INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

March 10, 2005

The Honorable Annette M. Sandberg
Administrator
Federal Motor Carrier Safety Administration
400 Seventh Street S.W.
Nassif Building, Room PL - 401
Washington, D.C. 20590-0001

Hours of Service of Drivers
Notice of Proposed Rulemaking (NPRM)
Docket No. FMCSA-2004-19608; formerly FMCSA-1997-2350

Dear Ms. Sandberg:

The Federal Motor Carrier Safety Administration (FMCSA) has requested information on the effects of the new hours-of-service rule in effect since January 1, 2004, including the effects on driver fatigue and safety. With this letter, the Insurance Institute for Highway Safety (IIHS) is submitting the results of a new survey of truck drivers in two states, Oregon and Pennsylvania. The results document that under the new rule drivers are driving more hours, and reports of fatigued driving remain high. Despite increases in allowable driving hours, reported violations of the new rule are widespread and generally at least as common as violations of the prior rule. These findings, coupled with a substantial increase in drivers of trucks with electronic on-board recorders (EOBRs), point to the need for an EOBR requirement for all trucks to enforce work rules. In the following comments, we discuss the survey findings in more detail in the context of the scientific literature on sleep and the effects of work hours and fatigue on safety.

The U.S. Department of Transportation (DOT) estimates that 15 percent of large truck crashes involving deaths and injuries are related to truck driver fatigue. The overriding goal of rulemaking on truck driver work schedules should be to reduce this toll. This was reflected in FMCSA's advance notice of proposed rulemaking in November 1996 (61 FR 57252) and is in keeping with the statutory mandate of FMCSA to "consider the assignment and maintenance of safety as its highest priority" (42 U.S.C. para 113). Thus, although economic factors may be considered they are secondary to safety.

The preceding eight years of rulemaking should culminate in safety reforms, not degradations in safety or maintenance of the pre-2004 status quo, even if the January 2004 rule change increases productivity. We submit evidence that safety has not been enhanced by the rule change.

Types of Evidence Needed to Assess Rule Change Effects
During the past year FMCSA, the American Trucking Associations (ATA), and some large motor carriers (Abramson, 2005; ATA et al., 2004; FMCSA, 2004; Woodruff, 2005) have asserted that the rule change may have contributed to a decline in large truck crashes, based on preliminary overall statistics on crashes involving large trucks or crash statistics for individual carriers. However, these assertions have no scientific basis. Their underlying data cannot possibly be used to assess the impact of the new rule so soon after its implementation. The effects of a rule change on crashes can be determined only through scientific study examining crashes involving trucks from a representative sample of carriers over a long period of time. Such a study must control for other potential crash factors such as economic trends and travel patterns.

ATA and some motor carriers have pointed to lower out-of-service rates under the new rule as evidence of improved safety (ATA et al., 2004; Woodruff, 2005). Although out-of-service rates are useful measures of compliance and enforcement, they are not evidence of safety per se, especially when based on selected carriers with good safety records.

At this juncture, two types of information pertain. The first is the scientific literature on sleep and the safety effects of fatigued driving. A recent position paper (Rosekind, 2005) claimed that key rule changes, including the increase in the daily driving limit and the 34-hour restart rule, are significant improvements based on sound scientific data. However, this paper did not consider many of the important studies, cited below, that do not support the increases in allowable driving and nondriving work hours or a 34-hour restart rule. In IIHS's (2003) amicus brief supporting the Petitioner in *Public Citizen Inc. et al., v. FMCSA*, we summarized for the Court research demonstrating the adverse safety consequences of several aspects of the new rule: allowing truckers to drive up to 11 hours at a stretch; failing to require EOBRs to monitor drivers' hours of service; increasing the number of driving hours in a 7- or 8-day period by introducing a restart provision; and requiring insufficient daily off-duty time (10 hours). We also have submitted summaries of relevant research in previous comments on hours-of-service rulemaking (e.g., IIHS, 2000b).

A second type of relevant information is evidence of the effects of the new rule on drivers' schedules, fatigued driving, and compliance with the rule, as requested by this notice of proposed rulemaking (NPRM). We attach a report of the preliminary findings of interviews with a large representative sample of long-distance truck drivers conducted in two states before (late fall 2003) and after (late fall 2004) the rule change (see Appendix A). The survey responses show that the rule change has resulted in substantially more hours of driving on a daily and weekly basis. Reported daily off-duty time and sleep time have increased. However, the additional opportunity for rest provided by the rule change apparently has not offset the negative consequences of the increase in work hours; reported incidents of fatigued driving and falling asleep at the wheel in 2004 are at least as high as the levels reported in the two states in 2003. Although drivers perceived an increase in 2004 compared with 2003 in roadside inspections to enforce the rules, reported rule violations generally are at least as high as in 2003. In sum, the survey indicates that safety has not been enhanced. Drivers are driving more hours as a result of the rule change, and fatigued driving is at least as common as before the rule change.

Increase in Daily Driving Limit

Numerous scientific studies have observed an increase in crash risk among drivers operating large trucks for more than 8-10 hours (Campbell, 1988; Frith, 1994; Harris, 1978; Jones and Stein, 1987, 1989; Kaneko and Jovanis, 1992; Lin et al., 1993, 1994; Mackie and Miller, 1978; National Transportation Safety Board, 1995; Saccomanno et al., 1995, 1996; Summala and Mikkola, 1994), even after controlling for the effects of time of day (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996). Increased crash risks associated with long hours of driving have been reported as twofold or higher (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996). Techniques used to control for the effects of time of day were matching cases and controls by time of crash (Frith, 1994; Jones and Stein, 1987, 1989), multivariate analyses (Lin et al., 1993, 1994), and stratification of the study population by daytime and nighttime (Saccomanno et al., 1995, 1996). The primary strength of these studies relative to other analyses is that the researchers used comparison groups, enabling control of confounding effects from travel patterns and other variables.

Confirming the findings of these studies with data from a national less-than-truckload firm, one group of researchers recently reported increased crash risk associated with increased hours of driving (Park et al., 2005) (see attached). Other studies have observed a relationship between long driving hours and falling asleep at the wheel of a large truck (Braver et al., 1992; IIHS, 1992; McCartt et al., 2000). FMCSA concluded that an increase in the daily off-duty requirement meant that the one-hour increase in driving time would not compromise safety (NPRM p.3342), but there is no scientific evidence to support this.

Based on drivers' estimated typical daily schedules before and after the rule change, IIHS's survey revealed a substantial increase in 2004 in the percentage of driving shifts lasting more than 10 hours. About a quarter of drivers indicated they took more off-duty time in 2004, compared with 2003, and a sizable percentage said they typically got more sleep under the new rule. However, about a quarter reported that they typically took fewer than the required 10 hours off duty in 2004, and most of these drivers took fewer than 8 hours off duty. About a quarter of drivers in 2003 and 2004 reported that they split their off-duty time into two periods.

Restart Rule

Although the new rule purports to maintain the prior 60/70-hour limits on "weekly" driving, the so-called restart rule actually allows drivers to log up to 88 hours of driving during an 8-day period (an increase of up to 30 percent) and up to 77 hours of driving during a 7-day period (an increase of up to 25 percent). Now drivers can approach their "weekly" 60-hour limit in about 4½ days and their 70-hour limit in about 5½ days. According to our driver survey, a large majority of drivers have embraced the restart provision. Thus, many drivers have dramatically increased their multi-day driving and work time, and they may do so week after week. Such a change should be allowed only if there is convincing scientific evidence that beginning another week of driving after such a short period of rest will not adversely affect safety.

As FMCSA acknowledges in the current NPRM, few studies address the effect of recovery periods between work periods spanning multiple days (NPRM p.3347). To justify the 34-hour restart rule, FMCSA points to a laboratory study of 10 drivers performing tasks on a simulator and a physical loading task over a 17-day period (O'Neill et al., 1999). The authors suggested that a full two nights and one day off would be a minimum safe restart period under the conditions tested. However, the study design considered the effects of a 58-hour off-duty period, not the 34-hour period provided by the restart rule, and the authors cautioned about generalizing the results to operations with different characteristics (for example those that are not day shifts). Further, the implications of the results for real-world driving in the context of the current rule are questionable. As acknowledged in the current NPRM (p.3347), other studies have not reached the same conclusions. In an observational study of on-the-road truck drivers, Wylie et al. (1997) found a 36-hour recovery period inadequate. Recent analysis of data from a national less-than-truckload firm (Park et al., 2005) concluded that restart programs should be approached with caution; evidence suggests there may be increases in crash risk associated with off-duty times of even 48 hours.

FMCSA ignored studies showing an association between long driving hours and reported falling asleep at the wheel of a large truck (Braver et al., 1992; IIHS, 1992; McCartt et al., 2000). Drivers reporting work hours longer than 60-70 per week or other hours-of-service violations were 1.8 times as likely to report falling asleep while driving during the month prior to their interviews as drivers who reported they worked fewer hours (IIHS, 1992).

A recent commentary on the rule change (Rosekind, 2005) claims a scientific basis for the 34-hour restart rule. However, the studies referenced are not based on commercial vehicle drivers. They mostly are experiments that primarily examine the effects on simulated performance of continuous hours of wakefulness, not time on task. The commentary does not consider the range of factors that may affect sleep debts among truck drivers (e.g., split rest time in a sleeper berth) created by long daily work shifts and their ability to get adequate recovery sleep in the real world. For example, for many drivers the 34-hour recovery period occurs on the road rather than at home.

Among drivers we interviewed in 2004 who had worked under both the old and new rules, more than 90 percent said they used the restart provision during 2004. A large majority reported that the restart provision was part of their regular schedule. When asked how many hours they typically took off duty between weekly shifts, a fifth of drivers took 34 hours, and more than 10 percent took fewer than the required 34 hours.

A concern is the additive effect of the increased daily driving limit and the restart provision. Among drivers we interviewed in 2004, 42 percent said they typically drove 10 or more hours each day and used the restart rule. Eleven percent said they typically drove more than 11 hours each day, the maximum allowed by the rule, and used the restart provision.

Changes in Reported Fatigued Driving

In our survey, reported instances of fatigued driving did not decline after the rule change. To the contrary, there was a slight increase in the percentage of drivers (from 40 percent in 2003 to 42 percent in 2004) who said they had driven while sleepy at least once in the past week. The percentage who reported actually dozing at the truck wheel on at least one occasion in the past month was 13 percent in 2003 and 15 percent in 2004. Although various other factors may influence fatigued driving among truckers, the most critical factors are the work rule and the extent of compliance with the rule.

Efforts to Improve Work Rule are Meaningless Without Enforcement
Numerous studies provide evidence that the prior rule was widely flouted and logbooks frequently were falsified (e.g., Beilock, 1995; Braver et al., 1992; Hertz, 1991; McCartt et al., 1997). According to our survey, drivers believe enforcement increased after the rule change. However, the survey also indicates that noncompliance with the rule remains widespread. About a third of drivers interviewed in 2004 said they often (19 percent) or sometimes (14 percent) omitted hours worked in their logbooks. Only 38 percent believed logbooks generally were accurate for most drivers. These responses were similar to those in 2003.

Reported violations of specific rule provisions generally were similar in 2003 and 2004. Even with an additional hour of allowable daily driving time, 7-13 percent of drivers in the two states where the survey was conducted reported in 2004 that they often exceeded this limit, and 15 percent said they sometimes did. There was a decline in reported noncompliance with the weekly driving limit. This presumably was a result of drivers' use of the restart provision.

Based on phone interviews IIHS conducted in January 2005 with a small sample of commercial vehicle inspectors (see Appendix B), the 14-hour daily work rule disallowing logging on and off duty improved inspectors' ability to enforce the daily work limit. However, inspectors noted that enforcement of the 34-hour restart rule can be problematic. Completed logs covering the prior 7 days, which are required of drivers undergoing inspection, may be insufficient to check compliance with a 60/70-hour weekly driving limit preceding a restart period, if the restart period occurred in the middle of the prior week.

The driver survey results indicate a large increase in the percentage of trucks with GPS systems (36 percent in 2003 versus 45 percent in 2004) and the percentage of trucks with EOBRs during this 1-year period (18 versus 38 percent). Among drivers with EOBRs, fewer than 1 in 10 in either year reported using the EOBR to report compliance with work rules. On numerous occasions IIHS has provided documentation of widespread noncompliance with work rules and availability of affordable tamper-resistant on-board recorders (e.g., IIHS 1995, 2000a, 2000b). In our comments on FMCSA's recent rulemaking on EOBRs (IIHS 2000a, 2004), we reiterated the need to mandate EOBR use in all trucks to monitor work hours. The results of our survey demonstrate that the current enforcement system remains dysfunctional, and even though not required by law EOBR and GPS systems increasingly are available in the vehicle fleet.

Requiring EOBRs in all large trucks is the single most critically needed hours-of-service reform. A requirement should be instituted without further delay. In November 2004 the Canadian Trucking Alliance (CTA) called for the mandatory use of EOBRs to monitor compliance with Canada's hours-of-service rules (IIHS, 2004). Support for recorders is increasing among some of the major motor carriers, and ATA's longtime opposition is softening (IIHS, 2005). In a recent editorial published in the *New England Journal of Medicine*, the lead author of the Federal Highway Administration's Driver Fatigue and Alertness Study (Wylie, 1996) called for improved enforcement of the hours-of-service policy (Wylie, 2005) (see attached) in light of new evidence by Barger et al. (2005) (see attached) of heightened risk from extended work shifts among medical interns. Acknowledging that shifts studied among interns extend considerably beyond the hours-of-service limits, Wylie noted that he has encountered such schedules in reconstructing the crashes of commercial vehicles and that these can go undetected by the present enforcement system.

It is notable that most of the inspectors interviewed by IIHS said they had not been trained in using EOBRS to perform inspections. Still none reported that they avoid inspecting trucks with EOBRs. Most believed the use of EOBRS would improve compliance with work rules.

FMCSA Leadership Needed
Recent reports that FMCSA will ask Congress to write the new hours-of-service rule into law and to change the definition of driver health are troubling (Abramson, 2005). Writing the current rule into law would not only circumvent the established process for addressing truck drivers' work rules but also ensure the continuation of a flawed rule that does not serve safety. We do not believe the increase in daily driving time from 10 to 11 hours is supported by the scientific evidence.

We believe the increase in required daily off-duty time from 8 to 10 hours is an important improvement, although we believe a 10-hour off-duty requirement still is inadequate to obtain restorative sleep and attend to other daily requirements. Our primary concerns are the 34-hour restart rule, for which there is no scientific basis, and the absence of an EOBR requirement, which is the only effective enforcement mechanism.

We support the change to the 14-hour rule on daily work limits. This removed the loophole allowing drivers to extend their daily work time. Combined with an EOBR requirement, the 14-hour rule could substantially improve compliance with driving limits. We are troubled by recent reports (McNally, 2005; Cable News Network, 2005) of proposed federal legislation to extend the workday for truckers to 16 hours. We fear that other proposals to weaken the work rule will be pursued if an hours-of-service law is enacted.

