

Car crashes rank among the leading causes of death in the United States.



Asleep at the Wheel: The Prevalence and Impact of Drowsy Driving.

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The Prevalence and Impact of Drowsy Driving

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Abstract

Studies have documented operator drowsiness, sleepiness, or fatigue as causal or contributing factors in aviation, maritime, and trucking accidents. However, estimates of the prevalence of drowsy drivers on the road and of the proportion of motor vehicle crashes that involve drowsy drivers vary widely. This study presents new estimates of the prevalence of drowsy drivers on U.S. roads and of the proportion of crashes that involve a drowsy driver.

In a nationally representative telephone survey of U.S. drivers conducted in the spring of 2010, 41.0% of drivers admit to having “fallen asleep or nodded off” while driving at some point in their lives, including 11.0% within the past year and 3.9% in the past month. More than one in four drivers admits to having driven when they were “so sleepy that [they] had a hard time keeping [their] eyes open” within the past month.

Examination of data from a nationally-representative sample of crashes that occurred between 1999 and 2008 and involved a passenger vehicle that was towed from the scene shows that 3.9 percent of all of those crashes, 7.7 percent of those that resulted in at least one person being admitted to a hospital, and 3.6 of those that resulted in death involved a driver who was coded as drowsy. However, the attention status of 45% of the drivers in the data was unknown. The statistical technique of multiple imputation was used to take into account additional information about these drivers and the crashes in which they were involved and to estimate the proportion of these drivers who were drowsy. Taking all of these drivers into account, an estimated 7.0% of all crashes in which a passenger vehicle was towed, 13.1% of crashes that resulted in a person being admitted to a hospital, and 16.5% of fatal crashes involved a drowsy driver.

Introduction

Speeding, drinking and driving, and failure to use occupant-protection devices such as seatbelts are all well documented as major contributors to motor vehicle crashes, injuries, and deaths. For example, 32% of motor vehicle crash fatalities in the year 2008 occurred in crashes that involved an alcohol-impaired driver, 31% involved a speeding driver, and 51% of fatally-injured passenger-vehicle occupants failed to use seatbelts, according to the National Highway Traffic Safety Administration (NHTSA) (2009d). Driver distraction has drawn increased attention in recent years as well. The NHTSA (2009a) reports that an estimated 16% of fatal crashes in 2008 involved driver distraction.

Operator drowsiness, sleepiness, or fatigue (hereafter referred to as *drowsiness*) has been documented as a causal or contributing factor in aviation, maritime, and trucking accidents (National Transportation Safety Board, 1990, 1991, & 1994). However, in comparison to some other highway safety problems, drowsy driving has received much less attention, and the studies most often cited as the source of estimates of the proportion of crashes that involve a drowsy driver are now more than 15 years old.

A nationally representative survey conducted in 2002 for the NHTSA found that 37% of drivers reported having “fallen asleep or nodded off, even for a moment, while driving” at some point, including 4% within the past month, 8% within the past 6 months, and 11% within the past year (Royal, 2003).

A study using data from years 1989 through 1993 reported that that 0.9% of all police-reported crashes and 3.6% of fatal crashes involved a drowsy driver (Knipling & Wang, 1994). In another study, the same authors attempted to refine this estimate using more sophisticated analysis, and estimated that 1.2% – 1.6% of all police-reported crashes involved a drowsy driver (Knipling & Wang, 1995). A study of a national sample of crashes that occurred in 1995 in which a passenger vehicle was towed estimated that 2.6% of these crashes involved a drowsy driver; however, the authors also noted that in 46% of crashes the attention status of at least one driver was unknown (Wang *et al.*, 1996). Another study used data from a sample of crashes in North Carolina to develop a statistical model to classify crashes as drowsiness-related vs. not drowsiness-related, applied this model to national data on fatal crashes, and estimated that 15% – 33% of drivers involved in fatal crashes nationwide from 2001 through 2003 were drowsy (Masten *et al.*, 2006). Finally, a naturalistic study in which 109 vehicles were equipped with cameras and other sophisticated data collection equipment for a period of 12 to 13 months estimated that 22% of crashes and near crashes involved drowsiness (Klauer *et al.*, 2006); however, the outcomes in this study were predominantly near crashes and minor crashes. The extent to which these findings may be generalized to more severe crashes is unknown.

