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DROWSY DRIVING AMONG OLDER ADULTS: A LITERATURE REVIEW

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16. Abstract

The goals of this literature review are to better understand the risk factors associated with drowsy driving, particularly those strongly affecting the older driver population, and to serve as the background information for the development of a questionnaire on this topic. The review is divided into two main sections: drowsy driving risk factors and countermeasures. Topics reviewed in the risk factors section include: sleep deprivation and disorders, medications that may cause drowsiness as a side effect, work schedules, circadian rhythm, personality attributes, alcohol use, lifestyle, and environmental characteristics. Topics reviewed in the countermeasures section included: common practices (e.g. turning up the volume of the radio), caffeine, napping, sleep disorder treatments, lifestyle, work schedules, alertness maintenance and in-vehicle technology. Emphasis was placed on finding studies performed on older drivers, although studies done on younger or middle-aged drivers were not excluded. Sleep disorders and various medical conditions and medications that may cause drowsiness are prevalent in the older population, putting older drivers at an increased risk of a drowsy driving crash. The circadian rhythm creates a risk for those driving between the hours of midnight and 6:00 AM and again in the mid-afternoon. Unusual work schedules, certain personality traits, alcohol use, and lifestyle practices (e.g. smoking) and monotonous road conditions may all lead to driver sleepiness and crash risk. Common practices to combat drowsy driving such as rolling down a window or turning up the radio's volume are not effective in combating drowsiness. Caffeine intake may help alleviate sleepiness, especially if combined with a short nap. Many non-medication treatments may benefit older adults suffering from sleep disorders or problems, but more research is needed to ascertain whether these treatments increase driving safety. Numerous types of in-vehicle drowsiness-detection technology have been developed to alert drivers before they crash. Overall, more research is needed to further understand drowsy driving risk factors and countermeasures regarding drivers age 65 and older. Findings indicated a strong need for more research on older drivers' crash risk relating to each topic.

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Introduction

All of us are familiar with the effects of drowsiness (sleepiness): heavy eyelids; a nodding head; drifting attention; and a strong desire to go to sleep. These effects can make operating a motor vehicle quite difficult. Indeed, as early as 1931, drowsy driving was identified as a risk factor for motor vehicle crashes (Williams, 1931). Today, drowsy driving is estimated to be responsible for more than 100,000 crashes, 40,000 injuries, and 1,550 deaths per year (National Highway Traffic Safety Administration, NHTSA, n.d.). However, NHTSA and others recognize that drowsy driving is a difficult problem to characterize for a number of reasons. First, crash data files do not accurately or specifically identify the role of drowsiness in crash causation. Second, crash estimates are based on single-vehicle, run-off-road, drift-off-road, or drift-out-of-lane events in which alcohol is not involved, occurring between midnight and 6:00 AM. Third, drowsy driving crashes involving multiple vehicles and daytime drowsy crashes are largely unaccounted for in crash analyses. Indeed, NHTSA's *National Survey of Distracted and Drowsy Driving Attitudes and Behavior: 2002* (Royal, 2003) has shown that 72 percent of drivers who admitted to falling asleep while driving reported that they did so outside the window of midnight to 6:00 AM. A more recent study by the National Sleep Foundation (2005) found that 60 percent of adult drivers (168 million people) reported having been drowsy at the wheel, 37 percent (103 million people) having fallen asleep while driving, and 4 percent having been in or had a near crash due to drowsiness while driving. Thus, the crash involvement of drowsy drivers is likely underestimated.

It is also not clear how accurately crash records reflect the drowsy driving risk among older adults (age 65 and older). First, older adults tend to avoid night driving (Eby, Molnar, & Kartje, 2009) and so have fewer nighttime crashes in general. Second, because of declines in critical driving skills resulting from age-related medical conditions, a drowsy-driving crash is more likely to be attributed to declining cognitive, perceptual, or motor skills than to a lack of sleep. In fact, a nationwide study of more than 4,000 drivers found a much smaller difference among age groups than is suggested by the crash records (Royal, 2003). In this survey, 30 percent of drivers age 65 and older reported that they had fallen asleep or nodded off while driving—only slightly less than the percentage across all age groups (37 percent). More research is clearly needed to understand the prevalence, causes, correlates, and associated crash risk of drowsy driving among older adults.