At this critical juncture, we urge FMCSA to live up to its safety mission by making the needed reforms so that safety can be served. The solution to the legitimate criticisms of the U.S. Court of Appeals for the District of Columbia is not to make the mistake of statutorily adopting the new rule. Instead, the agency must fix the new rule's critical shortcomings. The toll of injuries and deaths due to fatigued truck drivers is too high to do otherwise.

Sincerely,

Anne T. McCartt

Anne T. McCartt, Ph.D.
Vice President, Research

cc: Docket Clerk, Docket No. FMCSA-1998-3706

Appendix A
McCartt, A.T.; Hellinga, L.A.; and Solomon, M.G. 2005. Survey of long-distance truck drivers: work schedules before and after hours-of-service rule change in 2004. Preliminary report. Arlington, VA: Insurance Institute for Highway Safety.

Appendix B
Interviews with State Enforcement Personnel

Attachments
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APPENDIX A

SURVEY OF LONG-DISTANCE TRUCK DRIVERS: WORK SCHEDULES BEFORE AND AFTER HOURS-OF-SERVICE RULE CHANGE IN 2004

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PRELIMINARY REPORT

March 10, 2005

INTRODUCTION

In January 2004 a new federal hours-of-service rule for interstate commercial truck drivers was implemented by the Federal Motor Carrier Safety Administration (FMCSA). The hours-of-service rule is enforced primarily through roadside safety inspections conducted by state enforcement personnel. FMCSA requested that states conduct two months of "soft enforcement" and begin full enforcement of the new rule on March 1, 2004.

The new rule substantially altered daily and weekly driving limits and off-duty requirements (Table 1). Daily and weekly maximum driving limits and daily off-duty requirements were increased. Handwritten logbooks were retained for monitoring compliance with the rule, although voluntary use of automated on-board recorders is permitted.

To assess the effects of the rule change on long-distance truck drivers' work schedules and reported fatigued driving, surveys of on-the-road truck drivers were conducted in two states in late fall 2003 and 2004.

METHOD

Interviews were conducted with a representative sample of drivers of large trucks passing through roadside commercial vehicle weigh stations on heavily traveled interstate highways in western Pennsylvania (Route I-80, eastbound traffic) and northwestern Oregon (Route I-84, eastbound traffic). Interviews in Pennsylvania were conducted during November 18-22, 2003 and November 16-20, 2004; in Oregon interviews were conducted during December 3-6, 2003 and December 1-4, 2004.

These weigh stations are operated throughout the year on most days of the week and at various times of the day and night to enforce federal limits on total truck weights and axle weights. Given the heavy volume of truck traffic, a steady stream of vehicles drive over the scales when the stations are open. In Pennsylvania all trucks traveling by the station are required to drive over the scales. Oregon, like many states, has an automatic commercial vehicle identifier program that allows pre-certified participating vehicles equipped with transponders to bypass designated weigh stations, port-of-entry facilities, and other enforcement stations. Trucks participating in Oregon's "green light" program are weighed by an electronic scale as they approach the weigh station, and trucks in compliance are allowed to bypass the station. Approximately one-quarter of the truck traffic was "green lighted" during the two survey periods and, thus, not part of the survey sample. According to Oregon inspection staff, the trucks participating in the program are primarily local rather than long-distance carriers. At each station, overweight trucks were directed to a parking lot behind the scales. Citations were issued to these drivers, and vehicles could not be driven until their weight was brought within the limit or the load was redistributed.

The survey protocol in each state provided that when an interview had been completed another truck was selected from the stream of trucks approaching the scale, based on the next truck passing a predetermined reference point. The inspection staff asked this driver to drive to the parking lot, and an interviewer approached the driver to solicit participation in the survey. Drivers of trucks that were overweight or inspected, as well as known local drivers, were excluded, but this occurred infrequently. Interviews were conducted when the weigh stations were open; this included weekdays and at least one weekend day, daylight and evening hours.

When approaching drivers, interviewers explained they were researchers conducting a study and not enforcement staff. Drivers were asked to participate if they did over-the-road work that required them to spend at least one night away from home on a regular basis. A number of steps were taken to increase survey participation and elicit accurate responses. Person-to-person anonymous interviews were conducted by trained interviewers, drivers were offered $10 to participate, and the interview was described as research to determine truck drivers' schedules and their opinions about the hours-of-service rule.

The questionnaire was informally tested by drivers at private truck stops and formally tested at the Pennsylvania site. Most questions were asked in both 2003 and 2004. Differences between the 2003 and 2004 results were examined for reported schedules, violations of work rules, and incidents of fatigued driving. Many carrier and job characteristics of survey respondents varied by state. In addition, the distribution of sampled drivers by cargo type (own carrier, other carrier, self/other) and trailer type varied significantly between the 2003 and 2004 samples. Therefore, differences between the 2003 and 2004 results were tested using the Cochran-Mantel-Haenszel chi-square statistic after stratifying by state, cargo type, and trailer type. Differences were considered significant at $p < 0.05$. In 2004 an additional set of questions asked drivers who had worked for more than a year to compare their work schedules under the new and old rules.

RESULTS

Approximately 350 drivers were interviewed in each state in 2003 and in 2004. Overall participation rates were 96 percent in 2003 (98 percent in Pennsylvania, 93 percent in Oregon) and 91 percent in 2004 (92 percent in Pennsylvania, 90 percent in Oregon). Most drivers who declined to participate were hurrying to complete a the trip. Drivers unable to speak fluent English were not asked to participate.

Sample Characteristics

For both states combined, there were few differences between the 2003 and 2004 samples with regard to characteristics of drivers and their carriers and jobs (Tables 2-3). Drivers held their commercial licenses from a broad cross-section of states; a wide variety of types of carriers and types of trucks were represented. In both years drivers reported schedules requiring long periods of absence from home. About two-thirds of drivers reported road trips lasting more than 5 days, on average, and about one-third had trips typically lasting more than two weeks. Drivers estimated they would drive 134,500 miles in 2004, on average, compared with 124,000 miles in 2003. Ninety-two percent of drivers in each year were 30 years or older, and about 1 in 10 were 60 or older. More than 90 percent had been driving a large truck for more than one year. Only 50 of the 706 drivers interviewed in 2004 had begun driving in or after January 2004; thus, only 7 percent had worked only under the new rule.

Reported Fatigued Driving

The percentage of drivers who reported driving while sleepy at least once in the past week changed little, from 40 percent in 2003 to 42 percent in 2004 (Table 5). The percentage who reported actually dozing at the wheel of a truck on at least one occasion in the past month was 13 percent in 2003 and 15 percent in 2004. Neither of these differences was significant.

Reported Compliance with Work Rule

About a third of drivers in both years said they often or sometimes omitted hours worked from their logbooks (Table 5). The percentage who reported working longer than the rule permitted in the past month was 28 percent in 2003 and 30 percent in 2004. About two-thirds in each year said logbooks generally are not accurate for most drivers.

Many drivers reported violations of specific work provisions in 2003; reported violations of most provisions were as prevalent in 2004 (Table 5). About a quarter of drivers in each year said they often or sometimes exceeded the daily driving limit or took less than the required off-duty period. There was a change in the percentage of drivers reporting that they drove more than the weekly limit. A larger percentage of drivers in 2004 than in 2003 (71 percent versus 61 percent) said they never exceeded the weekly driving limit, presumably due to the availability of a provision allowing drivers to begin a new weekly driving clock after 34 hours off duty.

Reported Changes in Daily Work Schedules

A series of questions in the 2004 survey asked drivers with experience under both sets of rules to compare their daily and weekly work schedules under the two rules. These questions were not posed to drivers who began driving a truck after October 2003 (n=62). Results are presented separately for each state.

Table 6 summarizes reported changes in daily work schedules. An important change in the new rule was an increase in the maximum daily driving limit from 10 to 11 hours. About a fifth of drivers said they were driving more hours under the new rule, and 6-7 percent said they were driving fewer hours. Based on drivers' estimated typical daily schedules before and after the rule change, the percentage of driving shifts lasting more than 10 hours increased substantially in both states.

The new rule prohibits driving after 14 hours have elapsed since coming on duty. This is 1 hour shorter than the prior 15-hour work limit. In addition, drivers no longer may log off and on duty to extend the daily work limit. Drivers reported only slight changes in their nondriving daily work hours from 2003 to 2004.

The new rule increased required daily off-duty time from 8 to 10 hours and retained a provision allowing drivers to split this time into two periods in a sleeper berth. About a quarter of drivers in each year said they typically split their off-duty period. The percentage of drivers reporting that they took more off-duty time in 2004 compared with 2003 was 31 percent in Pennsylvania and 24 percent in Oregon. The percentage who said they took at least 10 hours off duty increased significantly in both states. Nevertheless, about a quarter reported that they typically took fewer than the required 10 hours off duty in 2004; this included 21 percent in Pennsylvania and 16 percent in Oregon who typically took fewer than 8 hours off duty. A sizable percentage of drivers in both states (35 percent in Pennsylvania, 21 percent in Oregon) said they typically got more daily sleep under the new rule.

Reported Changes in Weekly Work Schedules

Although the new rule retained weekly driving limits of 60 hours in a 7-day period or 70 hours in an 8-day period, a restart provision substantially increased this limit. Under the restart provision, when the weekly limit is reached (even if it is in fewer than 7 or 8 days) drivers can resume driving toward a new 60/70-hour limit after taking 34 hours off duty. This allows up to 77 hours of driving in 7 days and up to 88 hours of driving in 8 days. More than 90 percent of drivers who had worked under both rules reported that they used the restart provision during 2004. A large majority of drivers said the provision is part of their regular schedule (Table 7). When asked how many hours they typically take off duty between weekly shifts, 9 percent in Pennsylvania and 16 percent in Oregon said they take off fewer than the required 34, and about a fifth in each state take off 34 hours.

Drivers were asked to quantify the hours of driving and nondriving work in their typical weekly shifts during 2003 and 2004. The differences were not significant in either state (Table 7). However, presumably in 2004 the weekly limits were reached in fewer days for drivers using the restart provision.

Use of Restart and Expanded Daily Driving Limit

A concern is the additive effect of an increased daily driving limit (from 10 to 11 hours) and the restart rule. Among drivers in both states combined, 42 percent said their typical schedule included both 10 or more hours of daily driving and the restart rule (table not shown). Eleven percent said they typically drove more than 11 hours daily, the maximum allowd by the new rule, and used the restart provision.

Wait Times for Pickups and Deliveries

It was believed that the new 14-hour rule might result in reduced wait/pickup times, as drivers are no longer allowed to extend the daily work limit by logging on and off duty. Drivers in both the 2003 and 2004 surveys were asked to estimate the time they typically waited for pickups and drop-offs (Table 4). Responses included some very long wait times, which may have been skewed by including the required off-duty time. Estimated load drop-off and pickup wait times increased in 2004, but only the difference for drop-off times was significant. Typical wait times for pickup and drop-off in 2003 and 2004 varied only a little in Pennsylvania but were significantly longer in Oregon. In the 2004 survey (Table 7), drivers who had worked under both the old and new rules were asked whether time waiting to pick up or drop off deliveries was more, less, or about the same compared with 2003. About one-fifth of drivers in both states said it was less, and 7-8 percent said it was more. Thus, the survey yielded inconsistent findings with regard to changes in waiting times.

Enforcement of Work Rules

The new rule did not include a requirement for the use of electronic on-board recorders (EOBRs) to demonstrate compliance with the rule. As shown in Table 3, there was a large increase in the percentage of drivers driving trucks with global positioning systems (GPS) (45 percent versus 36 percent) or EOBRs (38 percent versus 18 percent). In both years almost all drivers with EOBRs also maintained paper logbooks for inspection purposes.

Among drivers who had worked under both the old and new rules, a substantial proportion in both states (40 percent in Pennsylvania, 28 percent in Oregon) said the level of enforcement of the hours-of-service rule had increased in 2004 (Table 8). About half of the drivers reported that they preferred the new rule, and about a quarter preferred the old rule.

State Differences

It appeared that the schedules of drivers in Pennsylvania had more often changed from 2003 to 2004. In particular, a larger percentage of drivers interviewed in Pennsylvania than in Oregon reported typical daily schedules in 2004 that included more driving hours, more off-duty hours, more actual sleep, and more naps. The drivers in Pennsylvania were much more likely to report using the restart provision in their regular weekly schedule and less likely to take off fewer than the required 34 hours before resuming driving. In both years, a larger percentage of drivers in Pennsylvania also reported driving sleepy at least once in the past week.

SUMMARY

Surveys of representative samples of long-distance truck drivers in two states provide consistent evidence that the rule change has resulted in substantially more hours of driving on a weekly and daily basis. Most drivers report regularly using the restart provision, allowing them to substantially increase their weekly driving and nondriving on a continuing basis. Reported daily off-duty and sleep time has increased. However, this additional opportunity for rest apparently has not offset the adverse effects of the added work time. Reported incidents of fatigued driving and actually falling asleep at the wheel remain high. Although drivers believe enforcement has increased under the rule change, reported violations of the rule generally are as high as they were before or higher. The results of this survey do not indicate that safety has been enhanced as a result of the rule change.