This report presents new estimates of the prevalence of drowsy driving among the driving population and of the proportion of crashes each year that involve a drowsy driver.

Prevalence of Drowsy Driving among Drivers

Methods

The data reported here were collected as a part of the AAA Foundation's 2010 *Traffic Safety Culture Index*, a nationally-representative telephone survey of 2,000 U.S. residents 16 years of age and older, conducted in English and in Spanish, via landline and cellular telephone, from May 11, 2010 through June 7, 2010 by Abt SRBI Inc. for the AAA Foundation. For a detailed description of the survey methodology, see AAA Foundation for Traffic Safety (2010).

In the 2010 Traffic Safety Culture Index, respondents who reported having driven in the past 30 days (n=1,728) were asked whether or not they had "ever fallen asleep or nodded off, even just for a second or two," while they were driving. Respondents who responded affirmatively were asked how long ago this last happened, and those who reported having fallen asleep while driving within the past 12 months were asked several more questions about the circumstances of their last occurrence of falling asleep while driving. All respondents were also asked how often they had "driven when they were so sleepy that they had a hard time keeping [their] eyes open," with response options of *regularly, fairly often, rarely, just once, or never*, within a battery of items addressing the frequency with which respondents had performed various other driving behaviors over the past 30 days.

Results

Two out of every five drivers (41.0%) reported having ever fallen asleep or nodded off while driving, including 3.9% within the past month, 7.1% within the past 6 months, and 11.0% within the past 12 months (Figure 1).

Drivers ages 16-24 were the most likely to report having fallen asleep while driving within the past year. There was a trend of decreasing likelihood of having fallen asleep while driving within the past year across the entire age spectrum ($p < 0.001$). Men were much more likely than women to report having ever fallen asleep while driving (52.2% vs. 30.1%, $p < 0.001$), and to report having done so within the past year (14.0% vs. 8.1%, $p = 0.005$).

More than one in four (26.1%) of those who reported having fallen asleep while driving in the past 12 months reported that they had done so between the hours of noon and 5 PM; as many as those who reported having done so between midnight and 6 AM (24.7%). Fifty-six percent of drivers said that their last instance of falling asleep while driving occurred on a multi-lane divided highway. Three of five (58.8%) who reported having fallen asleep while driving in the past 12 months reported that they had been driving for less than an hour before they fell asleep, whereas one in five (20.6%) reported having been driving for 3 hours or longer. Only 27.7% reported that they realized before they started driving that they might have difficulty staying awake; 71.0% reported having felt awake enough to drive.

