

## THE SLEEP OF LONG-HAUL TRUCK DRIVERS

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**ABSTRACT**

**Background** Fatigue and sleep deprivation are important safety issues for long-haul truck drivers.

**Methods** We conducted round-the-clock electrophysiologic and performance monitoring of four groups of 20 male truck drivers who were carrying revenue-producing loads. We compared four driving schedules, two in the United States (five 10-hour trips of day driving beginning about the same time each day or of night driving beginning about 2 hours earlier each day) and two in Canada (four 13-hour trips of late-night-to-morning driving beginning at about the same time each evening or of afternoon-to-night driving beginning 1 hour later each day).

**Results** Drivers averaged 5.18 hours in bed per day and 4.78 hours of electrophysiologically verified sleep per day over the five-day study (range, 3.83 hours of sleep for those on the steady 13-hour night schedule to 5.38 hours of sleep for those on the steady 10-hour day schedule). These values compared with a mean ( $\pm$ SD) self-reported ideal amount of sleep of  $7.1 \pm 1$  hours a day. For 35 drivers (44 percent), naps augmented the sleep obtained by an average of  $0.45 \pm 0.31$  hour. No crashes or other vehicle mishaps occurred. Two drivers had undiagnosed sleep apnea, as detected by polysomnography. Two other drivers had one episode each of stage 1 sleep while driving, as detected by electroencephalography. Forty-five drivers (56 percent) had at least 1 six-minute interval of drowsiness while driving, as judged by analysis of video recordings of their faces; 1067 of the 1989 six-minute segments (54 percent) showing drowsy drivers involved just eight drivers.

**Conclusions** Long-haul truck drivers in this study obtained less sleep than is required for alertness on the job. The greatest vulnerability to sleep or sleep-like states is in the late night and early morning. (N Engl J Med 1997;337:755-61.)

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**E**ACH year, over 110,000 people are injured and more than 5000 are killed in the United States in motor vehicle accidents involving commercial trucks.<sup>1</sup> Estimates of the percentage of crashes that are partially or completely attributable to fatigue range from 1 to 56 percent, depending on the data base examined and the level of detail available from crash investigations.<sup>2,3</sup>

There is increasing public and regulatory interest in the health consequences of fatigue, sleep deprivation, disruption of circadian rhythms, and sleep disorders.<sup>4</sup> Driver fatigue was recently judged to be the number-one problem in commercial transportation.<sup>5</sup> In 1988, Congress directed the Federal Highway Administration to study driver fatigue and its implications with respect to federal regulations that limit daily and weekly driving times for commercial truckers. The study consisted of 24-hour electrophysiologic and performance monitoring of 80 truck drivers who carried revenue-producing loads (loads carried in the course of their employers' normal business) and who were working day, night, or irregular shifts on common North American routes. We report on the sleep and drowsiness data from that study.

**METHODS****Design of the Study**

Driving schedules that represented the most demanding operations permissible were selected from the U.S. and Canadian trucking industries. In both countries the longest time on duty per day (which includes the time spent driving plus all other time at work) for drivers is 15 hours, the shortest off-duty time is 8 hours, and the longest time on duty during a seven-day period is 60 hours. However, drivers can drive only a total of 10 hours without having 8 hours off in the United States and 13 hours without 8 hours off in Canada. We used a parallel-group design to compare four driving schedules, two in the United States and two in Canada. The design and the associated informed-consent form were reviewed and approved by the Federal Highway Ad-

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ministration of the U.S. Department of Transportation and by the Transportation Development Centre of Transport Canada. The trucking companies that contributed trucks and personnel asked not to be identified.

We studied two schedules for the route between St. Louis and Kansas City, Missouri: a "10-hour, steady day schedule" consisted of five trips beginning at 9 a.m. each day, and a "10-hour, advancing night schedule" consisted of five trips, with the first trip beginning at 9:30 a.m. and subsequent trips beginning 2 to 3 hours earlier on each of the following days. We studied two schedules for the route between Toronto and Montreal: a "13-hour, steady night schedule" consisted of four trips beginning at about 11 p.m. each evening, and a "13-hour, delaying evening schedule" consisted of four trips, with the first beginning at 11:30 a.m. and subsequent trips beginning 1 hour later each day. All four schedules involved trucks and drivers engaged in revenue-producing runs between these cities.

**Subjects**

The subjects were 80 male, licensed commercial drivers, 40 from the United States and 40 from Canada. Twenty were assigned to each schedule. The subjects were recruited through participating trucking companies. The drivers were told the purpose of the study and asked to participate. From among those who volunteered, drivers were selected so that the average age of the drivers on each schedule was similar. All drivers read and signed an informed-consent form that detailed the study procedures. All drivers followed their appointed routes and successfully completed the study. At any time, drivers were free to stop and rest or nap or to withdraw from the study. The drivers had no financial incentive or disincentive to take naps. There was a uniform pay scheme for all drivers, but individual rates of pay varied depending on such factors as seniority and geographic location. The drivers were also compensated for spending their principal sleep periods in our laboratories and for engaging in other study-related tasks.