Table 1
Old and New Work Rules for Commercial Truck Drivers

	Old rules	New rules (January 2004)
Daily driving limits	10 driving hours after 8 off duty; up to 16 hours driving per 24-hour period	11 driving hours after 10 off duty; up to 14 hours driving per 24-hour period
Daily off-duty requirements	After driving 10 hours or working 15 hours, driving is not allowed again until after taking 8 hours off duty; may log off duty for breaks to extend 15-hour on-duty shift	After driving 11 hours or if 14 hours have passed since driver started duty, driving is not allowed again until after taking 10 hours off duty; may not log off duty during 14 hour on-duty shift
Sleeper berth exception	May split required 8 hours off duty into 2 periods in a sleeper berth (period must be 2 hours or more)	May split required 10 hours off duty into 2 periods in a sleeper berth (period must be 2 hours or more)
Restart provision	No provision	May restart official work week after 34 consecutive hours off
Weekly driving limits	60 hours in 7 days or 70 hours in 8 days	60 hours in 7 days or 70 hours in 8 days, but restart provision allows up to 77 hours in 7 days, 88 hours in 8 days
Work-hour limits	No daily work hour limits; no weekly work hour limits	No change
Monitoring for compliance with rules	Handwritten logbooks; voluntary use of automated recorders permitted	No change

Table 2
Carrier Characteristics – Interviews with Long-Distance Truck Drivers, November-December 2003 and 2004

	Pennsylvania		Oregon		Combined	
	2003 (N=355) Percent	2004 (N=356) Percent	2003 (N=338) Percent	2004 (N=350) Percent	2003 (N=693) Percent	2004 (N=706) Percent
Cargo hauling today						
Carrier's own cargo	18	13	10	8	14	11
Other carriers' cargo	75	83	72	88	74	85
Self/other	8	3	18	4	13	4
Operator mainly full or less than truckload						
Less than truckload	6	9	6	6	6	8
Full truckload	81	71	77	74	79	73
Both	13	20	17	20	15	20
Number of leased or owned trucks in fleet						
0-10	21	18	29	26	25	22
11-50	22	19	22	21	22	20
51-100	10	10	12	8	11	9
101-500	22	22	8	18	15	20
>500	26	31	29	27	27	29
Goods hauling today						
Perishables or livestock	27	27	14	16	22	22
Other goods	68	71	62	57	63	64
Empty trailer	5	2	24	27	15	14
Carrying hazardous materials today	4	3	5	5	5	4
Trailer type						
Dry box or bulk	50	62	47	38	48	50
Refrigerator	19	16	30	41	24	29
Flatbed	17	10	17	10	17	10
Tanker	5	4	2	3	4	3
Other	9	8	5	8	7	8
Two or more trailers	1	1	6	7	3	4

Table 3
Driver and Job Characteristics – Interviews with Long-Distance Truck Drivers, November-December 2003 and 2004

	Pennsylvania		Oregon		Combined	
	2003 (N=355) Percent	2004 (N=356) Percent	2003 (N=338) Percent	2004 (N=350) Percent	2003 (N=693) Percent	2004 (N=706) Percent
Years of age						
21-29	5	7	11	9	8	8
30-39	22	22	22	20	22	21
40-49	35	31	33	35	34	33
50-59	28	28	27	24	28	26
60+	10	11	7	13	8	12
Years driving large trucks professionally						
<u><</u>1	7	9	10	8	8	9
>1 to 4	12	13	16	13	14	13
>4 to 10	21	21	21	22	21	21
>10	60	57	54	56	57	57
Estimated miles driven in 2003/2004						
<100,000	19	18	19	15	19	16
100,000-124,000	38	33	34	30	36	32
125,000-149,000	25	27	17	18	21	23
≥150,000	18	22	29	37	23	29
Mean miles driven	119,500	122,100	128,700	147,100	124,000	134,500
Days usually on road from leave home to return						
≤5	44	40	26	22	35	31
6-7	18	16	17	18	18	17
8-14	14	16	19	19	16	17
≥15	24	28	38	42	31	35
CDL state						
Pennsylvania	26	23	1	1	14	12
Oregon	0	1	16	13	8	7
States bordering Pennsylvania	19	21	2	3	11	12
States bordering Oregon	3	3	29	24	16	13
Canada	0.3	1	5	5	3	3
Other states	52	52	47	53	49	52
Method of payment						
By the mile	66	70	64	70	65	70
Percent of load	26	22	21	19	24	20
Straight salary	2	2	1	1	5	5
By the load	4	3	6	7	1	1
Hourly wage	1	2	2	3	1	3
Other	1	1	6	1	4	1
Global positioning system (GPS)	36	46	37	44	36	45
Electronic onboard record or other onboard computer	19	41	17	36	18	38
If yes, also keep paper logbook	91	95	91	93	91	94

Table 4
Schedule Characteristics – Interviews with Long-Distance Truck Drivers, November-December 2003 and 2004

	Pennsylvania		Oregon		Combined	
	2003 (N=355) Percent	2004 (N=356) Percent	2003 (N=338) Percent	2004 (N=350) Percent	2003 (N=693) Percent	2004 (N=706) Percent
Sharing driving today with another driver	8	8	20	19	14	14
Split off-duty time	26	28	25	26	26	27
Legal places full when want to nap or sleep						
Often	52	54	59	51	55	53
Sometimes	25	23	20	18	23	21
Rarely/never	23	23	21	30	22	26
Unrealistic delivery time from dispatcher or shipper						
Often	12	11	15	14	13	12
Sometimes	14	15	18	13	16	14
Rarely	32	27	27	32	30	30
Never	43	47	40	41	41	44
Typical wait for pickup						
≤30 minutes	28	31	39	23	33	27
31 minutes to 1 hour	21	20	16	22	19	21
61 minutes to 2 hours	23	24	20	23	22	24
>2 hours	28	25	25	32	27	28
Mean minutes	116	115	131	183	123	149
Typical wait at terminal for drop-off*						
≤30 minutes	37	38	48	29	42	34
31 minutes to 1 hour	21	20	20	23	20	21
61 minutes to 2 hours	22	21	17	24	19	22
>2 hours	20	21	16	24	18	23
Mean minutes	89	96	77	117	83	106

*p<0.05: Cochran-Mantel-Haenszel chi-square test indicating 2003 and 2004 differences are significant in at least one state

Table 5
Reported Fatigued Driving and Violations of Work Rules – Interviews with Long-Distance Truck Drivers, November-December 2003 and 2004

	Pennsylvania		Oregon		Combined	
	2003 (N=355) Percent	2004 (N=356) Percent	2003 (N=338) Percent	2004 (N=350) Percent	2003 (N=693) Percent	2004 (N=706) Percent
Drove sleepy at least once in past week	43	48	36	36	40	42
Dozed at wheel at least once in past month	13	16	12	14	13	15
Drive more than 10 hours (2003) or 11 hours (2004) before taking required time off duty						
Often	5	7	11	13	8	10
Sometimes	14	15	14	15	14	15
Rarely	25	26	19	20	22	23
Never	56	53	56	52	56	52
Drive after being on-duty 14 hours						
Often	—	6	—	8	—	7
Sometimes	—	12	—	11	—	11
Rarely	—	19	—	16	—	17
Never	—	63	—	65	—	64
Take fewer than 8 hours (2003) or 10 hours (2004) off-duty						
Often	9	12	10	11	9	12
Sometimes	15	15	14	14	15	14
Rarely	22	21	17	16	20	18
Never	55	52	59	60	57	56
Drive more than weekly limit before taking required off-duty time**						
Often	6	4	9	7	7	6
Sometimes	9	7	10	9	10	8
Rarely	22	15	22	17	22	16
Never	63	74	59	68	61	71
Omit hours worked in logbook						
Often	12	17	19	21	15	19
Sometimes	18	13	17	15	17	14
Rarely	18	21	21	19	19	20
Never	52	50	43	45	48	48
Logbooks generally accurate for most drivers	32	38	35	38	34	38
Worked longer than rules permitted during last month	25	28	30	32	28	30

**p<0.01: Cochran-Mantel-Haenszel chi-square test indicating 2003 and 2004 differences are significant in at least one state

Table 6
Typical Daily Schedules Before and After New Work Rule among Drivers with at Least One Year Commercial Driving Experience – Interviews with Long-Distance Truck Drivers, November-December 2004

	Pennsylvania (N=323) Percent		Oregon (N=319) Percent	
Change in driving time				
More	22		17	
Less	6		7	
About the same	72		76	
Number hours of driving	**Old**	**New****	**Old**	**New****
≤10	77	62	68	58
10.1-11	11	30	18	29
>11	11	8	14	13
Change in nondriving work time				
More	4		4	
Less	7		3	
About the same	89		93	
Number hours of nondriving work	**Old**	**New**	**Old**	**New**
≤1	41	39	51	51
1-2.5	29	32	24	26
≥2.5	30	29	25	24
Change in off duty time				
More	31		24	
Less	8		5	
About the same	60		71	
Number hours of off duty time	**Old**	**New****	**Old**	**New****
<8	24	21	17	16
8-9.9	21	5	19	6
≥10	55	74	64	78
Split off-duty rest time	25		28	
Change in actual sleep time				
More	35		21	
Less	7		4	
About the same	58		75	
Number hours of actual sleep	**Old**	**New****	**Old**	**New**
<8	51	39	47	41
8-9	41	41	41	41
>9	9	21	13	19
Change in nap time				
More	23		14	
Less	17		13	
About the same	61		73	

**p<0.01, *p<0.05: chi-square test of within-state differences

Table 7
Typical Weekly Schedules Before and After New Work Rule among Drivers with at Least One Year Commercial Driving Experience – Interviews with Long-Distance Truck Drivers, November-December 2004

	Pennsylvania (N = 323) Percent		Oregon (N = 319) Percent	
Change in driving time	18		13	
More	11		5	
Less	72		81	
About the same				
Number hours of driving in weekly shift	**Old**	**New**	**Old**	**New**
≤50	23	22	20	19
50.1-60	34	35	30	29
60.1-70	39	40	42	43
>70	5	3	8	9
Change in nondriving work time				
More	4		5	
Less	11		5	
About the same	85		90	
Number of hours of nondriving work	**Old**	**New**	**Old**	**New**
<5.5	28	28	30	29
5.5-10.4	39	41	41	42
10.5-15.4	17	16	15	15
15.5-20	9	7	9	9
>20	7	7	5	5
Number of hours off duty before beginning new weekly shift				
<34	9		16	
34	19		21	
34.1-47.9	31		21	
≥48	41		41	
Ever used restart rule	92		93	
Restart provision part of regular schedule	85		75	
Change in time spent waiting to pick up/ drop off deliveries				
More	7		8	
Less	21		19	
About the same	72		74	
Change in number of miles driving				
More	24		20	
Less	11		7	
About the same	65		73	

Table 8
Perceptions about Enforcement Before and After New Work Rule among Drivers with at Least One Year of Commercial Vehicle Driving – Interviews with Long-Distance Truck Drivers, November-December 2004

	Pennsylvania (N =323) Percent	Oregon (N =319) Percent
Change in level of enforcement		
More	40	28
Less	6	6
About the same	54	66
Overall prefer old/new rules		
Old	27	26
New	53	52
Neither	20	22

APPENDIX B

Interviews with State Enforcement Personnel

Semi-structured interviews were conducted in January 2005 with enforcement staff in 12 states about their experiences in enforcing the new rule. Inspectors also were queried about their experiences conducting inspections with drivers using electronic on-board recorders (EOBRs) to document compliance with the hours-of-service rules. Telephone interviews were conducted with a commercial vehicle inspector working at a weigh station in 12 states located in different regions of the country (Alabama, Arizona, Idaho, Missouri, North Carolina, North Dakota, Pennsylvania, Oregon, South Carolina, South Dakota, Utah, and Wisconsin). The interviews were not designed to be a scientific survey of enforcement practices; rather they were intended to identify general perceptions about enforcement of the new rules and any major problems.

The inspectors reported that enforcement of the new rules began after a grace period ranging from 2 to 5 months. During the grace period, fines were not assessed for rule violations, but drivers were placed out of service if they were flagrantly violating the new rule. Inspectors reported that the level of enforcement under the new rule is similar to that under the old rule. All reported that the drivers had a good understanding of the rules. They noted that some drivers had difficulty understanding the 14-hour daily work limit, and many drivers preferred the provision in the old rule that permitted them to extend their daily clock by logging on and off duty. However, some inspectors believed that verifying compliance with the daily work limit is easier under the new rule.

The inspectors believed that the 34-hour restart provision has reduced the number of violations of the weekly driving limits. However, it was reported that checking compliance with weekly driving limits can be problematic with drivers using the restart provisions because drivers undergoing an inspection must show their logs only for the past week.

Inspectors in 2 of the 12 states reported that they had received some training on conducting inspections with EOBRs. All had some experience conducting inspections with EOBRs. Although most inspectors had no problems retrieving or interpreting data from EOBRs, two said it took longer to inspect drivers with EOBRs because the systems varied. In general, it was believed that compliance with the rules is greater among drivers with EOBRs and that overall compliance would increase if EOBRs were mandated for all drivers.

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 JANUARY 13, 2005 VOL. 352 NO. 2

Extended Work Shifts and the Risk of Motor Vehicle Crashes among Interns

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ABSTRACT

BACKGROUND
Long work hours and work shifts of an extended duration (≥24 hours) remain a hallmark of medical education in the United States. Yet their effect on health and safety has not been evaluated with the use of validated measures.

METHODS
We conducted a prospective nationwide, Web-based survey in which 2737 residents in their first postgraduate year (interns) completed 17,003 monthly reports that provided detailed information about work hours, work shifts of an extended duration, documented motor vehicle crashes, near-miss incidents, and incidents involving involuntary sleeping.

RESULTS
The odds ratios for reporting a motor vehicle crash and for reporting a near-miss incident after an extended work shift, as compared with a shift that was not of extended duration, were 2.3 (95 percent confidence interval, 1.6 to 3.3) and 5.9 (95 percent confidence interval, 5.4 to 6.3), respectively. In a prospective analysis, every extended work shift that was scheduled in a month increased the monthly risk of a motor vehicle crash by 9.1 percent (95 percent confidence interval, 3.4 to 14.7 percent) and increased the monthly risk of a crash during the commute from work by 16.2 percent (95 percent confidence interval, 7.8 to 24.7 percent). In months in which interns worked five or more extended shifts, the risk that they would fall asleep while driving or while stopped in traffic was significantly increased (odds ratios, 2.39 [95 percent confidence interval, 2.31 to 2.46] and 3.69 [95 percent confidence interval, 3.60 to 3.77], respectively).

CONCLUSIONS
Extended-duration work shifts, which are currently sanctioned by the Accreditation Council for Graduate Medical Education, pose safety hazards for interns. These results have implications for medical residency programs, which routinely schedule physicians to work more than 24 consecutive hours.

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N Engl J Med 2005;352:125-34.

Residents in their first postgraduate year (interns) in the United States frequently work shifts of an extended duration (≥24 hours), a practice that results in long workweeks.[1,2] Both the number and the distribution of work hours can affect sleep, productivity, and safety.[3] The risk of fatigue-related crashes, a leading cause of truck crashes that have been fatal to the driver in the United States,[4,5] increases markedly as a function of truckers' consecutive driving hours.[6] Despite long-standing concerns regarding the effects of work hours on performance and safety among postgraduate physicians,[7-10] prior studies have not directly associated safety outcomes with such a specific characteristic of their work schedule.

To address this issue, we administered a monthly Web-based questionnaire to interns nationwide to investigate the association between validated work hours, extended work shifts, and driving safety. Assessment of driving safely included documented motor vehicle crashes, near-miss incidents, incidents involving falling asleep while driving, and incidents involving falling asleep while stopped in traffic.

METHODS

DATA COLLECTION

In April 2002, advertisements announcing the Harvard Work Hours, Health, and Safety study and offering the chance of a monetary incentive for participation were sent by e-mail to people who were matched to a residency by the National Resident Matching Program and to graduates of U.S. medical schools. The advertisement that was used is contained in the Supplementary Appendix (available with the full text of this article at www.nejm.org). Thereafter, responses to detailed questions regarding work hours, shifts of extended duration (≥24 hours), motor vehicle crashes, near-miss incidents (near-miss motor vehicle crashes in which property damage or bodily harm was narrowly avoided), and incidents of involuntary sleeping were collected monthly through May 2003, when responses regarding the overall first postgraduate year were also collected. Although this report addresses only data regarding extended shifts, motor vehicle crashes, and near-miss incidents, the questions regarding these exposure and outcome variables were distributed among 60 other questions on the monthly surveys. The Human Research Committee of Brigham and Women's Hospital and Partners HealthCare approved all the study procedures, and all the participants provided electronic written informed consent.