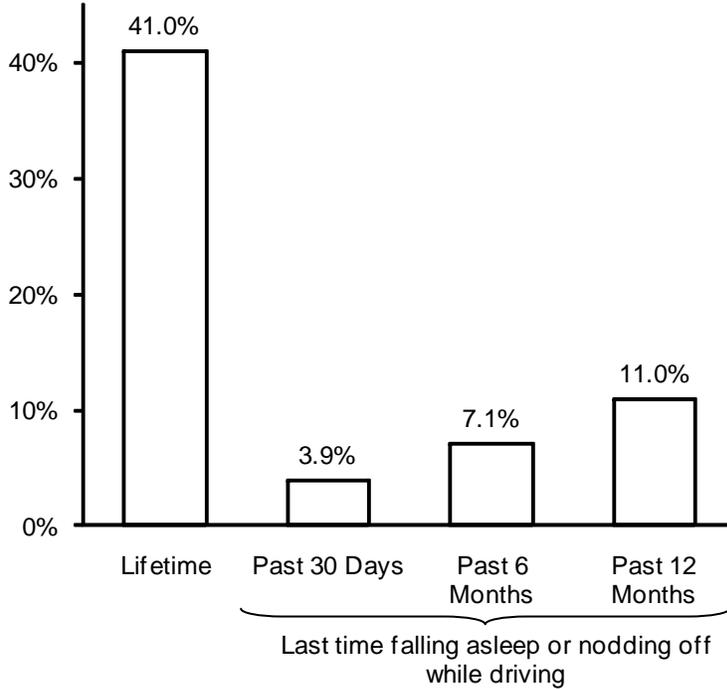


Figure 1. Proportion of drivers who report having “fallen asleep or nodded off” while driving. Data are from a representative telephone survey of 1,728 drivers ages 16+ conducted May 11 – June 7, 2010. Percents are weighted to reflect national estimates. Drivers were asked, “Have you ever fallen asleep or nodded off while driving, even just for a second or two?” Those who responded affirmatively were asked, “How long ago was the last time that happened?”

Drivers were also asked how often they had driven while they were “so sleepy that [they] had a hard time keeping their eyes open” in the past 30 days; 26.6% indicated that they had done so, with 9.0% reporting that they had done this just once, 15.2% rarely, and 2.4% fairly often or regularly. Compared with drivers who reported that they had not fallen asleep or nodded off while driving within the past year, those who reported that they had done so within the past year were much more likely to report having driven while so sleepy that they had a hard time keeping their eyes open within the past 30 days (60.0% vs. 21.6%, $p < 0.001$), even after excluding those who could have been referring to the same instance both when reporting having driven while drowsy and when reporting having fallen asleep while driving.

Discussion

The current study estimates that 3.9% of drivers have “fallen asleep or nodded off” while driving within the past month, 7.1% in the past 6 months, 11.0% in the past year, and 41.0% at some point in their lives.

A limitation of this or any similar study is its reliance on data that drivers voluntarily reported to an interviewer. This requires that the drivers were aware of their instance of having fallen asleep while driving in the first place, remembered it, and were willing to report it to the interviewer. Gastaut and Broughton (1965) reported that people had to have been asleep for as long as 2 to 4 minutes before 50% acknowledged that they had been asleep, suggesting that a driver who had only been asleep for perhaps a few seconds might be unaware (or forget) that he or she was asleep. Cummings *et al.* (2005) found that when interviewed, parents were only able to recall and report 82% of injuries sustained by their children as recently as the previous day; the recall proportion fell to 37% for injuries sustained 365 days ago. If respondents were never aware, did not remember, or were unwilling to report having fallen asleep while driving, this would result in underestimation of the proportion of drivers who have fallen asleep or nodded off while driving.

Assuming that falling asleep while driving is essentially a random event, then if 3.9% of drivers fell asleep while driving within the past month, it would be expected that $3.9\% \times 6 = 23.4\%$ would have fallen asleep while driving in the past 6 months, and 46.8% in the past 12 months; however, the self-reported 6-month and 12-month prevalence estimates were much lower. Because drivers were only asked about the last time that they fell asleep while driving, not the total number of instances over a period of time, it is possible that the drivers who reported falling asleep while driving more recently do so more frequently than those who reported having done so less recently; however, the current study cannot confirm this due to limitations of the data. The finding that drivers who reported having fallen asleep while driving with the past year were more likely than those who did not to have also driven while so sleepy that they had a hard time keeping their eyes open within the past month suggests that some drivers may indeed have greater risk of falling asleep while driving and may do so more frequently than others.

The self-reported prevalence of drowsy driving reported here is very similar to that reported by Royal (2003) for the NHTSA. The distributions of crashes according to crash characteristics and driver demographics were similar to those reported by Royal as well. Royal reported that 47% of drivers who had fallen asleep at the wheel within the past 6 months had been driving for an hour or less; this study found that 59% of those who had fallen asleep in the past year had been driving for an hour or less. Royal reported that 58% of drivers who had fallen asleep at the wheel within the past 6 months did so while driving on a multi-lane interstate highway; the current study found that 56% were on high-speed divided highways. The distribution of incidents by time of day reported by Royal was also very similar to that reported here.

