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CHARACTERISTICS OF CRASHES ATTRIBUTED TO THE DRIVER HAVING FALLEN ASLEEP

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Abstract—While it has been known for some time that crashes can result from the driver falling asleep at the wheel, this issue has received less attention in traffic safety programs than the role of alcohol or speed of the vehicle. The present study was done to investigate the characteristics of crashes attributed to the driver being asleep. The study utilized the database at the Highway Safety Research Center at the University of North Carolina that is based on the uniform crash reporting system in that state. Over the years 1990–1992, inclusive, there were 4333 crashes in which the driver was judged to be asleep but not intoxicated. The crashes were primarily of the drive-off-the-road type (78% of the total) and took place at higher speeds (62% in excess of 50 mph). The fatality rate was of similar magnitude to that in alcohol-related crashes with fatalities in 1.4% of such crashes (alcohol crashes had fatalities in 2.1%). The crashes occurred primarily at two times of day—during the nighttime period of increased sleepiness (midnight to 7.00 a.m.) and during the mid-afternoon "siesta" time of increased sleepiness (3.00 p.m.). These crashes occurred predominately in young people. Fifty-five percent of these were in individuals 25 years of age or younger, with a peak age of occurrence at age 20 years. Sleepiness may play a role in crashes other than those attributed by the police to the driver being asleep. Determining the magnitude of this role is a challenge to the traffic safety community.

Keywords—Sleep, Alcohol, Vehicular crashes, Circadian rhythm

INTRODUCTION

Even in non-sleep-deprived persons, sleepiness occurs at two particular periods of the day, i.e. during the night at the time of normal sleep and in the early afternoon, at the time of the siesta in certain cultures. This can be shown by measuring the physiological tendency to sleep as the latency to sleep in brief naps (Richardson et al. 1982). Increases in sleepiness can result from sleep deprivation (inadequate sleep) or from sleep disorders such as narcolepsy, chronic insomnia, and obstructive sleep apnea. Subjects who are excessively sleepy, from whatever cause, have performance lapses and slowed reaction times and an accelerated loss of attentional vigilance (Dinges 1992). They, moreover will exhibit the phenomenon of "microsleeps", i.e. sleepy subjects may briefly fall asleep in an unpredictable fashion and be temporarily unaware of their surroundings.

These behavioral changes that occur in sleepy individuals can have important consequences. These consequences will depend on the environment that the subject is in. Perhaps the most dangerous situation is while driving. Crashes occur in individuals who fall asleep at the wheel. Such crashes can be serious with resulting fatalities (Parsons 1986). That this occurs has been known for some time (for review of earlier work in this area, see Shinar 1978).

The goal of the study described in this report was to investigate, in detail, the characteristics of crashes attributed on the police report to the driver having fallen asleep. The study was a retrospective analysis of data from the state of North Carolina. We analyzed data for the years 1990–1992, inclusive. The data are maintained in the database at the Highway Safety Research Center (HSRC), University of North Carolina.

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METHODS

North Carolina uses a standard crash report form which, by state law, must be filled out by an officer of the law for each and every crash occurring on a public access area where there was personal injury or at least $500 of total property damage. These reports, completed within 24 h of the crash are sent to the Motor Vehicles Collision Reports Section for editing and entry into a computer. These data are given to HSRC for use in their database.

Particularly important variables in the database for the questions posed here are the following:

(a) *Physical condition of the driver.* This has the following codes: 0, not stated; 1, normal; 2, ill; 3, fatigued; 4, asleep; 5, other physical impairment; 6, impairment due to medicine/drugs; 7, restriction not complied with; 8, condition not known. The judgment is made by the investigating officer based on personal interview of the driver, circumstantial evidence or testimony of eye witnesses (this could be the other driver or drivers in the accident).

(b) *Driver intoxication.* This has the following codes: 0, not stated; 1, the driver had not been drinking or using drugs; 2, drinking, ability impaired; 3, drinking, unable to determine impairment; 4, unknown; 5, drinking, not impaired. This coding is done by the investigating officer. It is not necessary for the driver, who was judged to be intoxicated, to have been arrested.

(c) *Injury severity.* The injury codes are a standard five level KABCO scale where O = no injury; C = no visible sign of injury but complaint of pain or momentary unconsciousness; B = non-incapacitating injury (not A or K) but injury evident at the scene; A = incapacitating injury, i.e. injury serious enough to prevent carrying on normal activities for at least 24 h, e.g. massive loss of blood, or fractures; K = killed.