Data were collected in the United States between June 14 and August 22, 1993, and in Canada between September 27 and December 3, 1993.

Each driver completed a questionnaire on demographic char-

acteristics and sleep habits.<sup>6</sup> The items on the questionnaire were similar to those of population-based surveys by the Gallup Organization<sup>7</sup> and the American Cancer Society.<sup>8</sup> Table 1 summarizes the drivers' schedules, demographic characteristics, and perceived need for sleep as reported on the questionnaire. The estimate of perceived need for sleep indicated that our sample was representative. Respondents in a Gallup survey of the general population of the United States were asked, "How many hours of sleep do you feel you need each night in order to remain alert during the daytime?" The mean ( $\pm$ SD) was  $7.2 \pm 1.2$  hours.<sup>7</sup>

The electroencephalogram and eye movements were recorded continuously, yielding over 7500 hours of data.<sup>9</sup> Each truck was equipped with an infrared video system that continuously recorded views of the driver's face and the road ahead and a computer that recorded the truck's speed and road position and allowed all data to be synchronized. The video recordings were sampled every half-hour, and various judgments were made, including whether the truck was moving and whether the driver appeared drowsy on the basis of drooping eyelids and a bobbing head.<sup>10</sup> The results were entered into a relational data base that permitted assessment of episodes in which a driver appeared drowsy while driving in terms of their frequency during the four schedules and their distribution over the day and night.

**Polysomnography during Principal Sleep Periods**

Each driver determined his own bedtimes and awakening times according to his driving schedule. The principal period of sleep was defined as the longest period of sleep in a 24-hour period. Drivers slept in rooms near their travel routes. During sleep tin electrodes (Oxford Instruments, Abingdon, United Kingdom) were used for central and occipital electroencephalography, assessment of the movements of both eyes, and electromyography of the chin, for polysomnographic scoring.<sup>11</sup> Respiratory air flow and effort were also monitored and pulse oximetry was performed. The instruments were hooked up 60 to 90 minutes before the first period of sleep. Bad leads were replaced and respiratory sensors reapplied as needed.

Polysomnographic data were gathered on Oxford Medilog 9000-II recorders<sup>12</sup> and subsequently stored on optical disks. Oxi-

**TABLE 1. DRIVING SCHEDULES AND CHARACTERISTICS OF 80 LONG-HAUL TRUCK DRIVERS.\***

DRIVING SCHEDULE	DESCRIPTION OF SCHEDULE	NO. OF DRIVERS	AGE	HEIGHT	WEIGHT	BODY-MASS INDEX†	PERCEIVED AMOUNT OF SLEEP NEEDED‡
			yr	cm	kg		hr
Steady day	10 hours of driving beginning at about the same time each morning (9 a.m.) for 5 trips	20	49 $\pm$ 8	179 $\pm$ 5	94 $\pm$ 13	29.2 $\pm$ 3	7.0 $\pm$ 1
Advancing night	10 hours of driving beginning at 9:30 a.m. on day 1 and 2 to 3 hours earlier on each subsequent day for 5 trips	20	44 $\pm$ 11	181 $\pm$ 5	99 $\pm$ 22	30.0 $\pm$ 6	7.0 $\pm$ 1
Steady night	13 hours of driving beginning at about the same time each evening (11 p.m.) for 4 trips	20	40 $\pm$ 11	180 $\pm$ 8	92 $\pm$ 16	28.6 $\pm$ 6	6.9 $\pm$ 1
Delaying evening	13 hours of driving beginning at 11:30 a.m. on day 1 and 1 hour later on each subsequent day for 4 trips	20	38 $\pm$ 7	179 $\pm$ 8	89 $\pm$ 14	27.9 $\pm$ 4	7.8 $\pm$ 1
All schedules		80	43 $\pm$ 10	180 $\pm$ 5	94 $\pm$ 17	28.9 $\pm$ 5	7.1 $\pm$ 1

\*Plus-minus values are means  $\pm$ SD.

†The body-mass index is calculated as the weight in kilograms divided by the square of the height in meters.