Proportion of Crashes Involving a Drowsy Driver

Methods

The source of data used here was the NHTSA's National Automotive Sampling System Crashworthiness Data System (NASS CDS), a sample of police-reported crashes in which a passenger vehicle (car, light truck, SUV, or van) was towed. Data reported in NASS CDS is compiled by teams of investigators who obtain information from police crash reports, medical records, crash reconstructions, and interviews with drivers and passengers involved in roughly 5,000 crashes annually. Records are weighted to produce nationally representative estimates (NHTSA, 2009b).

Data from years 1999 – 2008 were obtained from the web site of the NHTSA and were analyzed using statistical software Stata (StataCorp, 2007). Vehicles coded as having no driver, vehicles not eligible for NASS CDS investigation (large trucks, motorcycles, construction equipment, etc.), and vehicles of unknown type were excluded. The resulting data set contained records of 80,821 vehicles involved in 47,597 crashes.

Information regarding whether or not a driver was drowsy was obtained from NASS CDS variable DRIVDIST, which is used to classify a driver's attention to driving and is coded on the basis of information from interviews conducted by NASS CDS investigators with crash-involved occupants and from police reports. Values of DRIVDIST include: attentive/not distracted, looked but did not see, 13 separate codes are used for specific distractions, sleepy/fell asleep (hereafter referred to as *drowsy*), and unknown. To avoid having categories with very small cell sizes in the analysis, DRIVDIST was collapsed into the following categories:

- Attentive/not distracted
- Looked but did not see
- Distracted by other occupant
- Distracted by outside person, object, or event
- Distracted by secondary task (e.g., cell phone, radio, climate control, eating)
- Other/unknown distraction
- Drowsy

This collapsed version of the variable DRIVDIST is referred to hereafter as *attention*.

DRIVDIST was coded as unknown in 45% of all driver records. Multiple imputation (Rubin, 1987) was used to estimate the proportion of these drivers who were likely to have been drowsy, thereby enabling the inclusion of these drivers in the overall estimate of the proportion of crashes that involved a drowsy driver.

Imputation is a statistical technique in which the missing values of a given variable are replaced by sampling the distribution of the variable conditional upon the values of other variables

included in a model. The objective of imputation is not to predict the actual values of variables whose values were missing in the original data, but to produce a set of complete data that preserves the relationships between the imputed variables and the other variables included in the model. Imputation can be performed multiple times, generating independent sets of complete data which can be analyzed by traditional methods. The results of these analyses then can be combined so that the variability across the imputed data sets reflects the uncertainty associated with the imputation. The NHTSA has been using multiple imputation methods since 2001 to address missing data on the blood alcohol concentration of drivers involved in fatal crashes (Subramanian, 2002).

Imputation was performed using the method described by Van Buuren *et al.* (1999) implemented in Stata (Royston, 2004, 2005, & 2009). Variables included in the imputation model (Table 1) were those that were to be used in subsequent analysis, were strongly associated with drowsiness or with the occurrence of missing data on attention, or were required to specify the NASS CDS

Table 1. Variables used in imputation of driver attention (derived from NASS CDS variable^a in parentheses).