The database is maintained in a SAS system data file which was used for all the analyses reported below.

RESULTS

During the years 1990–1992, inclusive, there were 5104 crash reports in which the driver was judged to have fallen asleep. In 771 of these the driver was also thought to have been intoxicated. We excluded these so that we could examine the characteristics of "pure" fall-asleep crashes. Thus, excluding those with intoxication there were 4333 reports in which the driver was judged to be asleep. It is the characteristics of this group of crashes that we first describe.

Characteristics of fall-asleep crashes and comparison to alcohol-related and all other crashes

Fall-asleep collisions, which represented 0.46% of the total number of drivers in crashes, had certain characteristics. These are given in Table 1 and compared to those in alcohol-related crashes and those from all other causes. They were primarily crashes in which the driver drove off the road to the right or left (78.5% of the total). This was more common than in the alcohol-related (48.4%) or in the other categories (9.0%). They were also primarily, and more commonly, single vehicle (77.5%) (see Table 1 for other numbers). They were also most commonly at high speed (62.4% were at speeds judged to be in excess of 50 mph). This percentage of crashes at speeds in excess of 50 mph was higher than in alcohol-related reports (41.6%) and those due to other causes (15.0%). As a group fall-asleep crashes were more serious crashes being of a similar level of severity to crashes in which the driver was judged to be intoxicated (see Table 1).

Fall-asleep crashes occurred predominantly in young people. The peak age of occurrence was at age 20 years and 55% of the crashes occurred when the driver was 25 years of age or younger (see Fig. 1). The mean (median) age of the driver was younger than in the alcohol-related or other crashes (see Table 1). Fall-asleep crashes also predominantly occurred in male drivers as did the other crash types.

Circadian plots of crashes of various types

The temporal distribution of those crashes attributed to the driver being asleep followed that antici-

Table 1. Comparison of characteristics of the following types of crashes: those attributed to the driver falling asleep; those where the driver was judged to be intoxicated but not asleep; all other crashes

	Characteristics of crash		
	Fall-asleep	Alcohol-related	All others
% of Reports*	0.46	2.99%	96.55%
Type of Crash			
% Drive off the road	78.5%	48.4%	9.0%
% Single vehicle	77.5%	50.7%	8.7%
% Speed in excess of 50 mph	62.4%	41.6%	15.0%
Level of Injury			
No personal injury	40.6%	35.2%	59.1%
Level C injury (mildest grade)	21.7%	20.6%	25.4%
Level B injury	22.8%	24.3%	9.9%
Level A injury (severest grade)	13.5%	17.8%	5.1%
Fatality	1.4%	2.1%	0.5%
Characteristics of Driver			
Mean (median) age of driver (yr)	30.2 (23.5)	31.5 (28.5)	35.9 (31.5)
% Male driver	74.5%	83.4%	57.9%

*The numbers given here are the percentage of drivers/total drivers in all crashes.

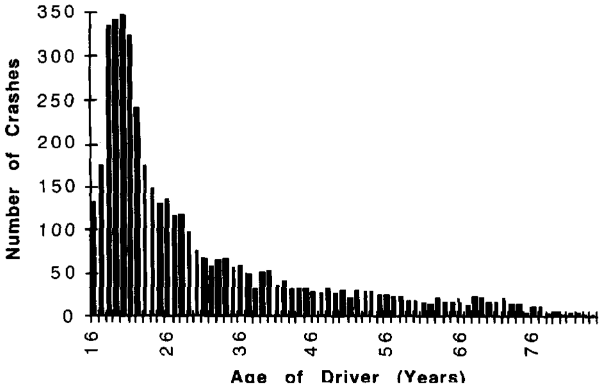

Fig. 1. Frequency histogram of number of crashes (Y axis) at different ages (X axis) in which the driver was not intoxicated but judged to have been asleep. Data for years 1990–1992, inclusive.

pated from what is known about sleepiness. They occurred predominantly at night and there was a secondary, albeit smaller peak, at the mid-afternoon period of sleepiness (see Fig. 2). The time of occurrence of these crashes varied as a function of age (see Fig. 3). Both in younger drivers less than 25 years of age and in drivers between the ages of 26 and 45 inclusively, there was an increased risk of these crashes during the night-time hours. However, in drivers whose ages were between 45 and 65 years, there were less such crashes during the night. There was a clear peak at 7.00 a.m. Finally, in the older driver (age greater than 65 years) fall-asleep crashes occurred predominately during the mid-afternoon.