‡Drivers were asked to respond to the following: "My ideal amount of sleep is X hours."

metric measurements were processed by Profox software<sup>13</sup> and then transferred to optical disks. The data obtained during principal sleep periods were scored on an Oxford 9200 system by experienced technologists using 30-second segments.<sup>11</sup> For the sleep variables that we measured, the reliability of scoring and rescored has previously been shown to exceed 0.90 for individual trained technologists and 0.80 between technologists.<sup>14</sup> We ensured that scoring would be consistent by rescored randomly selected records, having regular staff meetings, and reviewing the data. Although this study was not designed to measure the prevalence of sleep-disordered breathing in commercial drivers, we could identify sleep apnea by the presence of rapid, repeated periods of desaturation (a drop of more than 4 percent in the oxygen saturation value that lasted less than three minutes) on oximetry and scoring polysomnographic records using clinical criteria.<sup>15,16</sup>

**Electrophysiologic Recording during Driving**

After the principal periods of sleep, respiratory sensors were disconnected from the drivers and the remaining leads were checked. Scorers were unaware of the drivers' activity or truck speed and, for finer temporal resolution, used 20-second scoring periods during hours in which drivers were supposed to be awake.<sup>11</sup>

**Statistical Analysis**

We examined the frequency distribution of the duration of sleep across all drivers and found that the homogeneity-of-variance assumption was tenable and that the distribution appeared unimodal and nonskewed. Univariate, repeated-measures analysis of variance<sup>17</sup> was our basic analytic tool. All reported P values are two-tailed.

**RESULTS**

The 80 drivers had a total of 400 principal sleep periods (5 for each driver), 200 10-hour trips, and 160 13-hour trips. Over 96 percent of all data points from the principal sleep periods were collected. Our software required all data points, so missing data were replaced with means for the driver in question. The results of analyses of variance that replaced missing data with the grand means rather than means for the subject were similar.

**Work and Rest Schedules**

The drivers were given only general guidance about when they could rest during their schedules. However, we knew, from model patterns of work and rest, that it was possible to have eight hours off duty on any of the four schedules on most days. We estimated the lengths of time off during all 280 intervals between trips from the departure and return times of the trucks recorded by on-board computers or from our technicians' notes. There were 33 intervals (12 percent) during which the drivers had less than 8 hours off duty (average time available, 7.4 hours), when they were not involved in job- or study-related matters (10 on the advancing night schedule, 12 on the steady night schedule, and 11 on the delaying evening schedule).

**Sleep**

The amount of sleep a subject could have was defined by the amount of time spent in bed plus the opportunity for napping. The average length of time

spent in bed during principal sleep periods and the number of naps taken are shown in Table 2. Among all drivers, the average time spent in bed was 5.18 hours. There was a significant difference (P<0.001) between schedules, with the shortest times in bed occurring on the steady night schedule and the longest times on the steady day schedule. The younger drivers (average age, 36 years) spent more time in bed (5.34 vs. 5.03 hours, P=0.02) than the older drivers (average age, 50 years).

The periods of sleep latency (the length of time between turning off the lights and falling asleep) were 19.3 minutes for drivers on the steady day schedule, 12.9 minutes for drivers on the advancing night schedule, 7.4 minutes for drivers on the steady night schedule, and 14.8 minutes for drivers on the delaying evening schedule. The difference between the groups was significant (P<0.001). The overall average period of sleep latency was 13.6 minutes.

The drivers slept for an average of 4.78 hours, or about 2 hours less than their reported average ideal sleep (Table 1). Table 3 shows the duration of sleep according to the four driving schedules and the five principal periods of sleep. There was a significant ef-

**TABLE 2.** THE AVERAGE TIME SPENT IN BED AND THE TOTAL NUMBER OF NAPS TAKEN DURING THE STUDY, ACCORDING TO THE AGE AND SCHEDULE OF THE DRIVERS.\*

DRIVING SCHEDULE	YOUNGER DRIVERS	OLDER DRIVERS	ALL DRIVERS
All schedules			
Average time in bed (hr)	5.34	5.03†	5.18
No. of drivers	40	40	80
Age (yr)	36±7	50±7	43±10
No. of naps	32	31	63
Steady day			
Average time in bed (hr)	5.95	5.61	5.78‡
No. of drivers	10	10	20
Age (yr)	43±5	55±4	49±8
No. of naps	10	3	13
Advancing night			
Average time in bed (hr)	5.27	4.93	5.10‡
No. of drivers	10	10	20
Age (yr)	34±6	53±5	44±11
No. of naps	3	10	13
Steady night			
Average time in bed (hr)	4.58	4.16	4.37‡
No. of drivers	10	10	20
Age (yr)	32±6	49±7	40±11
No. of naps	11	11	22
Delaying evening			
Average time in bed (hr)	5.55	5.40	5.47‡
No. of drivers	10	10	20
Age (yr)	33±4	43±5	38±7
No. of naps	8	7	15

\*Plus-minus values are means ±SD. A nap was defined as an episode of sleep outside the principal sleep period that could be scored with the use of electrographic criteria. The average age of the younger drivers was 36 years, and the average age of the older drivers was 50 years.

†P=0.02 for the difference between age groups.

‡P<0.001 for the difference with the other driving schedules, by analysis of variance.