Variable Name	Values
Attention (DRIVDIST)	Attentive/not distracted; Looked but did not see; Distracted by other occupant; distracted by outside person, object, or event; Distracted by secondary task; Other/unknown distraction; Drowsy
Maximum injury severity in crash (ATREAT)	Not injured/no treatment; Injured/not hospitalized; Hospitalized+fatal
Driver injury severity (TREATMNT)	
Number of vehicles in crash (VEHFORMS)	1; 2 or more
Pre-event maneuver (PREMOVE)	Going straight; Other active driving maneuver
Crash type (ACCTYPE)	Road departure; other
Day of week (DAYWEEK)	Sun; Mon; Tues; Wed; Thurs; Fri; Sat
Hour of day (TIME)	1-2:59AM; 2-4:59AM; ... ; 9-10:59PM; 11PM-12:59AM
Trafficway flow (TRAFFLOW)	Undivided; Divided w/o barrier; Divided with barrier; One-way
Number of passengers (OCUPANTS)	0; 1 or more
Driver age (AGE)	16-24; 25-39; 40-59; 60+
Driver sex (SEX)	Female; male
Light condition (LGTCOND)	Daylight; Dawn/dusk; Dark-lighted; Dark
Relation to intersection/junction (RELINTER)	Intersection related; Not intersection related
Roadway alignment (ALIGNMNT)	Curve; Tangent
Speed limit (SPLIMIT)	<30 mph; 30-35; 40-45; 50-55; 60+
Number of travel lanes (LANES)	1; 2; 3; 4+
Surface condition (SURCOND)	Dry; Not dry (wet/ice/slush)
Pre-crash critical event (PREEVENT)	Departed travel lane; Other
Vehicle disposition (TOWPAR)	Not towed; Towed
Year (YEAR)	Binary indicator for each year
Stratum (PSUSTRAT)	Binary indicator for each stratum
Primary sampling unit (PSU)	Binary indicator for each PSU (nested within strata)

a. For definitions and coding of NASS CDS variables, see NHTSA (2009c).

sample design for accurate estimation of variances. The data were weighted using the NASS CDS record weights. Other variables in the imputation model were imputed when they were missing in the original data. Imputation was performed separately for crashes that occurred during the hours of 11 PM – 6:59 AM vs. 7 AM – 10:59 PM, and for crashes that resulted in at least one person being admitted to a hospital or fatally injured vs. those that did not. This is equivalent to including interaction terms between crash severity, time of day, and all other variables, so that subgroup analyses could be performed by time of day and crash severity. Ten independent imputations were performed. Imputed datasets were analyzed using statistical algorithms implemented in Stata (Carlin *et al.*, 2008).

Attention was missing for 92% of fatally injured drivers; only 238 records of fatally injured drivers contained non-missing values for attention. Due to concern that any potential misclassification of attention among these drivers in conjunction with the high proportion of missing values would severely bias the imputed results with respect to fatally-injured drivers, the injury severity variable was collapsed into three categories prior to imputation: not injured/no treatment, treated/not hospitalized, and hospitalized+fatal. This is equivalent to assuming that crashes resulting in death are a random sample of crashes resulting in a person being injured severely enough to be admitted to a hospital, conditional upon the other variables in the imputation model. Deaths were assumed to be fully observed; when injury severity was imputed as hospitalized+fatal, this was re-coded as hospitalized for subsequent analysis. Additionally, due to concerns about the reliability of the assessment of attention or drowsiness among deceased drivers, the non-missing values of attention were replaced with missing values and imputed in all records of fatally injured drivers, as a sensitivity analysis. This sensitivity analysis produced slightly more conservative (lower) estimates of the prevalence of crashes that involved a drowsy driver; these are the estimates reported here.

Imputation was not performed in a total of 809 records (1.1% of weighted drivers) for various reasons including missingness of critical variables (e.g., time of day), missingness of categorical variables that were difficult to impute for computational reasons (e.g., trafficway flow), and ambiguity regarding whether several drivers died prior to the crash or whether they died subsequently but for reasons unrelated to the crash (the same injury severity code is used for both scenarios).