VALIDATION OF WORK HOURS

A random subgroup of participants (7 percent) completed daily work diaries. We validated these diaries in a separate study in which direct observation was used for continuous monitoring of work hours. A very high correlation was found between work hours (r=0.98) and shifts of extended duration (r=1.0) as reported by observers and as recorded in the diaries.[11] This work-diary subgroup recorded their work hours for at least 21 out of 28 days and completed the corresponding monthly survey. Pearson's product-moment correlation was used to determine the association between the daily average number of work hours and the number of extended-duration work shifts that were reported in the diary and in the monthly survey.

DOCUMENTATION PROCESS FOR CRASHES

Participants who reported a motor vehicle crash were requested to provide documentation of the crash. A police report, an insurance claim, an auto-repair record, a medical record, a photograph of the damaged vehicle, or a written description of the crash was accepted as documentation. For participants who did not complete the year-end survey, no additional crashes were identified, either through a search of the Social Security Death Index or through inquiries to the interns' designated emergency contacts.

STATISTICAL ANALYSIS

We used two independent techniques to quantify exposure and to assess relative risk. First, the subgroup of crashes and near-miss incidents that occurred on the commute from work was analyzed with the use of a within-person case-crossover design. For each participant, we assessed the number and proportion of crashes and near-miss incidents that had occurred after an extended work shift, as compared with a shift that was not extended. The Mantel–Haenszel test (with each subject as a separate stratum) was used to calculate the odds ratio for crashes and near-miss incidents that occurred after an extended work shift as compared with a nonextended shift.[12] Second, to address potential reporting bias (because both the crashes and the number of extended shifts were reported in each monthly survey), we also prospectively assessed whether the mean monthly number of scheduled extended shifts (collected on the baseline survey) was associated with the subsequent occurrence of motor vehicle crashes as reported on the monthly surveys. We then used Poisson regression analysis that was adjusted for age and sex to determine whether the mean monthly number of scheduled extended shifts was associated with the occurrence of crashes. For each participant, the time at risk for the Poisson regression was considered to be the number of monthly surveys that each participant completed.

A case-crossover analysis was used to determine whether the number of extended shifts that interns worked per month was associated with incidents of falling asleep while driving or while stopped in traffic. The Mantel–Haenszel test was used to calculate odds ratios. The case-crossover study design eliminated the need to account for potential confounders, such as differences in age, sex, commuting time or distance, or medical specialty, since participants served as their own controls.[13] All data are reported as means ±SD. All odds ratios are reported with 95 percent confidence intervals; all P values are two-sided. Additional information about the methods used is provided in the Supplementary Appendix.

RESULTS

A total of 3429 interns volunteered to participate in the study. Of those, 2737 (80 percent) completed the baseline survey and were thus deemed the study cohort. Each month, an average of 1548±376 surveys were completed. Ninety-three percent of the study cohort completed at least one monthly survey and were eligible for the analysis of crashes and near-miss incidents; 82 percent completed at least two monthly surveys and were thus eligible to be included in all analyses (Fig. 1). We collected a total of 19,740 surveys, including 2737 baseline surveys and 17,003 monthly surveys.

DEMOGRAPHIC DATA

The demographic characteristics of the study participants were similar to those of all interns matched through the National Resident Matching Program in 2002. Of the participants, 53 percent were female, with a mean age of 28.0±3.9 years; 79 percent were in medical specialties, 11 percent in surgical specialties, and 10 percent in other or nonspecified specialties; and 85 percent were graduates of U.S. medical schools. Among all interns in 2002, 41 percent were female, with a mean age of 30.2 years; 88 percent were in medical specialties and 12 percent in surgical specialties; and 74 percent were graduates of U.S. medical schools. Sixty-nine percent of the study participants commuted by car, and their average weekly commute was 91.6±96.2 miles, with 4.4±3.4 hours spent each week commuting.

VALIDATION

Pearson's correlation coefficient for the number of hours reported on the monthly surveys (249.8±75.3 hours) versus the actual number of hours worked, as indicated by daily work diaries completed by a subgroup of 192 participants (244.0±69.3 hours), was 0.76 ($P<0.001$). Likewise, the number of extended work shifts reported on the monthly surveys (3.6±3.3) was highly correlated with the number of extended work shifts reported in the daily diaries completed by 40 participants (3.5±2.8; $r=0.94$, $P<0.001$) (Fig. 1).

WORK HOURS

Interns averaged 70.7±26.0 hours in the hospital weekly; they were awake 67.4±24.4 of those hours and asleep 3.2±4.2 hours (Fig. 2). They reported that they spent an additional 3.9±5.0 hours per week working or studying outside the hospital, classroom, or workplace related to their program and that they spent 0.1±1.6 hours per week working at a job outside their program. Interns averaged 6.5±4.0 days off per month, including weekends, holidays, and allocated time off.

EXTENDED WORK SHIFTS

The mean monthly number of extended work shifts that were reported was 3.9±3.4, with an average duration of 32.0±3.7 hours. The mean number of scheduled monthly shifts of extended duration correlated significantly with the mean number of extended shifts reported on the monthly surveys for participants who completed all 12 surveys ($r=0.71$, $P<0.001$). On 86 percent of monthly surveys, participants reported having worked extended shifts without any night-float coverage (the assignment of another physician to take calls for the on-call participant during an overnight shift for a period of time so that the participant could rest). On only 7 percent of the surveys did they report having had night-float coverage on all extended shifts, and on another 7 percent of the surveys, they reported having had some night-float coverage. Of those report-

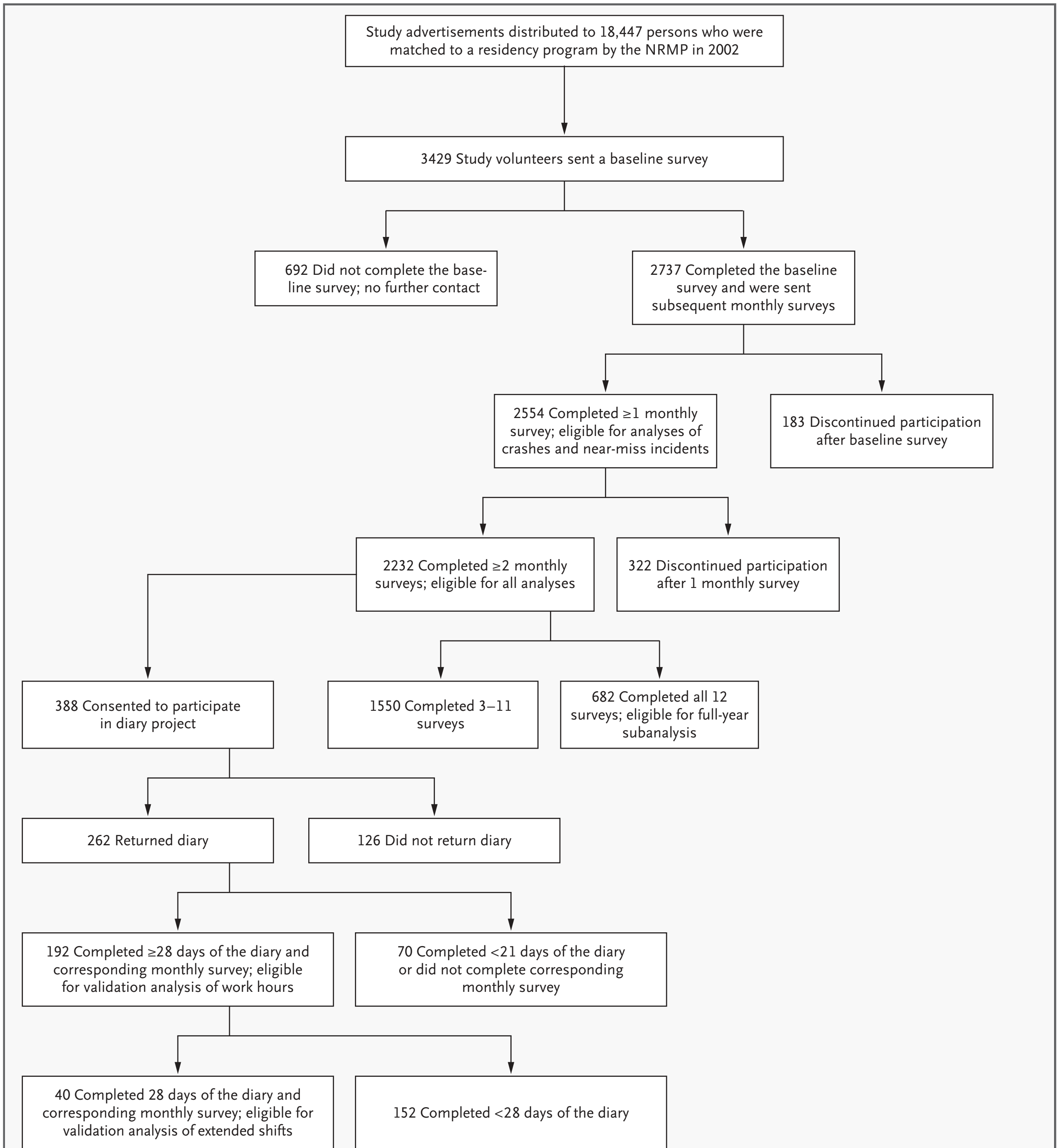

Figure 1. Flow Chart of Participation in the Study.
Although the primary means of advertisement and entrance into the study was through the National Resident Matching Program (NRMP), advertisements were also sent out to U.S. medical school graduates. Therefore, participants in the survey may have included those who arranged their internships outside of the NRMP.

ing night-float coverage, the average number of hours of night-float coverage per extended shift was 7.3±3.3 hours. The average number of sleep hours per extended shift for those with night-float coverage was significantly greater than the number for those without night-float coverage (3.2±1.6 hours vs. 2.6±1.7 hours; t=21.3; P<0.001). The number of sleep hours during extended shifts is shown in Figure 3.

The largest number of continuous hours that interns reported that they were physically at work averaged 27.6±10.5 hours (Fig. 4A). Although a quarter of the interns reported that their longest shift did not exceed 16 hours, the modal length of the longest shift worked for the remaining three quarters of the interns was 33 to 36 hours. The largest number of hours that interns remained continuously awake averaged 25.3±8.3 hours, with a subgroup remaining continuously awake much longer (Fig. 4D), indicating that extended work shifts of 48 to 84 hours still occurred in some residency programs, presumably on weekends.

MOTOR VEHICLE CRASHES

A total of 320 motor vehicle crashes were reported, including 133 that were consequential (i.e., crashes leading to treatment in an emergency department, property damage of $1,000 or greater, the filing of a police report, or a combination of these factors); 131 of the 320 crashes occurred on the commute from work. Documentation was obtained for 82 percent of all crashes. The risk of either a crash or a near-miss incident was significantly greater if the intern was commuting from work after an extended shift than it was after a nonextended shift. The Mantel–Haenszel odds ratio was 2.3 (95 percent confidence interval, 1.6 to 3.3) for motor vehicle crashes (χ^2=21.4, with 1 df; P<0.001) and 5.9 (95 percent confidence interval, 5.4 to 6.3) for near-miss incidents (χ^2=2419.5, with 1 df; P<0.001) (Table 1). To address possible reporting bias, we calculated these ratios for the 682 interns who completed all 12 monthly surveys, and the results were similar: 44 crashes during the commute from work (odds ratio, 2.5; 95 percent confidence interval, 1.4 to 4.7) and 663 near-miss incidents (odds ratio, 5.5; 95 percent confidence interval, 4.8 to 6.3). Crashes that occurred after extended shifts and those that occurred after nonextended shifts followed similar temporal patterns for both the time of day and the day of the week (Fig. 1 of the Supplementary Appendix).

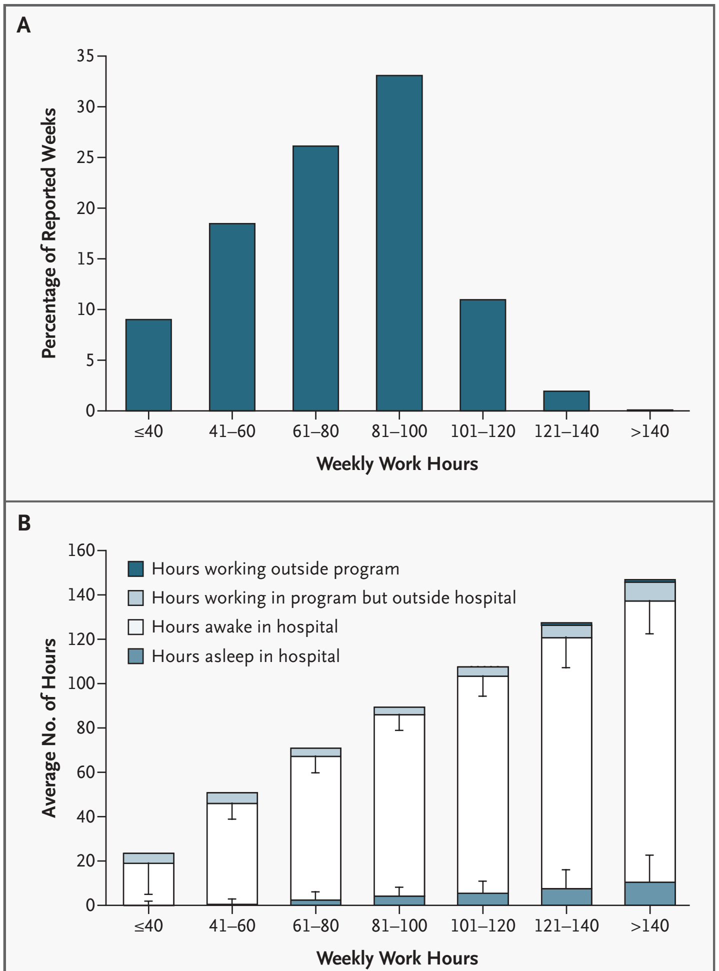

Figure 2. Weekly Hours That Interns Worked as a Percentage of Reported Weeks.

A total of 17,003 person-months of data were collected from a nationwide sample during 2002–2003. The distribution of the percentages of reported weeks with a given range of work hours is shown in Panel A. Panel B shows the average number of hours that interns spent asleep in the hospital, awake in the hospital, studying or working in relation to their program but outside the hospital, and working outside of the program. T bars indicate standard deviations. Interns reported spending an average of 193.4±88.8 of their waking hours in the hospital each month participating in direct patient care (e.g., examining patients; writing progress notes; interpreting diagnostic tests, radiographic studies, and pathological specimens; and consulting with other physicians), 43.3±47.0 hours in duties not directly related to patient care (e.g., completing other paperwork and scheduling tests), 23.5±20.1 hours in structured learning sessions (including classes, laboratories, and grand rounds), and 7.3±16.4 hours teaching students or house staff.