**TABLE 3.** AVERAGE DURATION OF SLEEP DURING THE FIVE PRINCIPAL SLEEP PERIODS, ACCORDING TO THE DRIVING SCHEDULE.\*

DRIVING SCHEDULE	PERIOD OF SLEEP					OVERALL AVERAGE
	1	2	3	4	5	
	hours of sleep					
Steady day	5.37	5.13	5.64	5.37	5.41	5.38
Advancing night	6.36	4.54	4.73	4.35	3.85	4.76
Steady night	3.22	3.88	4.41	4.28	3.38	3.83
Delaying evening	6.73	4.75	4.71	5.16	4.27	5.12
Overall average	5.42	4.57	4.87	4.79	4.23	4.78

\*There was a significant difference among driving schedules ( $P < 0.001$  by analysis of variance). The interaction between driving schedule and period of sleep was also significant ( $P < 0.001$ ).

fect of schedule on the duration of sleep ( $P < 0.001$ ), with the longest average durations (5.38 hours) on the steady day schedule and the shortest (3.83 hours) on the steady night schedule. The period of sleep also had a significant effect ( $P < 0.001$ ): the longest and the shortest sleep durations occurred in first sleep periods. There also was a significant interaction between schedule and sleep period ( $P < 0.001$ ). Although several interpretations are possible, the simplest is that the durations of sleep in periods 2 to 5 are typical of the various schedules, whereas the durations of sleep in period 1 vary because drivers were coming back to work after being off duty for at least 24 hours. The younger drivers slept for an average of 4.94 hours per principal sleep period, as compared with 4.61 hours for older drivers. Although significant ( $P = 0.02$ ), this difference was small and is attributable to the fact that younger drivers spent 0.32 more hours in bed per principal sleep period than older drivers.

Sleep efficiency (the ratio of the time asleep to the time spent in bed) exceeded 0.9 for all schedules. Sleep efficiency as well as other measures sensitive to sleep disturbance, such as the number of awakenings during the sleep period, indicated that sleep during principal periods was well consolidated (data not shown).

### Naps

A nap was defined as an episode of sleep outside the principal sleep period that could be scored with the use of electrographic criteria. Drivers took 0 to 3 naps per day for a total of 63 naps (Table 2). Neither age nor schedule was predictive of the number of naps.<sup>18</sup>

Thirty-five drivers took at least one nap. Naps increased the total amount of sleep obtained by an average of  $0.45 \pm 0.31$  hour (range, 0 to 1.63 hours), or 11 percent.

### Respiration during Sleep

Pulse oximetry disclosed repeated periods of desaturation in two drivers, who were 49 and 55 years of age. Both were on the steady day schedule. Polysomnography revealed that both drivers had sleep apnea, with 10 to 30 respiratory events per hour. However, the sleep data for these drivers were not substantially different from those of the other drivers.

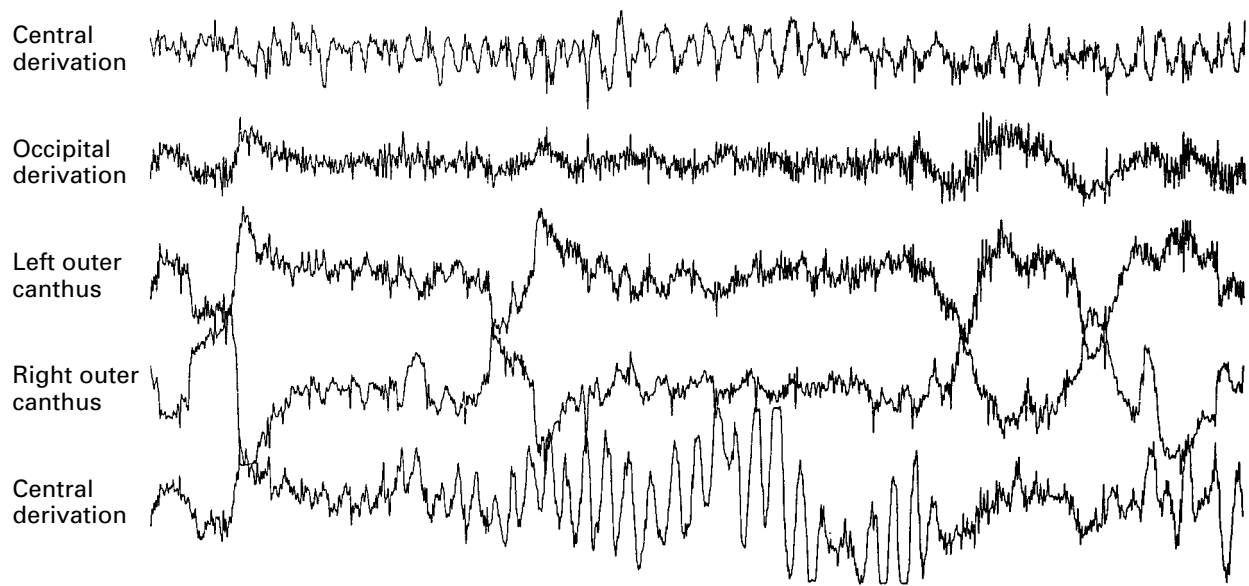
### Drowsiness or Sleep among On-Duty Drivers