This temporal variation of frequency of crashes throughout the day is different from that in which the driver was judged to be intoxicated (see Fig. 4). For alcohol-related crashes, there is a progressive increase in the hourly frequency of crashes from noon until midnight, with no mid-afternoon peak. In addition, alcohol-related crashes begin to decrease in frequency after 3.00 a.m., while fall-asleep crashes rise between 4.00 a.m. and 8.00 a.m.

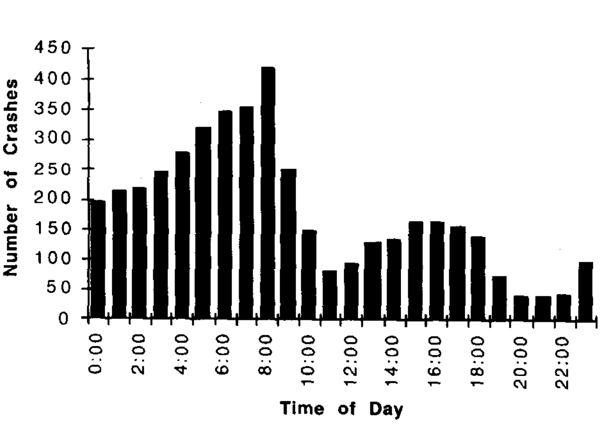

Fig. 2. Frequency histogram of time of occurrence during the day of crashes in which the driver was judged to be asleep but not intoxicated. Data for years 1990–1992, inclusive.

Since sleepiness is a much more difficult attribute for the investigating officer to detect, we questioned whether such crashes might be under-reported. If so, we reasoned that other types of crashes might have a circadian time of occurrence plot similar to the fall-asleep crashes, that was shown in Fig. 2. Since "fall-asleep crashes" had certain characteristics, i.e. they were drive-off-the-road and predominantly in young people (25 years of age or younger), we determined the time of occurrence of such crashes in which the driver was not judged to be asleep nor to be intoxicated. The resulting data are shown in Fig. 5 and Fig. 6, respectively. For both attributes, i.e. drive-off-the-road, age of driver 25 years or younger, the peak was at 3.00 p.m. The peak was, however, broad with elevated crash rates over a few hour period. This peak was present in all 3 years examined (1990–92). It is at the same time as the time of the secondary peak in the "fall-asleep" crashes.

DISCUSSION

Certain of the findings in this study are not unexpected. The temporal occurrence of the crashes in which the driver was judged to be asleep corresponds to the known circadian variation in sleepiness; there is a major peak during the night with a secondary peak at the siesta time in the afternoon (3.00 p.m.). This temporal occurrence of "fall-asleep crashes" has been reported previously for single car crashes in Israel (Lavie et al. 1986) and Texas (Langlois et al. 1985) (for review, see Mitler et al. 1988). The temporal occurrence of these crashes is a function of age. Up to the age of 45 years these crashes occur most commonly during the night. Over the age of 45 years this is, however, not the case. This may be the consequence of changes in lifestyle with age, i.e. older individuals are less likely to drive during the night. Between 45 and 65 years, the peak occurrence of these crashes is at 7.00 a.m. The leading hypothesis for this is that these crashes may be occurring in individuals returning from all night employment, but this is, at this time, conjecture. In the elderly the peak time of occurrence of these crashes is at the 3.00 p.m. siesta time. This may be a consequence of the elderly not being likely to be on the road during the night-time or around 7.00 a.m.

The crashes with the driver asleep were largely of a particular type-drive-off-the-road. They were also predominately single vehicle. Driving off the road may reflect the behavior that occurs when the driver falls asleep. It is, however, conceivable that there is a reporting bias since in such crashes, as compared to