Results

In the original (non-imputed) data, the attention status of 45% of drivers was coded as unknown. Taking into account additional information about these drivers and the crashes in which they were involved, an estimated 4.2% of these drivers were drowsy. With these drivers included in the crash-level estimates, an estimated 7.0% of all crashes in which a passenger vehicle was towed (95% Confidence Interval [CI]: 4.6% – 9.3%), 7.2% of crashes that resulted in a person being treated for any non-fatal injury (95% CI: 4.5% – 10.0%), 13.1% of crashes that resulted a person being admitted to a hospital (95% CI: 8.8% – 17.3%), and 16.5% of fatal crashes (95% CI: 12.5% – 20.6%) involved a drowsy driver (Figure 2).

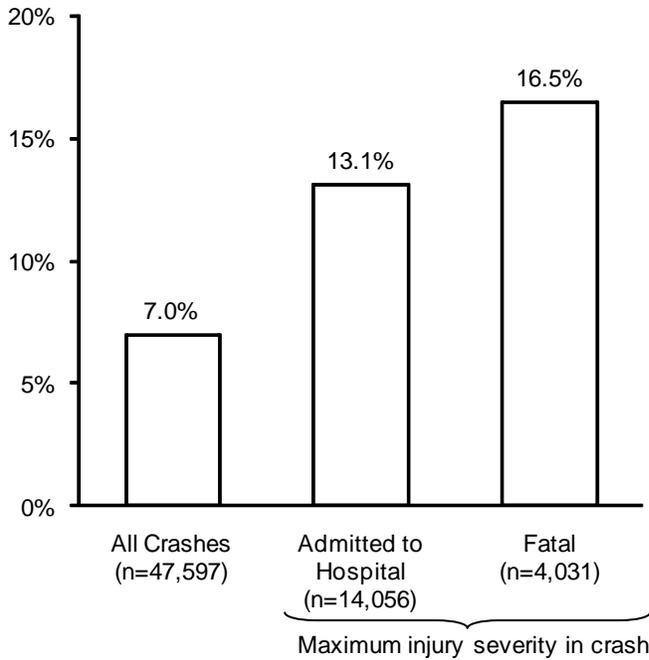


Figure 2. Percent of crashes involving a drowsy driver, by maximum injury severity in crash. Data are from a representative sample of crashes in the United States from years 1999–2008 in which at least one passenger vehicle was towed from the scene. Missing data were imputed at the driver level and aggregated at the crash level. Percents are weighted to reflect national estimates and are averaged from 10 imputations.

Over half of all drowsy driving crashes (56.9%) involved a single vehicle that left its travel lane; single-vehicle lane-departure crashes were nearly seven times as likely as other types of crashes to have involved a drowsy driver (23.7% vs. 3.6%, $p < 0.001$). Crashes that occurred during late night and early morning hours (11 PM – 6:59 AM) were nearly five times as likely as crashes that occurred later in the morning, afternoon, or evening to have involved a drowsy driver (20.3% vs. 4.3%, $p < 0.001$). Crashes that occurred on Saturday or Sunday were over twice as likely as crashes that occurred during the week to have involved a drowsy driver (12.1% vs. 5.1%, $p < 0.001$). There was some annual fluctuation in the estimated proportion of crashes that involved a drowsy driver, but there was no statistically significant trend over the study period ($p = 0.49$).

Among crash-involved drivers, males were 61% more likely than females to have been drowsy (5.0% vs. 3.1%, $p = 0.076$); 65% of crash-involved drivers who were drowsy were male. Drivers under age 25 were 78% more likely than drivers ages 40 years or older to have been drowsy (5.2% vs. 3.0%, $p = 0.005$). Drivers travelling alone were 81% more likely than drivers with passengers to have been drowsy (4.7% vs. 2.6%, $p = 0.02$).

Discussion

This study estimates that 7.0% of all crashes in which a passenger vehicle was towed, 7.2% of crashes that resulted in at least one person being treated for any non-fatal injury, 13.1% of crashes that resulted in at least one person being admitted to a hospital, and 16.5% of fatal crashes involved a drowsy driver. These are the estimated proportions of crashes that involved a driver who was drowsy; however, they do not indicate that drowsiness was necessarily the cause of the crash.

