to reduce skewness in their distributions and improve the normality, linearity and homoscedasticity of residuals. We made logarithmic transformations of frequency of breathing pauses during sleep and daytime sleepiness in the year preceding the interview. We performed a square root transformation on duration of driving. In all, seven factors were identified as possible determinants (as shown in Table 2). Table 2 displays the correlation between the variables, the unstandardized (B) and standardized (ß) regression coefficients, the R, R2, and adjusted R2. R for regression was significant ($F(7, 1990) = 118.45$, $p<0.0001$)

As can be seen in Table 2, the duration of driving was the most important determinant, followed by the discrepancy between total sleep time perceived as needed compared to total sleep time obtained on week days. This suggests that subjects who consider themselves to be "long sleepers" are more likely to decrease their total sleep time before their departure. Further down the list was the discrepancy between total sleep time on weekends compared to week days, which suggests that some degree of sleep deprivation during the year, on week days, is common. This also indicates that subjects who are not sleep–deprived during the year (no sleep rebound during the weekend nights) do not curtail their sleep duration before their departure, while chronically sleep–deprived subjects (sleep rebound during weekends) do increase this debt the night before their departure.

Not surprisingly, the time of departure was also a positive variable, with subjects who began their trip at night being more susceptible to sleep deprivation. Youth and being an "evening–type" person were also risk factors for sleep deprivation. Finally, having worked the day of the survey was a higher risk factor for sleep deprivation than being on vacation.

COMMENTS

We choose to interview subjects between 8:00 a.m. and 8:00 p.m., as this is the period of highest traffic volume on

Table 2: Stepwise regression of age, work, sleep and travel-related variables on sleep debt.

	Correlations								B [95% CI]	β
Variables	Debt	Age	Work	M-E	Driving	D1	D2	H Dep		
1) Age	-.03								-1.014 [-1.38 to -.64	-0.111**
2) Work	-.02	-.11							12.686 [.88 to 24.49]	0.041*
3) Morningness-Eveningness	.01	.36	-.04						-1.590 [-2.93 to -.25]	-0.048*
4) Duration of driving#	.34	.05	-.20	.06					7.389 [6.48 to 8.29]	0.344**
5) Discrepancy between total sleep time needed and total sleep time during week days	-.33[a]	-.21	.06	-.19	-.14				-0.338 [-.40 to -.28]	-0.239**
6) Discrepancy between week ends and week-days total sleep time (D2)	-.22[a]	-.14	-.04	-.12	.07	.37			-0.232 [-.28 to -.18]	-0.181**
7) Departure hour (H Dep)	-.28	-.08	.03	-.10	-.44	.12	-.01		-9.640 [-.001 to -.0006]	-0.122**
Means	29.73	42.77	1.19	16.2	13.04	-24.87	67.28	9:52		R^2=.29
S.D.	122.61	13.24	0.39	3.64	5.65	85.44	94.51	4:17		Adjusted R^2=0.29
										R=0.54

Square root transformation
* p<.05; ** p<.001
[a] A negative correlation between sleep debt and these variables means that a subject who was sleep deprived the night before departure had a little sleep debt during the previous year. Conversely, a subject who had an important sleep debt during the previous year had not a greater sleep debt the night prior to departure.

the highway. This allowed our limited investigation team to gather a large sample with almost no interruption of interviews. Selection of this time window may be responsible for an underestimation of the frequency of sleep–deprived car drivers, as we have no information on the drivers that passed through the toll booths during the night. Nevertheless, more than 18% of our subjects began their journey between 8:00 p.m. and 06:00 a.m. There is, thus, a substantial group of night drivers in our sample. Almost 15% (actually 14.6%) of drivers were on the road at the most dangerous period in terms of sleep–related accidents (2:00 a.m.–6:00 a.m.).

Our survey outlines risk factors that have been identified by others as factors involved in accidents related to sleepiness.[2,4,10,11] In our survey, driving a long distance is the most important risk factor for sleep deprivation. This is in agreement with the findings of Horne et al.[2] which show a higher prevalence of sleepiness–related accidents on highways, where the average driving distance is greater, than on local roads. Subjects who drive long distances need to maintain a high level of attention and alertness for long periods. They combine sleep deprivation, prior departure, and driving fatigue for long periods. Our sleep–deprived drivers complained of sleepiness at the wheel during the trip and a small percentage of them even admitted being involved in a near–miss accident related to sleepiness. We have shown in a previous study[11] that sleep–deprived drivers have very short sleep latencies when recorded during naps taken at rest areas, which leads us to believe that severe sleep restriction prior to departure can increase the risk of having a driving accident.

Young subjects often have sleep habits leading to greater sleep deprivation than older subjects, a fact that may play a role in their over–representation in the group of sleepiness–related driving accidents.

The "eveningness" of the subject is not usually mentioned in the risk profile of sleep–deprived drivers. Nevertheless these drivers tend to stay awake later at night and have a schedule that does not fit well with the professional and societal demand for early awakening that exists in western European countries. These conflicting demands can lead to sleep deprivation and may explain the sleep debt noted in the drivers with an "evening" typology.

Fifty percent of our randomly selected drivers had slept less than usual on the day of the study. Furthermore, 12.5% had an acute sleep debt of greater than three hours and 2.7% had a sleep debt greater than five hours. Although sleep deprivation does not necessarily lead to accidents, we know that, like alcohol intake, sleep deprivation impairs reaction time. Simple reaction time studies indicate that even with moderate sleep deprivation, the standard deviation of response time clearly increases, even if the mean response time does not vary much. This increase in standard deviation could be considered an index of what might manifest on the highway as erratic driving. Given that the speed limit on French highways is 140 km/h (87.5 mph) and that, according to our numbers, there was a mean of 30 cars passing by the same spot every minute, there is little room for erratic driving caused by a micro–sleep. The problem is compounded when we consider that subjects who had driven the longest distance, who suffered from added factors such as physical fatigue, were the ones with the greatest acute sleep deprivation.

Drivers implicitly accept that their fellow motorists are not going to behave erratically while driving at high speeds. Unfortunately, sleep–deprived drivers may be inclined to do just that, increasing the risk of accident not only for themselves but also for others. Better education about sleep needs and the negative effect of sleep restriction are needed early in life, possibly in driving school. Industrial medicine and work legislation in western–style societies should also consider the average commute time, a hidden cause of sleep deprivation.

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