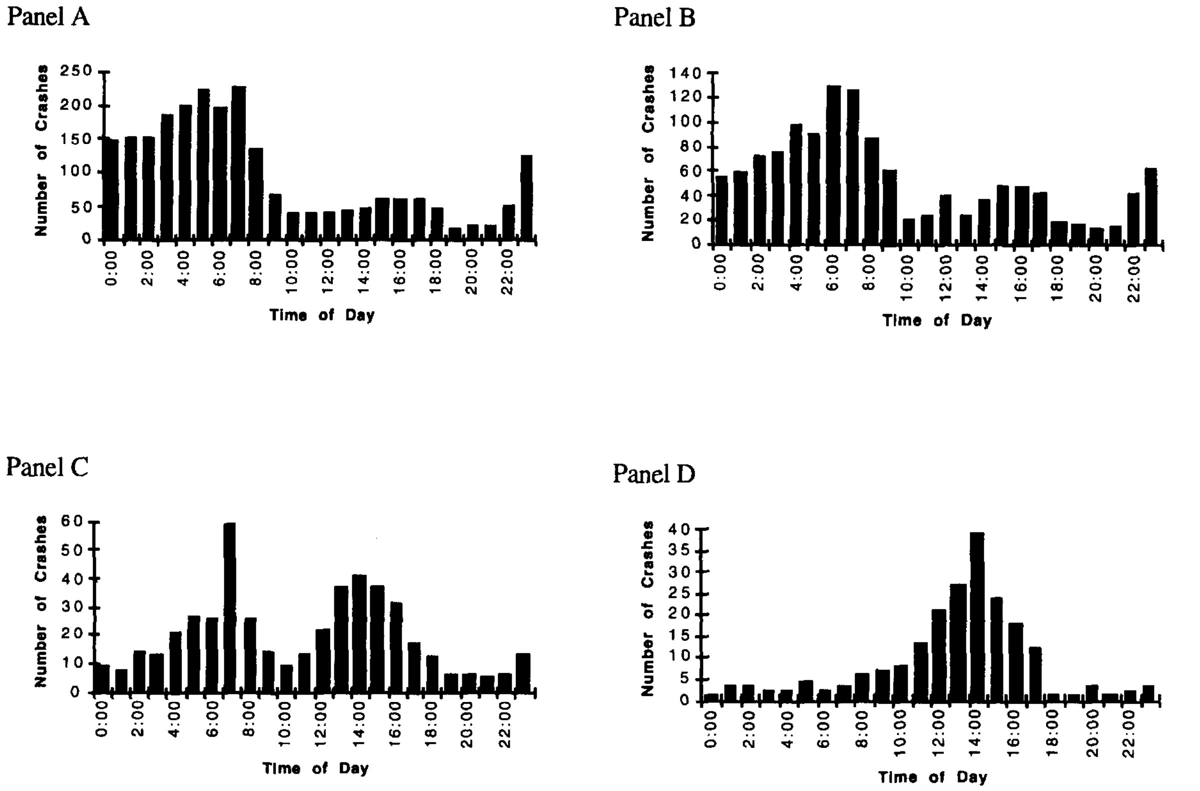

Fig. 3. Time of occurrence of crashes in drivers of different ages in which the crashes were attributed by the police to the driver being asleep but in which alcohol was not judged to have been involved. The four panels show plots for drivers of the following ages: (A) drivers aged 25 years of age or younger; (B) drivers between 26 years of age and 45 years, inclusive; (C) drivers between 46 years of age and 65 years, inclusive; and (D) drivers over 65 years of age. In each plot the *X* axis is time of day and the *Y* axis is number of crashes. However, the scale of the *Y* axis is different for the different plots. The data are for the years 1990–1992, inclusive.

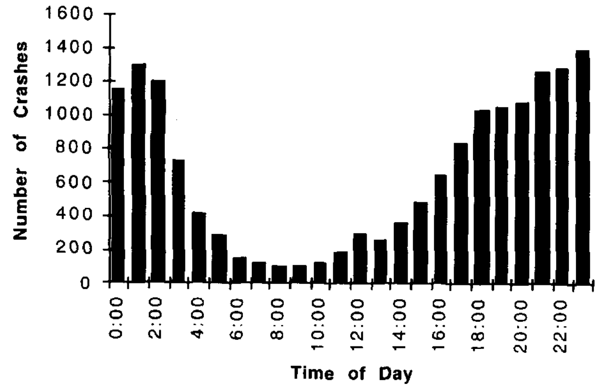

Fig. 4. Frequency histogram of number of crashes (*Y* axis) at different times throughout the day (*X* axis) in which the driver was judged to be intoxicated. Data are for one year, 1991. Data in the other years were essentially identical.