The proportion of crashes that involved a drowsy driver was estimated using multiple imputation. NASS CDS rather than FARS was selected as the source of data for current study because of the involvement of crash investigators in NASS CDS who interview crash-involved occupants when possible and take this information into account, as well as information from police reports, when making their assessment of driver attention. The NASS CDS data coding and editing protocol distinguishes between drivers known to have been attentive and drivers whose attention status was unknown, whereas FARS and other data based solely on police reports only distinguish between crashes in which inattention (e.g., drowsiness or distraction) was known to have contributed to the crash and those in which inattention was not known to have contributed. This explicit differentiation between *attention known-not drowsy* and *attention unknown* is critical for the use of multiple imputation. The inclusion of non-fatal crashes in addition to fatal crashes in NASS CDS also made it possible to estimate prevalence of drowsiness in non-fatal crashes, and to use information about the relationships between drowsiness and various driver- and crash-characteristics observed in non-fatal crashes when estimating the prevalence of drowsiness in fatal crashes.

For the results of imputation to be valid, the data must be missing at random. In other words, the probability that the variable of interest—driver attention—is missing must not depend upon whether or not the driver was drowsy, after controlling for the covariates included in the imputation model. The driver attention variable was overwhelmingly more likely to be missing for 2 groups of drivers: fatally-injured drivers (92% missing) and drivers of vehicles that were not towed (75% missing). These two variables, as well as numerous others that were clearly associated with driver drowsiness, were included in the imputation model to minimize the threat of bias due to violations of the requirement that the data being imputed is missing at random. However, as Cummings *et al.* (2002) note, bias could still be present if missing values of attention were strongly related to variables not included in the imputation model.

Another threat to the validity of the results of this study is the possibility of misclassification of driver attention in the non-missing NASS CDS data. This may be a special concern among fatally-injured drivers, who clearly could not have been interviewed, and for drivers of non-towed vehicles, from whom NASS CDS protocol does not require the collection of data. This potential source of bias was investigated through sensitivity analysis in which non-missing values of attention were replaced with missing values and imputed for both groups of drivers. The most conservative (lowest) estimated prevalence of crashes involving drowsy drivers was obtained from analysis with non-missing values of attention replaced with missing values and

imputed for fatally-injured drivers and with the original coding of non-missing values of attention for drivers of non-towed vehicles—these are the estimates that were reported here.

A potential source of bias that cannot be investigated directly with available data is the potential misclassification of drowsy drivers as attentive or distracted, or the misclassification of attentive or distracted drivers as drowsy. Gastaut and Broughton (1965) reported that people had to have been asleep for as long as 2-4 minutes before 50% acknowledged that they had been asleep, suggesting that a driver who had only been asleep for perhaps a few seconds might be likely to be unaware (or forget) that he or she was asleep. It is also possible that some crash-involved drivers who were actually distracted (and not drowsy) reported to police that they were drowsy, perhaps due to a belief that admission of drowsiness would result in less severe legal consequences than admission of distraction (Knipling & Wang, 1994). Additionally, driver attention can only be assigned one specific value for each driver in NASS CDS, thus, for example, if a driver was known to have been both drowsy and distracted, that driver's attention status could only be coded as drowsy or distracted, not both. Imputation can provide insight into the prevalence of drowsiness among crash-involved drivers for whom attention is recorded correctly as unknown; however, it cannot correct for misclassification bias in the original data. Whether or to what extent these potential sources of bias may have affected the estimates reported here is unknown.

Comparison to other research suggests that this study may still underestimate the contribution of driver drowsiness to motor vehicle crashes, especially during daytime hours. In the previous section of this study, the survey of the driving public found that as many drivers reported having fallen asleep or nodded off while driving between noon and 5 PM as between midnight and 6 AM. This contrasts sharply with the current study, which found that among crashes in which a passenger vehicle was towed, 41% occurred between midnight and 6 AM, as compared to only 20% between noon and 5 PM. It is possible that crashes severe enough to qualify for inclusion in NASS CDS are distributed differently than instances of falling asleep while driving in general. Nonetheless, it appears possible that current study may still underestimate the proportion of daytime crashes that involve a drowsy driver. If drivers who crash during the day are less aware of their drowsiness than are drivers who crash at night, then daytime crashes involving drowsiness would be more likely than nighttime crashes to be misclassified as not involving drowsiness.