Every extended shift that was scheduled per month increased the monthly rate of any motor vehicle crash by 9.1 percent (95 percent confidence interval, 3.4 to 14.7 percent) and increased the monthly rate of a crash on the commute from work by 16.2 percent (95 percent confidence interval, 7.8 to 24.7

Figure 3. Hours That Interns Slept during Extended Shifts as a Percentage of Monthly Surveys.

percent). The odds ratios for falling asleep while driving or while stopped in traffic increased significantly as the number of extended shifts worked per month increased (Table 2).

DISCUSSION

We found that the odds that interns will have a documented motor vehicle crash on the commute after an extended work shift were more than double the odds after a nonextended shift. Near-miss incidents were more than five times as likely to occur after an extended work shift as they were after a nonextended shift. These findings, which are of particular concern because motor vehicle crashes are the leading cause of death in this age group,[14] are consistent with the findings that sleep deprivation degrades performance[5,15,16] and that the number of fatigue-related crashes increases in proportion to the time spent on task.[6] Given the percentage of interns in our study who commuted by car (69 percent), these data suggest that implementation of a work schedule for interns without any extended shifts[11] could prevent a substantial number of crashes.

We also found, with the use of a validated survey instrument, that in the 2002–2003 academic year, 46.2 percent of the weeks that interns worked averaged more than 80 work hours, and 11.0 percent of the weeks they worked averaged more than 100 work hours. These findings are consistent with earlier studies of self-reported work hours.[1] Overall, interns reported that they were awake during 96.1 percent of their hours in the hospital. Contrary to conventional wisdom, interns whose weekly work hours exceeded the equivalent of three full-time jobs (i.e., >120 hours per week) slept just as small a percentage of their time in the hospital as did interns working the most common weekly work hours (81 to 100 hours per week).

These findings reveal that the schedule of present-day resident physicians in the United States is far different from that of resident physicians 60 years ago who lived, worked, and slept in the hospital in order to follow the evolution of the illnesses of patients who were hospitalized for extended periods.[17] Currently, interns work extended shifts with minimal sleep in the hospital while caring for patients who are hospitalized during the most acute phase of their illness. Yet interns are still anachronistically described as being "on call" during these extended shifts, even though they are working 96 percent of the time. In today's climate of pressure to reduce the length of patients' hospital stays, 85.6 percent of monthly surveys indicated that interns slept four hours or less while working on extended shifts.

Given that there are 168 hours in a week, the opportunity for sleep is severely limited among interns who are working more than 100 hours per week. Their ability to sleep for the recommended eight hours per night becomes physically impossible and inevitably leads to progressively more severe chronic sleep restriction, with its attendant consequences.[15-18]

Most interns in our study routinely worked more than 30 consecutive hours, a schedule that involved at least one night of acute sleep deprivation. It is remarkable that there were 275 reports from interns who worked more than 40 continuous hours, a shift that necessarily involved the intrusion of acute sleep deprivation into a second consecutive night. Given the 1400 person-years of data collected, extrapolation of these results to the wider population of 102,577 person-years worked by residents in U.S. hospitals in 2002–2003[19] suggests that physicians in training worked approximately 20,000 extended shifts that exceeded 40 consecutive hours while caring for patients. Of note, extrapolation from our data suggests that 10 percent of these shifts may have exceeded 64 continuous hours in duration, indicating potential intrusion of acute sleep deprivation into a third consecutive night on a single work shift.

Our study has a number of limitations. First, even

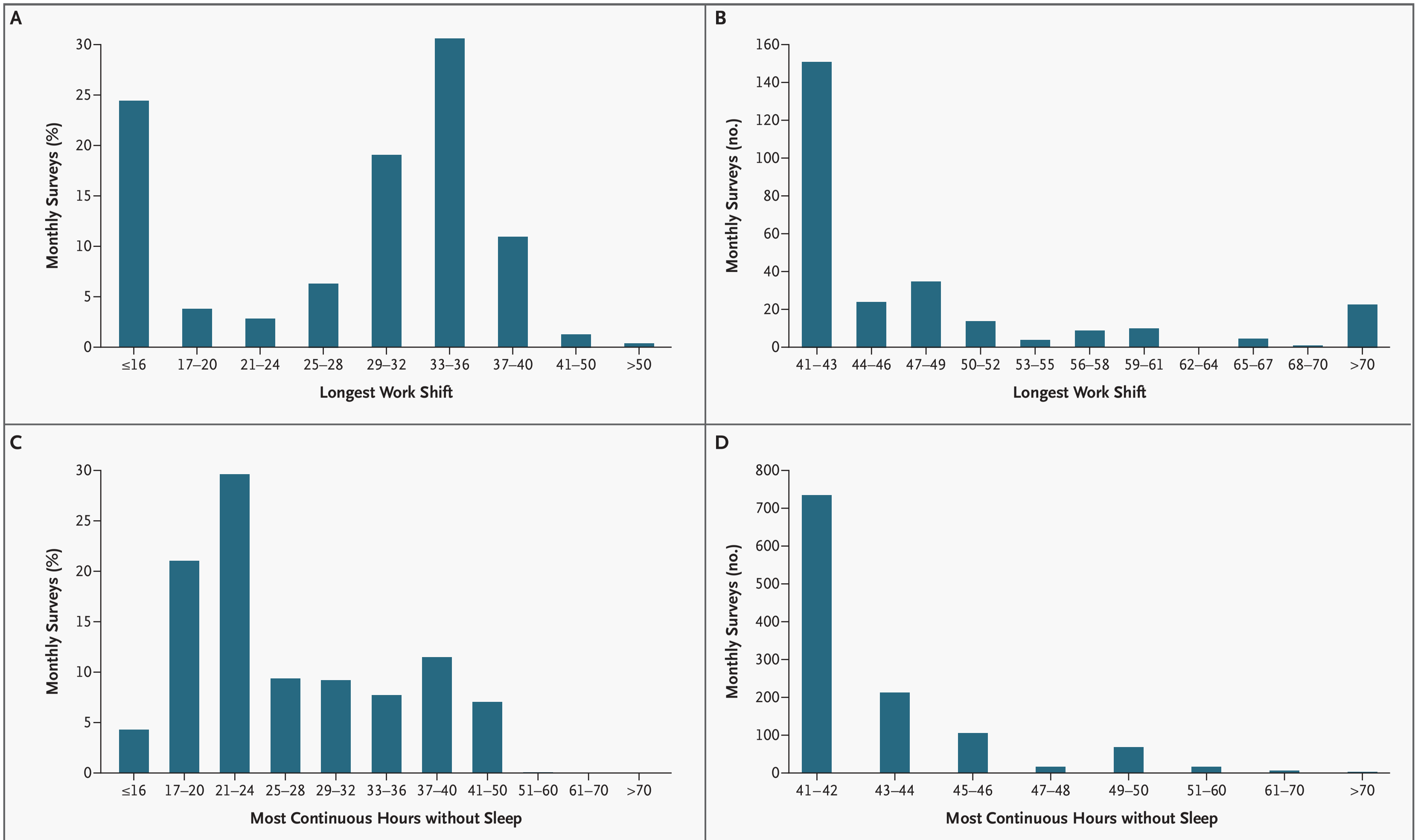

Figure 4. Longest Reported Shifts at Work.

The longest shifts reported by participants are shown in Panel A. Panel B shows the number of surveys in which participants reported shifts that exceeded 40 hours. The greatest number of hours without sleep as a percentage of monthly reports is shown in Panel C. Panel D shows the number of surveys in which participants reported more than 40 continuous hours without sleep. Although the majority of interns worked extended shifts of 30 to 39 hours, some reported working much longer hours — presumably reflecting the long-standing practice, in some programs, of working a “power weekend” (≥48 continuous work hours) in order to obtain one weekend off.

Table 1. Risk of Motor Vehicle Crashes and Near-Miss Incidents after Extended Shifts.*

Variable	Extended Work Shifts (≥24 hr)	Nonextended Work Shifts (<24 hr)
Crashes		
No. reported	58	73
No. of commutes	54,121	180,289
Rate (per 1000 commutes)	1.07	0.40
Odds ratio (95% CI)	2.3 (1.6–3.3)	1.0
Near-miss incidents		
No. reported	1,971	1,156
No. of commutes	54,121	180,289
Rate (per 1000 commutes)	36.42	6.41
Odds ratio (95% CI)	5.9 (5.4–6.3)	1.0

* A within-person case-crossover analysis was used to assess the risks of motor vehicle crashes and near-miss incidents among interns during commutes after extended shifts as compared with nonextended shifts. A two-by-two table was constructed for each intern who reported either a crash or a near-miss incident, consisting of the number of crashes or near-miss incidents after an extended shift, the number of crashes or near-miss incidents after a nonextended shift, the number of extended shifts that did not precede a crash or a near-miss incident, and the number of nonextended shifts that did not precede a crash or a near-miss incident. CI denotes confidence interval.

though we had a response rate of 80 percent from interns who volunteered to participate, those who did may not be representative. However, the distributions of age and residency-program type of our participants were comparable to those in the entire National Resident Matching Program. Notably, participants were not apprised of the study hypotheses, and the questions regarding our primary variables of exposure (work shifts of extended duration) and outcome (motor vehicle crashes) were validated and documented, respectively, and distributed among numerous other questions. As such, we believe that it is highly improbable that the participants — even those with a specific interest in the work hours of residents — could have deliberately affected the specific data regarding crash and near-miss rates that we report here. Second, the case-crossover analysis cannot account for the contribution of within-person factors that may have been covariates with exposure status. For example, interns probably had higher average blood levels of caffeine during their commutes after extended shifts as compared with commutes after nonextended shifts — a factor that may have had an effect on our results.[20] However, even if extended shifts were to elicit behavior that affected risk, this elicited behavior would not obviate the potential causal relationship between exposure to extended shifts and motor vehicle crashes. Third, our prospective analysis may have been confounded by uncontrolled covariates, although the results of that analysis were consistent with the results of our case-crossover analysis, which was free of such confounders because each participant served as his or her own control. Fourth, by collecting data on a monthly basis, we attempted to reduce, but could not eliminate, the effect of recall bias. Fifth, reporting bias could have confounded the results of our case-crossover analysis if participants preferentially completed monthly surveys after having had a motor vehicle crash. However, the prospective analysis, which was relatively free of this type of reporting bias, yielded similar results. Furthermore, case-crossover analysis of the subgroup of participants who completed all the surveys yielded an odds ratio of 2.5 (95 percent confidence interval, 1.4 to 4.7) for having a motor vehicle crash after working an extended shift (as compared with a nonextended shift) that was similar to that of the entire study population (odds ratio, 2.3; 95 percent confidence interval, 1.6 to 3.3). Overall, the convergence of our crash results with the use of two independent methods of exposure-data collection strongly supports our conclusion that an increased risk of crashes and near-miss incidents is associated with working extended shifts.

The increased rate of actual motor vehicle crashes and near-miss incidents during interns' commutes after extended work shifts that we have documented has legal implications, since drivers in both the United States[21,22] and Great Britain[23] have already been convicted of vehicular homicide for driving when impaired by sleepiness. Furthermore, the state of New Jersey has recently amended its vehicular-homicide statute to add to the definition of reckless driving "driving after having been without sleep for a period in excess of 24 consecutive hours," a revision that explicitly subjects drivers in that state to a conviction of criminal homicide under such circumstances.[24] Similar legislation is pending in New York, Massachusetts, and Michigan. Moreover, appeals courts in two states have ruled that an employer's responsibility for fatigue-related crashes can continue even after an employee has left work, similar in concept to the liability incurred by people who serve alcohol to drivers who are subsequently involved in alcohol-related mo-

Table 2. Odds Ratios for Falling Asleep while Driving or while Stopped in Traffic, According to the Monthly Number of Extended Work Shifts.*

Question	0 Extended Work Shifts				1–4 Extended Work Shifts				≥5 Extended Work Shifts			
	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio (95% CI)	No. of Person-Months	No. of Person-Months with Positive Response	Rate of Positive Response	Odds Ratio (95% CI)
Did you nod off or fall asleep while driving?	3035	199	0.066	1.00	3068	286	0.093	1.82 (1.73–1.93)	6933	872	0.126	2.39 (2.31–2.46)
Did you nod off or fall asleep while stopped in traffic?	3039	311	0.102	1.00	3078	508	0.165	1.74 (1.68–1.81)	6944	1608	0.232	3.69 (3.60–3.77)

* Data are from interns' monthly reports on extended shifts. The number of person-months varies because nonresponses were eliminated from the analysis. Rates represent the proportion of months in which participants reported one or more incidents of nodding off or falling asleep, regardless of how many incidents were reported. CI denotes confidence interval.

tor vehicle crashes.[25,26] The Department of Surgery at the University of Michigan has taken the initiative to address this concern by offering round-trip taxicab vouchers to surgical residents on request (Mulholland M: personal communication). However, the impairment of judgment about one's own ability to perform after sleep deprivation[15] could limit the use of such transportation vouchers by residents, even when they are available.

In 2005, the current work-hour guidelines of the Accreditation Council for Graduate Medical Education still allow interns in the United States to work 30 consecutive hours every other shift. This practice has recently been prohibited by the European Union, which stipulates a "minimum daily rest period of 11 consecutive hours per 24-hour period" (thereby limiting the duration of shifts for all physicians to 13 hours), although the regulation includes some exceptions and a controversial opt-out provision.[27] Our data indicate that scheduling physicians to work such extended shifts, which our group has recently shown to increase the risk of failures of attention[11] and serious medical errors,[28] poses a serious and preventable safety hazard for them and other motorists. These results have important implications for scheduling practices in medical-residency programs.

Supported by grants from the National Institute for Occupational Safety and Health (1 R01 OH07567), which provided a certificate of confidentiality for data protection, and by the Agency for Healthcare Research and Quality (RO1 HS12032). Dr. Cronin is the recipient of a National Research Service Award from the Agency for Healthcare Research and Quality (F32 HS14130); Drs. Cronin and Barger are the recipients of National Heart, Lung, and Blood Institute fellowships in the Program of Training in Sleep, Circadian, and Respiratory Neurobiology at Brigham and Women's Hospital (T32 HL079010); and Dr. Ayas is the recipient of a New Investigator Award from the Canadian Institutes of Health Research/British Columbia Lung Association, a Michael Smith Foundation Scholar Award, and a Departmental Scholar Award from the University of British Columbia; Dr. Czeisler is supported in part by the National Space Biomedical Research Institute through the National Aeronautics and Space Administration (NCC9-58).