To assess the frequency of drowsiness or sleep among drivers while they were driving, we focused on the times when the trucks were traveling faster than 72 km per hour (45 miles per hour), according to computer records. Using the same scoring criteria applied to the principal sleep periods,<sup>11</sup> we identified one trip by a 30-year-old driver and one trip by a 25-year-old driver involving a total of seven episodes with electrographic features of drowsiness, such as slow, rolling eye movements and electroencephalographic alpha activity. These episodes qualified as stage 1 sleep.<sup>11</sup> Stage 1 sleep, the lightest stage of non-rapid-eye-movement sleep, is characterized by a relatively low voltage, mixed-frequency electroencephalogram with prominent activity in the range of 2 to 7 Hz. There were other episodes of electroencephalographic slowing and slow, rolling eye movements of insufficient duration to be scored as stage 1 sleep.

The 30-year-old driver, who was on the steady night schedule, had five episodes of stage 1 sleep between 11:12 p.m. and 11:53 p.m. (duration, 20 to 520 seconds) during his first trip. The subject had been driving for 10 hours and 15 minutes when the first episode occurred. The 25-year-old driver, who was on the delaying evening schedule, had two stage 1 episodes at 2:24 a.m. (Fig. 1) and 4:38 a.m. (duration, 60 and 80 seconds, respectively) during his fourth trip after 9 hours off duty. The subject had been driving for 2 hours and 3 minutes when the first episode occurred. Neither driver showed evidence of sleep apnea.

Of the total of 29,310 six-minute video recordings of the drivers' faces that we analyzed, 1989 of the segments (7 percent) were judged to show a drowsy driver. Forty-five of the 80 drivers (56 percent) were judged to be drowsy in at least one segment, but 1067 of the 1989 segments (54 percent) showing drowsy drivers involved just 8 drivers. Five of these drivers were on the steady night schedule, two were on the delaying evening schedule, and one was on the advancing night schedule.

Table 4 shows the number of segments in which drivers were judged to be drowsy according to the driving schedule and time of day. Of the 1989 segments in which the driver was judged to be drowsy, 1646 (83 percent) occurred between 7 p.m. and 6:59 a.m. The average number of consecutive



**Figure 1.** Electrographic Data Showing Sleep-Like Patterns in a 25-Year-Old Driver on the Delaying Evening Driving Schedule. This 20-second segment, recorded while the subject was driving, began at 2:24 a.m. There are slow, rolling eye movements (the large curves on the eye-movement tracings), a high level of alpha activity throughout the occipital tracing, and large peaks and troughs in the middle section of the central tracings, which are known as paroxysmal hypnagogic hypersynchrony.<sup>16</sup>

**TABLE 4.** SIX-MINUTE SEGMENTS OF VIDEO RECORDINGS JUDGED TO SHOW A DROWSY DRIVER, ACCORDING TO THE TIME OF DAY AND DRIVING SCHEDULE.\*

DRIVING SCHEDULE	7 A.M. TO 6:59 P.M.		7 P.M TO 6:59 A.M.		TOTAL	
	NO. OF SEGMENTS	PERCENT	NO. OF SEGMENTS	PERCENT	NO. OF SEGMENTS	PERCENT
All schedules						
Drowsy driver	343	2.19	1,646	12.06	1,989	6.79
Total	15,660		13,650		29,310	
Steady day						
Drowsy driver	53	1.07	47	2.63	100	1.49
Total	4,940		1,785		6,725	
Advancing night						
Drowsy driver	91	2.08	222	8.04	313	4.38
Total	4,385		2,760		7,145	
Steady night						
Drowsy driver	151	4.79	739	16.37	890	11.61
Total	3,150		4,515		7,665	
Delaying evening						
Drowsy driver	48	1.51	638	13.90	686	8.82
Total	3,185		4,590		7,775	

\*The total number of six-minute segments of driving for each entry in the table was used as a denominator. Since the video recordings were sampled every 30 minutes, we estimated the required number by counting, for each entry in the table, the number of these 30-minute sampling periods that occurred while the truck was moving at a normal speed (as opposed to being parked or stopped) and multiplying this number by 5, since 30 minutes equals five 6-minute segments. According to these calculations, there were 29,310 six-minute segments during which a driver could have been judged to be drowsy while driving.

segments in which the driver was judged to be drowsy was 6.44 (range, 1 to 37; mode, 1; median, 4). The driver on the delaying evening schedule whose electroencephalograms showed stage 1 sleep while driving had video records in which he was judged to be drowsy at or near the time when stage 1 was recorded. The other driver in whom stage 1 sleep was recorded did not have any corresponding video records in which he was judged to be drowsy.