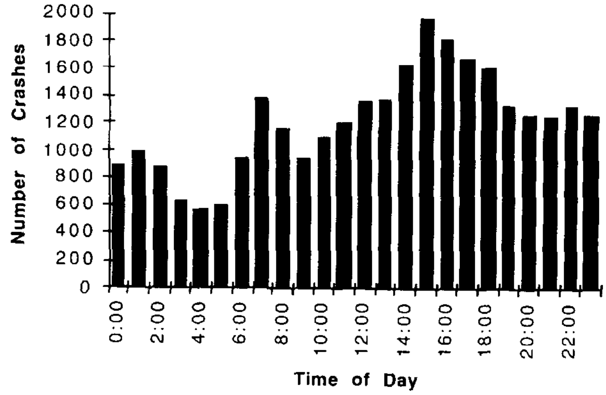

Fig. 5. Number of crashes (*Y* axis) at different times of day (*X* axis) for those crashes where the driver drove off the road, right or left, but was neither asleep nor intoxicated. Data are for one year, i.e. 1991. The patterns in the other years were very similar. There is a much larger number of events here as compared to that in Fig. 2.

other types, it may easier for the investigating officer to come to a conclusion that the driver fell asleep. Alcohol-related crashes are also commonly of the drive-off-the-road type. Conceivably, therefore, in some of the fall-asleep crashes alcohol could have played a role. This is, however, speculation since we do not know the exact criteria that police employ.

Since the driver asleep is essentially "comatose," and not taking corrective action, it is not surprising that the crashes tend to be associated with serious injury or fatality. Indeed, fatalities occurred in 1.4% of such crashes. The crashes were of a similar level of

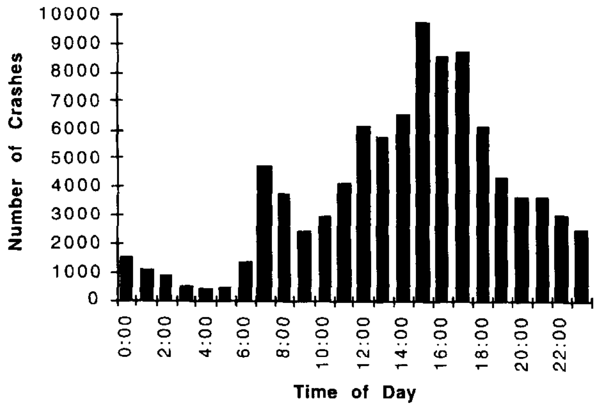

Fig. 6. Number of crashes (Y axis) at different times of day (hour intervals) (X axis) for crashes where the driver is <25 years of age but was neither judged to be asleep nor intoxicated. Data are for one year, i.e. 1991. Temporal patterns in the other years were essentially the same. The much larger number of crashes in this category than for "fall-asleep accidents" is to be noted (cf. Fig. 2).

severity to those in which the driver was judged to have been intoxicated.

Somewhat surprisingly the crashes due to the driver being asleep were by far the most common in young people with a peak age of occurrence at age 20 years. This is not the age at which one would anticipate a high prevalence of sleep disorders. At least two major sleep disorders have been shown to result in an increased risk of traffic crashes. First, sleep apnea is a condition in which there is recurrent obstruction of the upper airway during sleep; it results in sleep fragmentation and excessive sleepiness (Pack 1994). It occurs in about 4% of middle-aged males and 2% of middle-aged females (Young et al. 1993) and produces a 2- to 7-fold increase in the rate of traffic crashes (George et al. 1987; Findley et al. 1988) (for review, see Findley et al. 1992). But sleep apnea is not expected to be more prevalent in the 20–25 year age group. In contrast, narcolepsy, a disease which can result in uncontrollable sleepiness and increased risk of crashes (Aldrich 1989), usually starts in adolescence or early adult life. But this is not a particularly common disease with a prevalence of the order of 0.067% (Dement et al. 1973).

The high rate of fall-asleep crashes in young drivers is probably the result of them being excessively sleepy due to sleep deprivation secondary to lifestyle. Studies of sleep patterns in adolescents show decreased total sleep time, later bedtimes, and an increased level of daytime sleepiness (Carskadon 1990).

The characteristics that we have described are for crashes in which the driver was judged to be asleep. But sleepiness, even in the absence of frankly being asleep, also degrades performance with reduced vigilance, slowed reaction times and attentional deficits (Dinges 1992). Thus, there may be many more crashes in which sleepiness plays a role than that described here. Sleepiness may contribute, therefore, to crashes attributed to loss of attention. Moreover, sleep deprivation markedly augments the impaired driving performance that results from alcohol ingestion (Roehrs et al. 1994). Thus, excessive sleepiness could play a much larger role in causing crashes than the number of fall-asleep crashes would imply. The actual scope of the problem will be difficult to assess since currently there is no simple test for the investigating officer to apply. A recent population survey in Finland suggests, however, that the problem is large in scope (Martikainen et al. 1992). Fifteen percent of the middle-aged population reported having fallen asleep driving at least once; 4.8% of males reported falling asleep more than five times; and 1.3% of the population reported an accident or mishap due to having fallen asleep while driving.