We are indebted to the interns who took time from their busy work schedules to participate in this study; to the National Resident Matching Program and the Association of American Medical Colleges (especially Jordan J. Cohen, Paul Jolly, and the Division of Medical School Services and Studies) for their assistance with recruitment; to DeWitt C. Baldwin and Steven R. Daugherty for their assistance in designing the questionnaires; to Tim Ayas and Sharlene Hudson for their help in reviewing the questionnaire; to Michael Schulzer for his assistance with data analysis; to Steven W. Lockley for his assistance with the study design and data interpretation; to Darrell Drovnich and the National Sleep Foundation for information about legislation regarding driving while drowsy; to Joseph B. Martin for his support and encouragement; to Cherelyn Werre and Mohammed Rasheed at Pearson NCS for their commitment to this project; and to K.C. Malvey, Patrick Glew, and Christian Lima for their assistance in crash documentation and validation procedures.

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Safety Implications of Multi-day Driving Schedules for Truck Drivers: Comparison of Field Experiments and Crash Data Analysis

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ABSTRACT

The detailed analysis of pre-existing crash and non-crash data representing an estimated 16 million vehicle miles of travel has revealed strong consistency between crash analysis using data from the 1980s and field experiments conducted in the 1990s. Time of day of driving, is associated with crash risk: night and early morning driving has elevated risk in the range of 20-70% compared to daytime driving. Overall, 16 of 27 night and early morning driving schedules had elevated risk. Irregular schedules with primarily night and early morning driving had relative risk increases of 30-80%.

In addition, there remains a persistent finding of increased crash risk associated with hours driving, with risk increases of 30-over 80% compared to the first hour of driving. These increases are less than previously reported and are of similar magnitude to the risk increases due to multi-day schedules. Finally, there is some evidence, although it is far from persuasive, that there may be risk increases associated with significant off-duty time, in some cases in the range of 24-48 hours. The implication is that “restart” programs should be approached with caution.

Areas for additional research include further studies of crash risk associated with extended off-duty time, closer examination of irregular schedules that better reflect truckload operations and analysis of irregular schedules with primarily daytime driving (largely non-existent in this data set) to further explore the effect of variability.

1. INTRODUCTION

1.1 Background

Management of driver hours of service (HOS) for commercial vehicle operators has been a continual safety challenge. After over 50 years with the same regulations, the USDOT implemented changes in the HOS in January of 2004, only to have them overturned in a recent law suit. The European Union has also been active in the area, considering changes in their regulations as this paper is written (Usdaw, 2004).

While there are many reasons why managing service hours is a challenging task, one of the most perplexing aspects is the inconsistency in research findings concerning the effect of driving schedules on driver performance and safety. A recent major study sponsored by USDOT (Wylie, et. al., 1996), using instrumented vehicles, off-line tests of driver performance, video recording of driver faces on the road, physiological monitoring and a series of driver ratings through surveys, found that the principle factor associated with a decline in driving performance was time of day. Number of hours driving (time on task) and cumulative number of days driving were not strong or consistent predictors. The study was one of the most extensive field studies of its kind involving 80 drivers measured for performance during revenue-producing runs for a carrier operating in both the US and Canada (in order to allow legal driving for up to 12 hours consecutively).

These findings stand in contrast to work with carrier crash data conducted over several years (Jovanis, et. al., 1991; Kaneko and Jovanis, 1992; Lin et. al., 1993; Lin, et. al., 1994), in which driving time has been most strongly associated with increases in crash risk, and night driving, while significantly associated with crash risk in some situations, was neither consistently of the same magnitude nor significance. Others have noted that the use of different performance measures often yield different findings; the search for convergent validity is important (Wylie et. al., 1996)

The objective of this paper is to examine the effect of multi-day driving and continuous driving (time on task) on crash risk. This is an exploratory study using pre-existing data to seek convergent results. It is recognized that the crash data used in this analysis is from the 1980's and that the measurements from Driver Fatigue and Alertness Study (DFAS) were conducted in the mid-1990s. Nevertheless, the nature of the driving task is similar and physiological capabilities of humans are similar. The research explores whether a more detailed examination of time of day of driving, particularly over multiple days, indicates associations with crash risk. The paper concludes with a summary and a review of the implications of the findings for future consideration of changes in HOS.

2. DATA DESCRIPTION

All crash data are obtained from a national less-than-truckload firm. At the time of data collection, the company conducted operations from coast to coast, with no sleeper berths. The findings are thus not intended to typify the trucking industry as a whole. The carrier undertook scheduled service between its own terminals, with significant knowledge of the time to be taken to complete trips and safety supervisors in the field to verify driver behavior. This reduces the incentive for drivers to misstate driving hours on their logs. While an independent assessment of driving hour data was not feasible, given the type of service provided and the steps taken by the company to adhere to U.S Department of Transportation (U.S. DOT) service hour regulations, the researchers believe the driving hour data reflect operations that adhere to HOS regulations in existence at the time.

The analyses presented in this paper use data from 1984 through 1985. The data set consists of accident-involved drivers and non-accident-involved drivers. For accident involved drivers, the day of the crash serves as the starting point for additional data collection (this day can be called the day of interest). For each crash-involved driver, driving logs are assembled and coded which represent the duty status of the driver on the accident-involved day as well as the previous 7 days. These data are used to develop a detailed characterization of the driving status of the accident-involved drivers for each 15 minutes of each day for an eight day period (the accident day and 7 prior days). This data structure corresponds to the hours of service policy in effect at the time of operations (maximum multi-day driving or on-duty time of 70 hours in eight days).

In addition to the crash data, a data set of 2 non-accident-involved drivers was assembled by having a person from the trucking firm randomly select 2 sets of driver logs from the same terminal as each accident-involved driver. In this way, 2 non-accident drivers are selected as controls for each crash involved driver, where the selection from the common terminal serves as a mechanism to help control for driving environment. A day and a trip within the day were selected at random for each non-crash driver so there would be a starting point of a randomly selected trip that would be comparable to the accident trip for the crash-involved drivers (again, this day that begins the measurement of the driving schedule is referred to as the day of interest).

The data set includes 954 accident-involved drivers and 1506 non-accident drivers in 1984; 887 accident drivers, and 1604 non-accident drivers in 1985 for a total sample size of 5050 drivers. This is a large data set for a truck safety study, estimated to encompass approximately 16 million vehicle miles of travel (assuming an average of 8 hours driving over the 8-day period and an average speed of 50 mph). There are many possible schedules for drivers over an eight-day period; it is only through the use of a large data set that common schedules can be identified for enough drivers to allow statistical estimation of crash risk.

3. METHODOLOGY

Under the hours-of-service regulation enforced during the time of data collection, drivers could drive for a maximum of ten hours followed by a mandatory minimum eight-hour off duty period. Driving time was divided into 10 one-hour periods, starting with the first hour.

3.1 Identification of multi-day driving schedule

Previous research (Jovanis et. al., 1991; Kaneko and Jovanis, 1992; Lin, et. al., 1993; Lin, et. al., 1994) used cluster analysis on a small subset of the study data (either 6 months or 1 year of crash and non-crash data). As a result, only 10 sets of driving schedules were identified.

For this analysis, data for a full 2 years were used. As a starting point, the Driver Fatigue and Alertness Study was carefully reviewed and an attempt made to extract driving schedules from the data set that included those from DFAS (Wylie, et. al., 1996; p 3-6 to 3-7). In particular, an attempt was made to identify drivers with regular and irregular schedules over multiple days. It was not possible to identify drivers with 12 hour driving times, as used in the DFAS, but the pattern of day and night driving and irregularity of schedules were specifically sought within the crash data.

Drivers were manually grouped based upon their multi-day schedule by searching through the record of the 5050 drivers to find those who started driving at approximately the same time every day; for example, starting to drive at 10AM the day before the crash (or more generally the day of interest). An accuracy of plus or minus 2 hours was used to group drivers with similar driving schedules. The set of drivers starting at 10AM on the day before the day of interest was then searched further for those drivers who started driving at 10AM the previous day (2 days before the crash). This process was continued for 3 and 4 days before the crash as well. While searching back in time from the day of interest, the sample size of drivers was successively reduced, so in some cases it was only possible to go back one or two days (see Table 1 for summary of manually extracted driving schedules and their sample sizes). The occurrence of a crash on the day of interest was irrelevant to this search; the driving schedules on the days prior to the crash (or randomly selected matching trip) were the only information used to form the schedules.

Figure 1, an example of one manually derived driving schedule, helps illustrate the method and the outcome of the driver grouping. The figure illustrates the percentage of drivers within the group that are on duty or driving for every 15 minutes for 7 days prior to the day of interest (here time zero is midnight). Each day is represented by 24 hours, so hour 168 is midnight on the beginning of the eighth day (the day of interest). In this particular driving schedule, over 90% of the drivers are on duty or driving starting at around 10AM for the 2 days prior to the day of interest. Prior to these 2 days, the drivers have a less well-structured pattern of driving, with at most 40% of the drivers on duty at any one time. Note also that there is virtually no early morning driving for the 2 days prior to the day of interest. This grouping then represents drivers with a regular, largely daytime driving schedule for 2 consecutive days. The figure contains 2 very similar lines, one representing data from 1984 and one from 1985, even though the procedure would not necessarily lead to this outcome.

Table 1 summarizes all 23 manually-developed driving schedules. Note that schedules C21 through C28 are regularly scheduled drivers who started driving at either 10AM or midnight for 1-4 days before the crash (Figure 1 represents schedule C22). These particular times were selected because they match the time of day used in the regularly scheduled driver in DFAS. In addition to time of day, there is an interest in the off duty status of drivers. Drivers, who had one or more days off duty and regular driving on previous days, are represented in driving schedules C29 to C35.

Irregularly scheduled drivers were first extracted based upon the irregular schedules driven in DFAS. Schedules C36 and C37 were derived from the description of the irregular schedule in the DFAS report (Wylie, et. al., 1996). Additional irregular schedules included:

- drivers who alternated the start of driving between 7PM and 10PM (schedules C38 through C41),
- drivers starting driving at 10PM the day before the crash and shifting ahead in time by 3 hours (to 7 PM and then 4PM respectively),
- drivers with no driving the 2 days prior to the crash and very infrequent driving previous to those days; these drivers were grouped in schedule C43.

An example of irregularly scheduled driver group C39 is shown in Figure 2. As in Figure 1, the 2 lines representing separate years of data are very similar.

After allocation to the 23 manually derived groups, there remained approximately 2500 drivers unallocated. Cluster analysis was used to allocate these remaining drivers to one of 20 clusters using the same procedure as the previous research (e.g. Kaneko and Jovanis, 1991). The schedules derived from cluster analysis were assigned schedule numbers C1 through C20.

Figure 3 is a schedule identified through cluster analysis notably:

- The drivers in this schedule (109 in all) drive during the night and early morning hours starting 4 days and continuing during the 3rd day before the day of interest.
- Two days before the day of interest (around hour 144) there is little driving with most drivers seeming to be off duty during this time.
- On the day before the day of interest, drivers again start to drive, but a bit earlier than before, starting at times more like late afternoon and early evening.
- Around the night of the 4th day before the crash day, 90% or more of the drivers are on duty; there are also very few times when no drivers are on duty. This is in contrast to the manually derived schedules which are more "precise" in the sense that they have more well-defined peaks and troughs.

Table 4 contains a qualitative description of the nature of the driving schedule for each of the 20 clusters, including the sample size.

3.2 Characterization of driving time

One of the most important aspects of early studies of safety and hours of service (e.g. Harris, et. al., 1972; Mackie and Miller, 1978) is the need to characterize continuous driving by using the notion of "survival". Specifically, a driver who has a crash after driving 9 hours, for example, has successfully "survived" the first 8. Any model that attempts to characterize the probability of a crash as a discrete outcome must recognize in its statistical formulation that most drivers can thus be considered to have multiple outcomes during a crash-involved trip: the survival for hours prior to the crash and a crash outcome (i.e. a failure) for the time period of the crash. Early statistical models of driving time crash risk proposed the use of survival theory in recognition of this phenomenon (Jovanis and Chang, 1989; Chang and Jovanis, 1990).

Subsequent research (e.g. Lin, et. al., 1993) used a data replication scheme and logistic regression to capture the survival effect. In the case described earlier of a driver having a crash in the ninth hour of driving, there is a need to have each prior hour coded individually with an outcome of a non-accident; this would occur for each of the 8 hours prior to the crash event. In addition, the 9^{th} hour would be coded as the alternate outcome, a crash. Similarly a 9 hour trip without a crash would need to be replicated for all 9 hours with a non-accident outcome. It is only through this replication that the logistic regression is able to account for the survival phenomenon. There is evidence in the statistical literature to support the use of this type of model (e.g. Brown, 1975; Hosmer and Lemeshow, 1989). The model is thus:

$$P_{it} = P(Y_{ti} = 1 \mid Y_{t'i} = 0 \text{ for } t' < t, X_i) = \frac{\exp[g(X_i, t, \beta)]}{1 + \exp[g(X_i, t, \beta)]} \tag{1}$$

The model is interpreted as the probability that driver *i* has an accident (outcome Y = 1) at time *t*, given survival until that time (i.e. an outcome Y = 0, for all time periods *t´* prior to time period *t*) is given by the familiar logistic function with time *t*, predictor variables, *X*, and estimated parameters, β. A linear addition function is assumed for $g(X, t, \beta)$.

4. EMPIRICAL RESULTS AND INTERPRETATION

Two sets of models were estimated with the data. Model 1 is developed to assess the effect of driving time where the time is divided into 10, one-hour periods with the first hour (designated T0) serving as the baseline. The second model retains driving time and adds as covariates the 43 driving schedules manually derived and developed by cluster analysis. The interpretation of the model is that a parameter being statistically different from zero implies that a driver with that characteristic has a significantly higher crash risk, *compared to the first hour*. In this way the model estimates the relative risk of a crash, compared to the baseline. The baseline for multi-day driving schedules is schedule C22, daytime driving for 2 days prior to the day of interest; changes in risk for driving schedules are relative to this baseline risk.

4.1 Interpretation of Model 1

As seen in Table 3, the positive parameter in each covariate represents an increase in the log of the odds ratio or, more simply, an increase in the probability of accidents among the drivers in the specific driving time category compared to the drivers in the baseline category (i.e. the first hour). All driving hour variables are significant at $\alpha = 0.05$, which leads to the rejection of the hypothesis of constant hazard over time. The crash risk increases slightly, but significantly, as driving time increases through the fourth hour of driving. Statistical tests of equality of the parameters 1 through 4 fails to reject the null hypothesis that the parameters are equal. Parameters for hours 5-10, however, are all significantly higher than the baseline first hour, and significantly higher than hours 2-4, but are unable to be differentiated from each other in additional statistical tests. One may thus infer that crash risk appears to increase only slightly between the first and 4th hour of driving, increases significantly in the fifth hour, and is sustained at a higher level through hour ten. Importantly, the risk trend with driving time differs in comparison to earlier findings (e.g. Lin, et. al., 1993): the risk increase after hour 4 (variable T5) is not nearly as steep, particularly in the last hour of driving. While unable to statistically differentiate the crash risk, the trend in risk is a general increase from hours 5 through 10.