### DISCUSSION

Round-the-clock electrographic data were collected for four parallel groups of 20 long-haul truck drivers who were working 10-hour driving schedules in the United States or 13-hour schedules in Canada. Two of the 80 drivers had sleep apnea detected on the basis of polysomnographic criteria. Drivers averaged 5.18 hours in bed and 4.78 hours of sleep per day. This amount of sleep was about two hours less than their reported ideal.

One limitation of our study was that the drivers' estimates of their ideal amount of sleep were obtained from questionnaires rather than recordings of the men's sleep when they were not at work. However, only 19.3 percent of a representative sample of men reported sleeping less than five hours a night.<sup>7</sup> The sleep durations we did observe were much shorter (4.78 hours) than most standards. Sleep-restriction experiments show that a person's tendency to fall asleep during normal waking hours increases if he or she has slept less than six hours and also increases with successive days of restricted sleep.<sup>19,20</sup> Psychomotor performance is impaired if sleep is limited to five hours for two or more consecutive nights.<sup>19,21</sup> It is also known that getting fewer hours of sleep leads to inattention and increased error rates and that little sleep and circadian influences act synergistically.<sup>22</sup> Night driving after relatively little sleep is a better predictor of fatigue-related accidents than is night driving alone.<sup>23</sup> An analysis of accidents involving commercial trucks found that drivers in fatigue-related accidents had slept an average of 5.5 hours during their last sleep period, as compared with 8.0 hours of sleep for drivers in non-fatigue-related accidents.<sup>23</sup>

Another limitation of our study is related to sample size. Since we used a parallel-groups design, each driver could not be studied on all schedules. Nevertheless, the demographic characteristics and ideal sleep times reported by the drivers indicated that the four groups were comparable. The short times spent in bed, found in all schedules, are disturbing and are attributable in part to driver choice. Our study required no more than 50 to 60 minutes of the drivers' time per day, and over 88 percent of all intervals between trips still allowed an opportunity for 8 hours off duty. Possible reasons for such short times in bed include duty-related demands, involve-

ment in social activities, and time-of-day effects, which reduce one's inclination to go to bed during daylight.

The short durations of sleep — the inevitable result of short times in bed — probably explain the findings suggesting that the drivers got too little sleep. We found high rates of sleep efficiency (the ratio of the time asleep to the time spent in bed), an observation that is consistently reported in sleep-restriction studies<sup>24</sup> and indicates an increased tendency to sleep. Thirty-five of the 80 drivers took naps, which averaged 0.45 hour and augmented the amount of sleep obtained by 11 percent. Two drivers had episodes of stage 1 sleep while driving.

O'Hanlon and Kelley also found sleep-like patterns in electroencephalograms of subjects who were driving.<sup>25</sup> In our study, the episodes of stage 1 sleep occurred while the subjects were driving between 11 p.m. and 5 a.m., suggesting a circadian influence. The observed nighttime increase in drowsiness, as assessed by analysis of video recordings of the drivers' faces, was consistent with the expected effects of circadian influences, decreased stimuli during night driving, and too little sleep.

On the basis of available rates of accidents severe enough to be reported to the Department of Transportation,<sup>1,26</sup> and making no adjustments for roads and schedules, one would expect one accident involving a combination truck (a tractor pulling one or more trailers) about every 1.9 million km (1.2 million miles). During this study the trucks involved were driven about 327,000 km (204,000 miles). Thus, we did not expect an accident, and in fact, none occurred. Since no episode of sleep-like electroencephalographic patterns was associated with a crash, the drivers were probably drowsy during these episodes but not actually asleep. During normal sleep, there is marked unresponsiveness to stimuli<sup>27</sup> that would preclude safe driving. Thus, it may not be correct to use standard sleep-scoring criteria for records obtained when the subject is behaviorally active as opposed to lying in bed.<sup>28</sup>

Truck drivers in the study obtained less sleep than is required for alertness on the job and the greatest vulnerability to unwanted sleep or sleep-like states was during the late night and early morning, a finding that is consistent with published data on other industries.<sup>29</sup> Other studies have shown a smaller midafternoon period of vulnerability to unwanted sleep.<sup>30,31</sup> We may have missed detecting such a period because there was considerable irregularity in the times that drivers were on duty and there were only 20 drivers on any one schedule.

Since physicians are a primary source of information about fitness for duty and its relation to sleep, they should be alert to the possibility of sleep deprivation in people who engage in shift work. It is also important to recognize the deleterious synergistic ef-

fects on alertness of alcohol and other sedatives in the presence of sleep deprivation or medical conditions known to increase the tendency to fall asleep, such as sleep apnea.<sup>32-34</sup> Our findings underscore the need to educate workers and schedulers about the importance of adequate sleep with respect to public safety.