The data presented here suggest the hypothesis that sleepiness could play a much larger role than the number of fall-asleep crashes would allow us to conclude. We have found that crashes in which the driver was neither asleep nor intoxicated had their peak time of occurrence at 3.00 p.m. (a time of increased sleepiness) both for those in young people (≤ 25 years of age) and for those where the driver drove off the road. This is earlier than the period of peak road use between 4.00 and 6.00 p.m. (Schwing 1990). It is, however, at a time that high school children could be out of school. It is difficult, however, to assess the role of sleepiness since other factors such as exposure, traffic congestion, will play a role. We did not observe in these data another peak during the night-time hours. This could be the result of the large difference in road usage at these different times (Schwing 1990). The temporal occurrence of these crashes therefore does not prove that sleepiness played a role. There is, however, a need for further studies to investigate the cause of these robust rhythms of temporal occurrence of crashes. It may be that crashes are more commonly attributed by the investigating officer to sleep during the night-time hours when sleep seems natural but not during the afternoon when sleep, at least in our society, is not acknowledged to be a biological imperative.

These data point to the difficulty of determining the role of sleepiness in a particular crash. As stated above, there is no measurable test that the investigating officer can employ. Moreover, following the crash the driver should regain full alertness and there will be no residual evidence of impaired performance as occurs with alcohol. Thus, the evidence that sleepiness plays a role is currently based on the self-report of the driver or as a conclusion derived from excluding other factors, e.g. excessive speed, etc. Given the inexact nature of this determination, it can be argued that it is unrealistic to expect police to determine whether sleepiness contributes to a crash. This has been the conclusion in New South Wales, Australia, where it has been asserted that police accident reports underestimate the scope of this problem (Fell 1994). They have developed criteria to identify a crash as a likely fall-asleep crash. These criteria have, however, not been validated. Based on these criteria they estimate that driver sleepiness accounts for 6% of all crashes, 15% of fatal crashes and 30% of fatal crashes on rural roads (Fell 1994). These estimates are higher than those provided by the police accident reporting system in the U.S.A. The Fatal Accident Reporting System provides estimates that falling asleep while driving accounts for 3–4% of fatal crashes. The difficulty in determining the role of sleepiness in crashes should not lead to the assumption that this is a minor problem in traffic safety. Rather, it should lead to the design of new approaches to investigating and determining the scope of this problem. This issue is discussed in detail by Knipling and Wang (1994).

Another important consideration about such crashes is whether there are effective countermeasures. Both the public and medical profession are largely unaware about sleep, sleep disorders and sleepiness as alluded to in the recent report of the U.S. National Commission on Sleep Disorders Research (1993 National Commission on Sleep Disorders Research 1993). Thus, increased awareness of this issue is an important first step. The public need to understand the risks involved and that these risks are enhanced by factors that increase the physiological pressure for sleep, i.e. driving at times of increased sleepiness (e.g. night-time), after long periods of prior wakefulness, or when the driver has had a less than adequate amount of sleep in the previous 24-hour period. Apart from increasing awareness, there are some other more specific approaches. Devices are being constructed to alarm the driver before they fall asleep (Knipling and Wierwille 1994). Another approach—use of rumble strips—seems highly effective for one class of such crashes. These strips are deep grooves at the side of the road which cause a loud noise if the car does drift off the road. They have been used on various turnpikes and major roads. A recent synthesis of all reports on the effectiveness of this countermeasure concludes that they produce a 30–50% reduction in drive-off-the-road crashes (Gårder and Alexander 1995). This is a low-cost solution with benefit-to-cost ratios of the order of 20:1 to 200:1 depending on assumptions employed in this analysis (Gårder and Alexander 1995).

In conclusion, we have described here, in detail, the characteristics of crashes attributed to the driver being asleep. There are beginning to be data about the effectiveness of countermeasures such as continuous shoulder rumble strips. Sleep disorders and sleepiness are growing issues in traffic safety and there is a need to better define the scope of the problem related to sleepiness, to develop and evaluate effective countermeasures, and to increase public awareness of the issue.

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