4.2. Interpretation of Model 2

Estimation results for model 2 are summarized in Table 4. All the driving time variables are significant and have similar relative magnitudes and interpretation to those in model 1.

The pattern of significance for the multi-day driving schedules is of particular interest. In keeping with the recommendations of others in the safety field (e.g. Hauer, 2004) the discussion of each parameter will be conducted without a strict use of null hypothesis tests of significance; a very liberal level of significance (any with alpha less than .25) will be used to screen driving schedules and identify those of possible interest, a procedure consistent with the research being exploratory in nature.

Using the screening criteria of alpha less than 0.25, there are twenty one schedules identified for further exploration (specifically C1, C2, C7-C9, C12, C13, C16, C17 and C20 derived from the cluster analysis; C25, C27, C31, C32, C34, C35, C38-C40, C42, and C43 derived manually). Importantly, 16 of the 21 involve increased crash risk associated with night and early morning driving, irregular schedules or both. Closer examination indicates that 16 of the 27 night and early morning driving schedules (specifically C1, C7-C9, C12, C13, C16, C17, C20, C25, C27, C 32, C38-C40, C42) have elevated crash risk compared to the baseline.

The exceptions to the general trends are also of interest. There is a reduction in risk for schedule C2, consistent regular daytime driving for all 7 days, further evidence of the safety benefits of regular driving schedules. Schedule C31, drivers who started driving at midnight 2 days prior to the day of interest but had a day off in between, is one of the few driving schedules that showed a *decrease in crash risk associated with a day or more off-duty*. However, schedules C34 and C35 indicate *increased* risk for *daytime* driving, immediately after 2 full days off duty, as does schedule C32 for drivers starting at midnight after 2 days off duty.

Lastly, schedule C43 consists of drivers who are off duty for the 2 days prior to the day of interest and prior to that are infrequently driving. This schedule may be reflecting drivers from the "extra board" who may differ in some other fundamental ways from other drivers at the firm; for that reason they are separated from the other schedules.

Taken as a whole, Model 2 shows rather conclusively that night and early morning driving results in increased crash risk relative to daytime driving, and that irregular schedules during night also have elevated risk. The benefits of extended off-duty time are unclear: in some cases there are risk decreases, but there are also several cases of risk increases.

Comparison of parameter scale for driving schedule and driving time indicate that many schedules have a relative risk increase comparable to driving time. For example, clusters C32, C34, C38, C40, and C42 all have parameters in the range of 0.5 to 0.7, indicating a relative risk increase of 60 to 90% compared to the baseline (see Table 2, column 5); previous modeling did not indicate risk increases of nearly these magnitudes.

5. DISCUSSION

Among the schedules that involved night driving and no days off immediately prior to the day of interest, 9 (schedules C1, C12, C13, C16, C17, C20, C25, C27, C38) out of 12 schedules have elevated risk (see Figure 4 for summary). Drivers with one or two days off immediately prior to the day of interest have elevated risk in 3 (C7, C8, C32) of 7 cases; and, drivers with irregular schedules have elevated risk in 4 (C9, C39, C40, C42) of 8 cases. These detailed comparisons further highlight the elevated risk posed by night driving compared to the baseline regular daytime driving.

There is also evidence that even as much as a 24 hour off-duty period may not be sufficient to alleviate the elevated risk of night and early morning driving. Driving schedules C7 to C9 (averaging about 100 drivers in each group) involve drivers with night and early morning driving and include large amounts of off-duty time one or two days prior to the day of interest; all show elevated crash risk. A similar result appears for schedule C32, although the sample size is only 19 drivers. These findings raise questions about the efficacy of a "restart" period (Smiley and Heslegrave, 1997); there appears to be evidence from this analysis that 24 and perhaps 48 hours may be insufficient, particularly for night and early morning driving. Further, the elevated risk associated with schedules C34 and C35 indicate that two days off duty prior to driving may actually *elevate risk*, compared to more regular schedules even for day time driving. This may be due to the relative unfamiliarity of driving a heavy vehicle again, or other personal factors, but the evidence exists for those driving at night as well as during the day.

The inconsistency with the DFAS study is the continued importance of driving time (time on task) as a significant correlate of crash risk. This result has been consistently obtained by one of the co-authors, admittedly using partially overlapping data sets. It is interesting to recall, however, that increases in crash risk beyond the 4th hour was also observed in the 1970's (Harris, et. al. 1972). This remains an area of additional study.

Examining the findings in the context of the HOS implemented in 2004 in the US, there appears to be support for the changes in regulations that sought more regular schedules. Several of the driving schedules with the highest relative crash risk (e.g. C38, C39 and C40) involved irregular schedules. While the sample size in each group was small, the increase in relative risk was large and significant. Previous studies using smaller crash data sets were unable to identify this important effect.

6. CONCLUSIONS

The detailed analysis of drivers representing an estimated 16 million vehicle miles of travel has revealed a stronger consistency between field experiments, such as DFAS, and crash data analysis than has previously been reported. In particular:

a. The time of day of driving is significantly associated with increased crash risk: drivers with predominately night and early morning schedules have crash risk 20-70% higher than drivers in the baseline regular daytime driving schedule.

b. Drivers with irregular schedules also have elevated risk, again in the 30-80% range.

These findings of convergent validity are an important independent verification of some of the DFAS findings.

In addition, there remains a persistent finding of increased crash risk associated with hours driving, with risk increases of 30-over 80% compared to the first hour of driving. These increases are less than previously reported and are of similar magnitude to the risk increases due to multi-day schedules. Finally, there is some evidence, although it is far from persuasive, that there may be risk increases associated with significant off-duty time, in some cases in the range of 24-48 hours. The implication is that "restart" programs should be approached with caution.

Areas for additional research are many, including further studies of crash risk associated with extended off-duty time, closer examination of irregular schedules that better reflect truckload operations and analysis of irregular schedules with primarily daytime driving (largely non-existent in this data set) to further explore the effect of variability. These findings, taken as a whole, support the case of continued research and evaluation of HOS along with other truck safety regulatory actions.

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Table 1 Manually-identified Driving Schedules

Schedule Number (Sample Size)	4 Days Prior to Crash	3 Days Prior to Crash	2 Days Prior to Crash	1 Day Prior to Crash
	Created using cluster analysis software			
C21 (481)	-	-	-	10 am
C22 (125)	-	-	10 am	10 am
C23 (28)	-	10 am	10 am	10 am
C24 (19)	10 am	10 am	10 am	10 am
C25 (517)	-	-	-	12 am
C26 (134)	-	-	12 am	12 am
C27 (52)	-	12 am	12 am	12 am
C28 (17)	12 am	12 am	12 am	12 am
C29 (32)	-	-	10 am	Off-Duty
C30 (20)	-	10 am	10 am	Off-Duty
C31 (41)	-	-	12 am	Off-Duty
C32 (19)	-	12 am	12 am	Off-Duty
C33 (11)	12 am	12 am	12 am	Off-Duty
C34 (29)	-	10 am	Off-Duty	Off-Duty
C35 (25)	10 am	10 am	Off-Duty	Off-Duty
C36 (83)	-	-	3:30 pm	11 am
C37 (20)	-	7 pm	3:30 pm	11 am
C38 (657)	-	-	-	10 pm
C39 (113)	-	-	7 pm	10 pm
C40 (67)	-	10 pm	7 pm	10 pm
C41 (24)	7 pm	10 pm	7 pm	10 pm
C42 (20)	-	4 pm	7 pm	10 pm
C43 (362)	-	-	Off-Duty	Off-Duty

Table 2 Description of Driving Schedules Derived from Cluster Analysis

Cluster #	Description	Sample Size
C1	Regular night and early morning driving for 3 days prior to day of interest	86
C2	Consistent regular daytime driving for all 7 prior days	200
C3	Afternoon and night driving 1 day prior; day off 2 days prior, and afternoon and night driving previous days	146
C4	Little driving 2 days prior; consistent daytime driving prior days	114
C5	Little driving 1 day prior; daytime driving 2-3 days prior	63
C6	Early morning to noon driving consistently for all days	152
C7	Little driving 1 day prior; night and early morning driving consistently for 4 – 5 days prior to day off.	109
C8	Night and early morning driving; almost all drivers on duty 5 days prior to day of interest; decreasing numbers on duty to 1 day prior	121
C9	3-4 days off duty just prior to day of interest, but night and early morning prior to that	97
C10	Consistent daytime driving for 4 days prior; little driving 6-7 days prior	123
C11	Night and early morning driving 2-3 days prior; largely a day off 4 days prior; consistent night and early morning driving before that	101
C12	Consistent afternoon and late night driving for 2 days prior; little driving for 3-5 days prior	182
C13	Evening and night driving day before, with some drivers on duty 2 days before; little driving 3-5 days prior	146
C14	Late night driving night before; some are off duty 2 days before, but very consistent night and early morning driving 3-7 days before	113
C15	Intermittent daytime driving 1-3 days before; very consistent daytime driving 4-7 days before	86
C16	Consistent afternoon and night driving for 4 days prior	156
C17	Night and early morning driving for 3 days prior; almost no driving5-7 days prior	148
C18	Very consistent daytime driving 1-2 days prior; day driving before that but not with high % of drivers	97
C19	Daytime driving 2 days before; minimal driving 3-7 days prior	138
C20	Night and early morning driving 3-4 days prior; 5 days prior is off duty; 6-7 days prior night and early morning	104

Table 3 Model 1 Estimates: effect of driving time

	coefficient	S.E.	Sig.	Exp(B)
Constant	-1.238	.707	.080	.290
D.H. < 1*				1.000
1 ≤ D.H. < 2	.229	.113	.043	1.257
2 ≤ D.H. < 3	.348	.111	.002	1.417
3 ≤ D.H. < 4	.287	.114	.011	1.333
4 ≤ D.H. < 5	.623	.107	.000	1.865
5 ≤ D.H. < 6	.601	.109	.000	1.825
6 ≤ D.H. < 7	.608	.111	.000	1.837
7 ≤ D.H. < 8	.678	.112	.000	1.969
8 ≤ D.H. < 9	.555	.122	.000	1.741
9 ≤ D.H.	.746	.135	.000	2.108

* baseline category

Table 4 Driving time and multi-day schedule model estimates

	B	S.E.	Sig.	Exp(B)
Constant	-3.688	.186	.000	.025
T1	.230	.113	.041	1.259
T2	.351	.111	.002	1.421
T3	.292	.114	.010	1.339
T4	.632	.107	.000	1.882
T5	.612	.109	.000	1.844
T6	.625	.111	.000	1.867
T7	.700	.112	.000	2.014
T8	.581	.122	.000	1.788
T9	.786	.135	.000	2.194
C1	.284	.247	.251	1.328
C2	-.271	.223	.225	.763
C3	.197	.222	.373	1.218
C4	.238	.233	.307	1.269
C5	.172	.275	.532	1.188
C6	.129	.222	.560	1.138
C7	.404	.230	.079	1.498
C8	.363	.226	.109	1.437
C9	.301	.235	.200	1.352
C10	.080	.236	.735	1.083
C11	.166	.243	.495	1.180
C12	.240	.210	.252	1.272
C13	.262	.219	.232	1.299
C14	.086	.238	.716	1.090
C15	-.229	.283	.418	.796
C16	.286	.215	.182	1.332
C17	.254	.217	.243	1.289
C18	.150	.245	.540	1.162
C19	-.039	.233	.866	.962
C20	.289	.235	.219	1.334
C21	.059	.192	.759	1.061
C23	.251	.451	.579	1.285
C24	-.480	.534	.368	.619
C25	.311	.183	.090	1.365
C26	.115	.226	.609	1.122
C27	.370	.295	.210	1.447
C28	-.283	.535	.597	.754
C29	-.150	.420	.721	.861
C30	-.457	.534	.392	.633
C31	-.567	.418	.175	.567
C32	.608	.384	.114	1.837
C33	-.472	.736	.522	.624
C34	.513	.332	.123	1.670
C35	.451	.367	.219	1.570
C36	-.099	.274	.717	.905
C37	-.294	.484	.544	.745
C38	.647	.182	.000	1.909
C39	.482	.231	.037	1.619
C40	.605	.248	.015	1.831
C41	.337	.366	.357	1.401
C42	.764	.370	.039	2.146
C43	.479	.197	.015	1.614

Figure 1 Example of Regular Multi-day Driving Schedule – Start Driving at 10AM for 2 Days Prior to Day of Interest

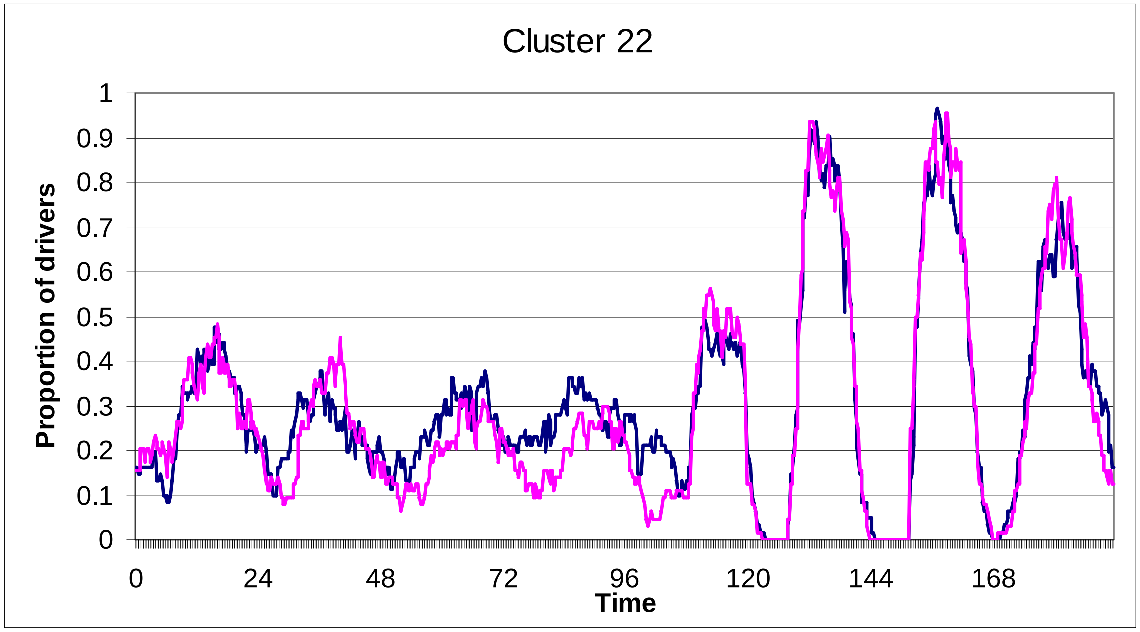


Figure 2 Example of Irregular Schedule – Initiate Driving 10PM One Day Prior and 7PM Two Days Prior to Day of Interest