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## CORRECTION

## The Sleep of Long-Haul Truck Drivers

*To the Editor:* The article by Mitler et al. on the sleep of long-haul truck drivers (Sept. 11 issue)<sup>1</sup> presents data on drowsiness. The authors state, "Of the total of 29,310 six-minute video recordings of the drivers' faces that we analyzed, 1989 of the segments (7 percent) were judged to show a drowsy driver." However, according to a footnote to Table 4, it appears that the numerator for this percentage is derived from the sampled segments (consisting of one 6-minute segment per 30 minutes of observation time) and the denominator is the universe of segments from which the sample was drawn. With the use of standard methods of statistical inference from samples,<sup>2</sup> the correct calculation should have been the number of sampled segments in which a driver was seen as drowsy divided by the number of sampled segments reviewed. With this calculation, 34 percent of sampled segments included drivers who were judged to be drowsy during at least part of the segments, with corresponding increases in other categories of driving schedule and time of day. Therefore, segments involving drowsiness occurred more than four times as often as reported.

The study has additional weaknesses that limit the conclusions that can be drawn. Volunteer drivers were neither randomly assigned to the four driving-schedule groups nor rotated through each group. Thus, the drivers were not necessarily comparable. For example, the mean ages of the two Canadian driver groups were significantly lower than those of the U.S. "steady-day" group, on the basis of 95 percent confidence intervals for the means,<sup>2</sup> notwithstanding the authors' statement that "drivers were selected so that the average age of the drivers on each schedule was similar." Another shortcoming is that the observers who rated the video recordings of the drivers' faces for drowsiness were aware of the time of day and ambient light level for each segment. If the observers expected that the drivers would be drowsier at night, they may have been more likely to consider the drivers drowsy on video recordings made at night. Although the investigators report measures taken to ensure consistent scoring of polysomnographic data, including the rescoring of randomly selected records, they report no similar reevaluations of randomly selected video segments.

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2. Snedecor GW, Cochran WG. *Statistical methods*. 7th ed. Ames: Iowa State University Press, 1980.

*To the Editor:* The ambitious report on the sleep patterns of long-haul truck drivers acknowledges only the funds received from the Federal Highway Administration ("Supported by contracts [DTFH61-89-C-096 to Essex Corporation and DTFH61-90-C-053 to the Trucking Research Institute]") and subcontracts to the Scripps Clinic.

The acknowledgment does not mention that funds were also contributed by the American Trucking Associations' Trucking Research Institute. In 1992, the American Trucking Associations Foundation announced its intention "to raise \$476,000 to fund its share of the project."<sup>1</sup> The Federal Highway Administration's briefing package for the study stated that the Trucking Research Institute "is funding part of the data collection and analysis."<sup>2</sup> Support from the Trucking Research Institute is noted in the Federal Highway Administration's report describing the same study.<sup>3</sup>

The Trucking Research Institute is a research affiliate of the American Trucking Associations Foundation, a nonprofit arm of the American Trucking Associations, which is a trade association for the trucking industry. Failure to acknowledge the support of the Trucking Research Institute is especially troubling because the Federal Highway Administration is in the process of revising its rules that limit driving hours for interstate truck drivers and has described this study as providing "a technically sound basis for evaluating the current hours-of-service requirements for commercial motor vehicle operators."<sup>4</sup>

The trucking industry has a financial interest in any changes in work-hour limits (some American Trucking Associations affiliates have called for lengthening the permissible driving period from 10 hours to 14 hours) and clearly has a financial interest in this study. Table 4 of the article shows that drivers on 13-hour schedules had more than twice as many video-recorded episodes of drowsiness (identified on the basis of drooping eyelids and a bobbing head) as drivers on 10-hour schedules.

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2. Driver fatigue and alertness study briefing package. Washington, D.C.: Federal Highway Administration, December 1990.
3. Wylie CD, Shultz T, Miller JC, Mitler MM, Mackie RR. Commercial motor vehicle driver fatigue and alertness study: project report. Washington, D.C.: Federal Highway Administration, 1996. (Report no. FHWA-MC-97-002.)

4. Federal Highway Administration. Hours of service of drivers. Fed Regist 1996;61:57252-57266.

*To the Editor:* The analysis by Mittler et al. failed to emphasize the impact of fatigue on fatal truck crashes. Their study suggests that most of the drivers were sleeping less than five hours per night. In 1996, in the United States, more than 44,000 persons died and 2.3 million were injured from car crashes. Despite the fact that trucks account for less than 4 percent of the vehicle fleet, nearly 18 percent of the deaths resulted from truck crashes.