The prevalence of drowsy driving crashes reported here is higher than that reported in other studies of crash data (with the exception of Masten *et al.* [2006]). Wang *et al.* (1996) found that 2.6% of crashes in NASS CDS in the year 1995 involved a drowsy driver, and Stutts *et al.* (2001) reported that 1.8% of drivers in NASS CDS from 1995 through 1999 were coded as drowsy. These studies analyzed the percent of drivers in NASS CDS who were coded as drowsy, effectively treating drowsiness as a fully-observed variable and unknown as a substantive category. The current study is the first to estimate the proportion of drivers in NASS CDS whose attention status was coded as unknown who were likely to have been drowsy. Presuming that proportion is not zero, the current study would necessarily produce higher estimates than the previous studies.

Most studies limited to fatal crashes have reported that the proportion of crashes involving drowsiness is lower than the estimate reported in this study. Knippling and Wang (1994), for example, reported that 3.6% of fatal crashes in the NHTSA's FARS database were coded as having involved a drowsy driver. The results of the current study pertaining to fatal crashes, however, apply only to crashes in which a passenger vehicle was towed; they cannot be generalized to fatal crashes not involving passenger vehicles (e.g., those involving motorcycles or large trucks, but not passenger vehicles) or crashes involving passenger vehicles that were not towed (e.g., crashes with pedestrians). From 1999 through 2008, 82% of all fatal crashes in FARS involved a passenger vehicle that was towed and thus were eligible for sampling in NASS CDS. Of those, 3.3% involved at least one driver for whom drowsiness was coded as a contributing factor (FARS, 1999-2008). This is nearly identical to the proportion of fatal crashes in NASS CDS that involved a drowsy driver in the original (non-imputed) data analyzed in the current study (3.6%). This is consistent with expectations, because the fatal crashes analyzed in the current study are sampled from those crashes.

In the study perhaps most similar to the current study, Masten *et al.* (2006) used data from a sample of police-reported crashes in North Carolina to classify crash-involved drivers as drowsy or not drowsy, applied the model to fatal crashes nationwide from 2001 through 2003, and estimated that 15% – 33% of drivers involved in all fatal crashes and 23% – 43% of drivers involved in fatal crashes between midnight and 6:59 AM were drowsy. The current study estimates that 11.6% of drivers in all fatal crashes and 24.1% of drivers in fatal crashes that occurred between midnight and 6:59 AM were drowsy, similar to the lower end of the range of estimates that Masten *et al.* reported.

Klauer *et al.* (2006) estimated that drowsiness contributed to 22% of crashes and near crashes. Using directly-observed pre-event video, this study arguably obtained the most reliable assessment of driver drowsiness; however, the outcome measure was composed of principally near crashes and very minor crashes; it only included 5 crashes that resulted in injury or airbag deployment (Dingus *et al.*, 2006). The extent to which those results are generalizable to more severe crashes is not known. Klauer *et al.*'s estimate of the prevalence of drowsiness in crashes and near crashes lies slightly beyond the upper bound of the 95% confidence interval for fatal crashes in the current study, and is much higher than the current study's estimate of the prevalence of drowsiness in less severe crashes (which were still severe enough to result in a vehicle being towed). This may reflect a peculiarity of the relatively small and geographically clustered sample of drivers that Klauer *et al.* studied, or may reflect that the prevalence of crashes involving drowsiness is actually higher than the current study estimates. It does not seem plausible that drowsiness is more prevalent in crashes that are avoided successfully than in crashes that occur.

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