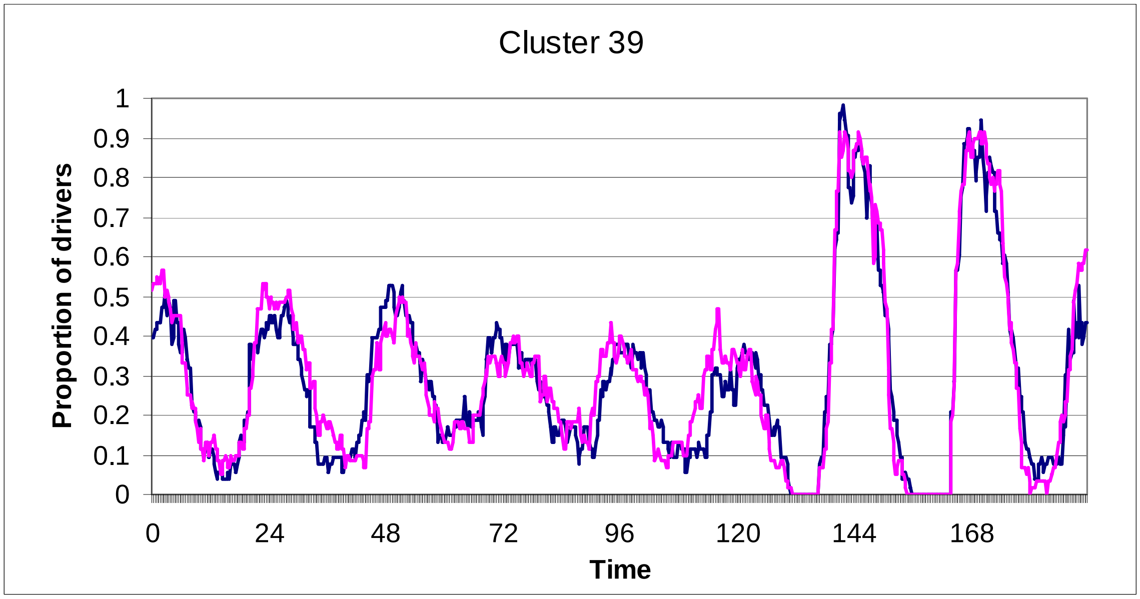
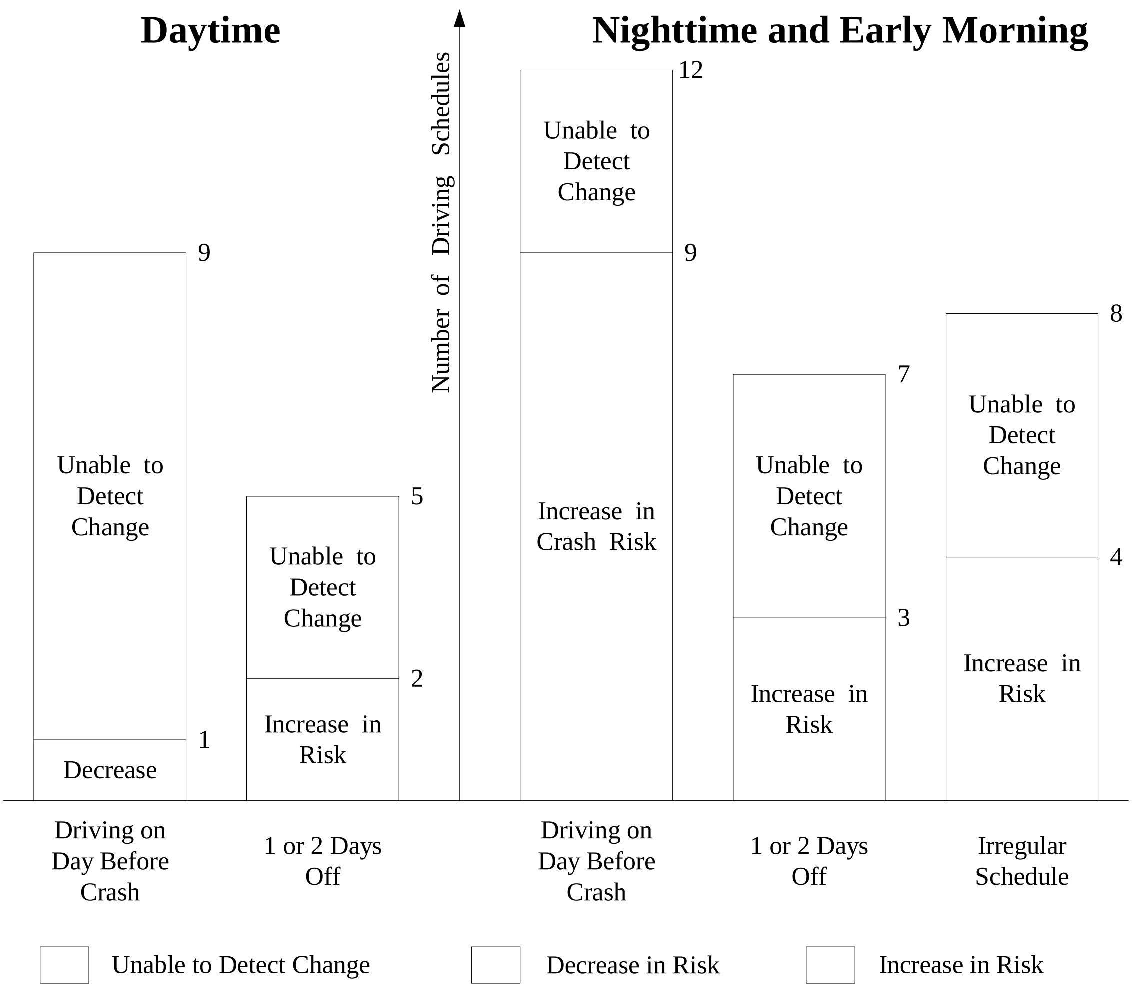
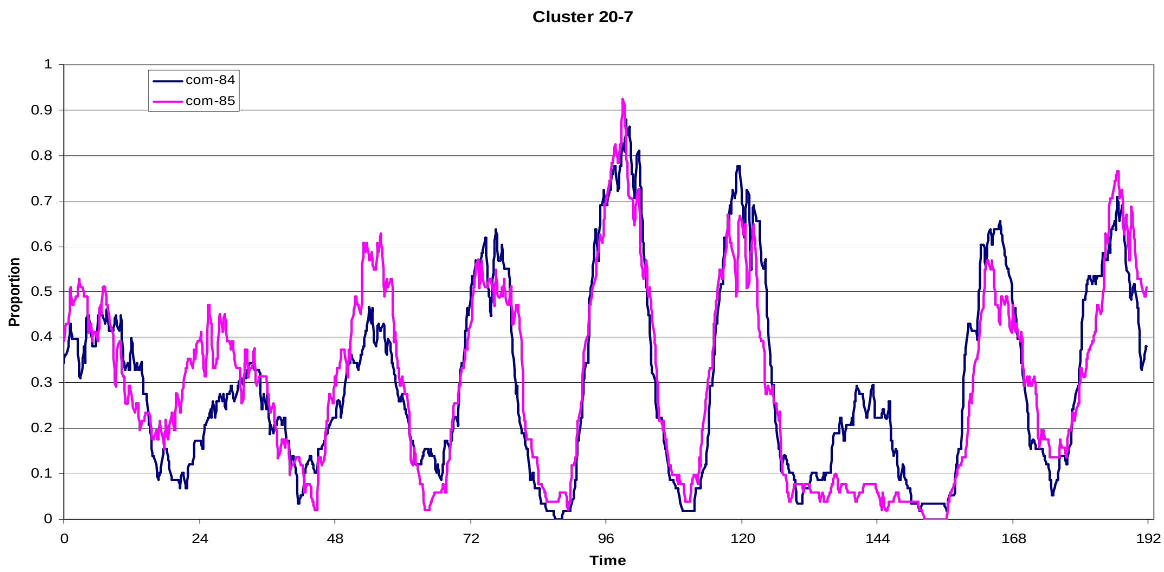


Figure 3 Example of Schedule Derived from Cluster Analysis

Figure 4 Detailed Analysis of Crash Risk During Daytime and Night/Early Morning Driving Schedules




Cluster 20-7
com-84
com-85
Proportion
Time
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
24
48
72
96
120
144
168
192

EDITORIAL

Sleep, Science, and Policy Change

C. Dennis Wylie, B.A.

Policies can be very difficult to change, and advocates of change who claim a logical or scientific foundation need valid, reliable, and convincing data. An example of the process is the policy of regulating truck drivers' hours of service in order to reduce motor vehicle crashes. In 1935, Congress directed the Interstate Commerce Commission to establish hours-of-service rules for truckers. In 1938, despite a finding that no scientific basis had been provided, the commission established rules that limited driving to 10 hours in a 24-hour period and required a minimum of 8 consecutive off-duty hours within 24 hours. Weekly driving was limited to 60 hours in seven days (or, alternatively, 70 hours in eight days). The agency also commissioned the first large study of fatigue among drivers, which, in 1941, showed a decline in performance on a battery of psychomotor tests during a period of 10 hours. However, the study did not link these results with the likelihood of motor vehicle accidents.[1] A decade later, McFarland and Moseley reported on the deterioration in the performance of one driver in a driving simulator during a 4-hour period after 24 hours of sleep deprivation.[2] They concluded that sleep is of great importance to drivers, but they observed that "little is known about sleep."

In the 1970s, studies of driver fatigue sponsored by the Department of Transportation found short-term, cumulative, and diurnal effects occurring for work that was performed within existing hours-of-service limits.[3,4] However, the studies made no quantitative link between these data and the risk of accidents. The Department of Transportation proposed changes to the hours of service, but the recommendations were not implemented and the effort was dropped in 1981. As Mitler et al. reported, during the 1970s and 1980s the growth of research on sleep and the "biological clocks" that control it led to important discoveries about the many ways in which these processes influence human health and functioning.[5] In 1988, Congress directed the Department of Transportation to conduct additional research, and in 1989, a joint study of fatigue and alertness among drivers was begun that involved truckers in both the United States and Canada. In this study, my colleagues and I conducted round-the-clock monitoring of the electrophysiological results and performance of 80 truck drivers during more than 200,000 driver-miles.[6] In planning the study, we had a strong interest in measuring performance during substantially extended shifts but concluded that it would be too risky to carry out such an investigation on public highways. In the study that we conducted, drivers operated on public highways in compliance with hours-of-service rules, taking eight hours off duty daily. Even without extended shifts, we found that drivers slept less than was required for alertness on the job.[7] In 2003, the Department of Transportation increased required off-duty time from 8 hours to 10 hours in every 24-hour period.

In this issue of the *Journal*, Barger et al.[8] address the issue of medical interns' working extended shifts and the connection of those schedules with motor vehicle accidents. The authors report the results of their analysis of 1400 person-years of data collected from interns (2737 residents in their first postgraduate year), in which they found that the participants' extended work shifts averaged 32.0± 3.7 hours and involved a mode of 2 to 3 hours of sleep. The odds ratio for reporting a motor vehicle crash after working an extended work shift was 2.3 (95 percent confidence interval, 1.6 to 3.3) and for reporting a near-miss incident was 5.9 (95 percent confidence interval, 5.4 to 6.3), as compared with the odds for the same person after working a nonextended shift. The monthly risk of a crash during the commute after an extended work shift was increased by 16.2 percent (95 percent confidence interval, 7.8 to 24.7 percent). In months in which interns worked five or more extended shifts, the risk that they would fall asleep while driving or while stopped in traffic was significantly increased (odds ratio, 2.39 [95 percent confidence interval, 2.31 to 2.46] and 3.69 [95 percent confidence interval, 3.60 to 3.77], respectively).

Some indication of the applicability and implications of the results of the study by Barger et al. can be found in studies of the effects of prolonged wakefulness and alcohol. One study showed that 17 hours of wakefulness decreased performance on a cognitive psychomotor task about as much as did a blood alcohol concentration of 0.05 percent.[9] A similar study showed that 17 to 19 hours of wakefulness decreased performance on a battery of tests about as much as did a blood alcohol concentration of 0.05 percent.[10] A driving simulator was used in a study that showed that 18.5 and 21 hours of wakefulness produced decrements of the same magnitude as blood alcohol concentrations 0.05 and 0.08 percent, respectively.[11] The results of a recent case–control study of accidents conducted to determine the relative risks of a crash at various blood alcohol concentrations showed that a relative risk of 1.6 to 3.3 (the 95 percent confidence interval that Barger et al. showed for interns' reporting a crash after an extended work shift) corresponds approximately to a blood alcohol concentration of 0.06 to 0.09 percent.[12] In the United States, the legal limit of the blood alcohol concentration for commercial drivers is 0.04 percent, and for most noncommercial drivers is 0.08 percent; in Europe, the limit is 0.05 percent for most drivers.

A potential limitation of applying data from the study of Barger et al. to hours-of-service policy would be the differential effects of fatigue between 32-hour shifts worked by interns and those worked by truck drivers. The 1941 study of fatigue among drivers ranked the following as factors in fatigue, along with 11 lesser factors:

> (1) Performance of a skilled operation requiring a high degree of alertness and attention . . .; (2) Nervous strain due to driving under adverse conditions. Fear of accidents and feeling of responsibility for cargo play a part in causing strain. . . .; (3) Muscular exertion . . .; (4) General irregularity of habits, particularly in respect to sleep, food, recreation, and exercise; (5) Failure to obtain satisfactory rest or sleep during rest periods at work or when off duty.[1]

Drivers and interns no doubt share exposure to stressors like these. We now believe that sleep debt and circadian rhythms, associated with the fourth and fifth factors, are predominant in affecting performance, so extended shifts are likely to affect drivers and interns similarly. Therefore, I believe that the data of Barger et al. have valid applications for policymaking in trucking as well as in other areas involving extended shifts.

Work shifts of 32 hours with 2 to 3 hours of sleep are egregiously beyond current hours-of-service limits, yet they can go undetected by the present enforcement system. I have encountered such schedules in reconstructing the crashes of commercial motor vehicles.[13] I believe the heightened risk associated with extended work shifts that has been identified by Barger et al. is convincing scientific evidence of the need to improve the enforcement of the hours-of-service policy. With respect to interns, Barger et al. stated in their advertisement for participants in the study that "data from this study may have an important impact on future policy guidelines concerning work hours of health professionals." I sincerely hope so.

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