Several lines of evidence point to inadequate sleep as a major culprit in truck crashes. A survey of tractor-trailers in four states indicated that 10 to 23 percent of drivers had fallen asleep while driving in the previous month.<sup>1</sup> The National Highway Traffic Safety Administration (NHTSA) cited drowsiness and fatigue as factors in 15 percent of single fatal truck crashes and estimated that in 1990, 31 percent of 182 large-vehicle crashes that were fatal to the drivers were attributable to the drivers' fatigue.<sup>2</sup>

Large mass, very high mileage, and long operational life mean that tractor-trailer trucks, in particular, have the highest involvement in fatal crashes, despite an overall low risk of total crashes per miles traveled. When speed limits were raised from 90 to 100 km per hour (56 to 63 mph) in Israel, deaths from truck crashes increased by 60 percent, contributing to 40 percent of the additional road toll.<sup>3</sup> A recent NHTSA study found that 67 percent of drivers with irregular schedules had been involved in fatigue-related crashes, as compared with 38 percent of drivers with regular schedules. The most important predictive factor in a fatal crash was the duration of the driver's most recent sleep period and the total hours slept.<sup>4</sup>

It is time to enforce reduced speed limits for trucks and mandatory rest periods for truck drivers, particularly at night. Eliminating incentive premiums and providing higher salaries and reasonable work conditions are essential steps in reducing fatigue-related fatal truck crashes.

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3. Barach P. Impact of raising the speed limits on interurban highways on accidents, deaths and injuries in Israel. (Master's thesis. Jerusalem: Hebrew University, 1996.)

4. National Transportation Safety Board. Factors that affect fatigue in heavy truck accidents. Vol. 1. Washington, D.C.: National Transportation Safety Board, 1995. (Safety study NTSB/SS-95-01.)

*To the Editor:* While driving, 56 percent of the truck drivers showed evidence of drowsiness on video recordings, and 2 of the 80 drivers had one episode each of stage 1 sleep, as detected by electroencephalography. I cannot help but wonder how high these numbers would have been had the study been conducted with interns, residents, and fellows instead of truck drivers.

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*To the Editor:* Could there be a connection between the "near absence" of teaching about sleep in America's medical schools, noted by Dement in his editorial,<sup>1</sup> and the observation that physicians and medical trainees continue to work extended shifts, sometimes lasting 36 or more consecutive hours? Despite recent regulations, many physicians consistently work while fatigued. If sleep deprivation is deemed dangerous for truckers, there should be similar concern about those who are entrusted with the care of patients who are seriously ill.<sup>2</sup>

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#### References

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2. Green MJ. What (if anything) is wrong with residency overwork? Ann Intern Med 1995;123:512-517.

The authors reply:

*To the Editor:* We thank Braver and Pantula for the opportunity to clarify the formula we used to compute episodes of drowsiness as evaluated on the video recordings of the drivers' faces. It appears that the numerator was based on 6-minute samples every half-hour because the following sentence was omitted: "When drowsiness was noted, the video was viewed from 30 minutes before to 30 minutes after the initially detected episode, and scored as 10 6-minute epochs."

This procedure allowed us to investigate the duration of episodes of drowsiness and ultimately resulted in 1989 six-minute segments judged as showing drowsy drivers. The procedure also resulted in the viewing of most of the video recording, which is why the denominator is the universe of segments from which the 1989 observations of drowsiness were drawn. The resulting percentage was expected to be a slight underestimate, because it was unlikely that all the segments showing drowsiness were identified. With the overall unbiased estimator, based on the every-half-hour samples, the result was 8.1 percent (476/5862); the reported 6.8 percent (1989/29,310), which was based on the six-minute segments, was 1.3 percentage points lower. With this method, there were enough observations to permit the detailed breakdown of the data according to time of day and driving schedule, as shown in Table 4 of our article.

In reply to Baker: we did not acknowledge a number of important organizations that were helpful to our project, including the American Trucking Associations, Transport Canada, the Canadian Trucking Association, the Teamsters Union, and local drivers' organizations. We did not mean to obscure their involvement in the project. However, our direct financial support came from the cited contracts, including one with the Trucking Research Institute, which is, as Baker points out, affiliated with the American Trucking Associations. Through contract number DTFH61-90-C-053, which governed operations among the Federal Highway Administration, Trucking Research Institute, Essex Corporation, and Scripps Clinic, the Trucking Research Institute contributed about \$240,000 under a cost-sharing agreement with the Federal Highway Administration. This accounted for about 5 percent of the total cost of the study, which was \$4.45 million.<sup>1</sup>

With respect to Baker's observation that Table 4 of our article shows that drivers on 13-hour schedules had more than twice as many video-recorded episodes of drowsiness as drivers on 10-hour schedules, this table also shows (in the denominators) that drivers on 13-hour schedules had twice as much night driving as drivers on 10-hour schedules. It is not evident which is more important: time of day or time on the job. However, we addressed this question using additional statistical analyses (nonparametric methods, graphic analysis, mathematical modeling, and canonical correlation). We found that the prevalence of drowsiness was strongly related to the time of day but not significantly related to the number of hours spent on the job.<sup>1</sup>

We thank Barach and colleagues for their comments. There are indeed many sources of evidence that justify studying the extent of, and ways to reduce, fatigue in truck drivers.

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