The purpose of this literature review is to synthesize the current literature related to drowsy driving among older adults to support the development of a questionnaire on this topic. We include in this review specific information on older adults as well as general information that can help inform questionnaire development. Note that the literature often uses the terms "fatigue," "drowsy," and "sleepy" interchangeably. In this review, we use the term drowsy driving to cover all three terms. Individuals with obstructive sleep apnea, and possibly other sleep disorders that are known to cause excessive daytime sleepiness, may deny sleepiness and instead describe their primary symptom as fatigue, tiredness, or lack of energy (Chervin, 2000). Sleepiness, regardless of the cause or descriptive term used, causes individuals to be less alert and attentive (Vanlaar, Simpson, Mayhew, & Robertson, 2008). This review covers two general areas with regard to drowsy drivers, each with several topics: driver risk factors (demographics, sleep disorders, medical conditions, medications, work schedules, circadian rhythm, personality, alcohol use, and lifestyle); and drowsy driving countermeasures (common practices; caffeine consumption; naps; medical treatments; shifting work schedules; technology; lifestyle changes; and medications).

Driver Risk Factors

A number of factors have been found to be associated with an increased risk of drowsy driving and drowsy-driving-related crashes. This section reviews these factors.

Environmental Factors

Certain types of road and driving conditions may contribute to drowsiness in motorists. The vast majority of drowsiness-related crashes occur in passenger vehicles; the rest mostly occur in large trucks (Lyznicki, Doege, Davis, Williams, & for the Council on Scientific Affairs, 1998). These crashes tend to occur on monotonous roads (Horne & Reyner, 1995). One study found that drowsiness comes about early when driving on monotonous roads and that breaks from the monotony may help to counteract the drowsiness (Thiffault & Bergeron, 2003b). A study on young men age 20-26 found that longer durations of monotonous driving was a risk factor for drowsy driving, with 80 minutes being the limit one can safely drive on a monotonous highway (Ting, Hwang, Doong, & Jeng, 2008). Motorists driving 20,000 or more miles a year, 2 or more hours a day, or in the dark conditions are at increased risk for a drowsy-related crash (Stutts, Wilkins, Osberg, & Vaughn, 2003). Another risk factor is driving alone. A study in New York on drivers who had been in a drowsy driving crash found that 83 percent of drivers were driving alone in the vehicle (McCartt, Ribner, Pack, & Hammer, 1996). This same study found that 40 percent of these crashes took place on an expressway or highway and 48 percent were single, vehicle drive-off-the-road type crashes. A similar study found that 78 percent of sleep-related crashes were drive-off-the-road type (Pack et al., 1995). NHTSA (2006) has reported that young men, shift workers and those with untreated sleep disorders such as sleep apnea and narcolepsy are at the highest risk of experiencing a drowsy driving crash. Other work has supported this result (Pack et al., 1995).

As expected, drivers in drowsiness-related crashes are more likely to indicate that they were sleepy before the crash. A population-based study was done on 571 drivers who had been involved in a crash so severe at least one car occupant needed to be admitted to the hospital. Participants were asked to rate how alert they felt before the crash on the Stanford Sleepiness Scale. Researchers found that those who rated their alertness as 4 or greater on the scale (indicating significant sleepiness) were 11 times more likely to be involved in a crash as those who rated themselves as 1 on the scale (Connor et al., 2002). This study also found that driving after 5 hours of sleep, or driving between the times of 2:00 and 5:00 AM, increased the risk of crash. Excessively and moderately sleepy drivers, with a tendency to fall asleep as measured by the Multiple Sleep Latency Test, are at an increased crash risk compared to alert drivers (Drake et al., 2010).

Sleep Deprivation

The National Sleep Foundation (2009) estimates that adults need between 7 and 9 hours of sleep each night. Studies have shown that failing to get an adequate amount of sleep can result in reduced driving ability. In one study, drivers sleeping for 5 hours or less were at a significantly increased risk of a crash (Connor et al., 2002). Averaging less than 5 hours of sleep a night increased the risk of a sleep-related crash in North Carolina drivers by nearly five times (Stutts et al., 2003). However, half of 567 drivers surveyed while driving on a summer vacation (mean age 37.7 years) did not get a full night's sleep, with 10 percent not sleeping at all beforehand (Philip et al., 1996) and 88 percent of drivers traveling on a long trip did not sleep an adequate amount the night before departing (Philip et al., 1997). A study of 22 young, healthy males in their early twenties found that those who drove after getting 8.5 hours of sleep had fewer inappropriate lane crossings (535 versus 66) during an on-road driving test than those who only slept 2 hours (Philip et al., 2005). One night of sleep deprivation (4 hours of sleep) increased right edge-line crossings when healthy males (age 25-55) were tested in a driving simulator (Otmani, Pebayle, Roge, & Muzet, 2005). Overall, however, Otmani and colleagues found one night of sleep restriction did not severely impair driving performance, a finding supported by Peters et al. (1995). Peters and colleagues deprived 12 participants (six male, six female, age 26-35) of sleep progressively over the course of 4 days. Four hours of sleep resulted in little changes in crashes, lateral placement of the vehicle and lane departures. However, as sleep deprivation increased, all of these driving-related measures increased including the drivers' speed in a 35-mile-per-hour zone. Braking reaction time slowed in sleep-deprived subjects (mean age 29.2 years) who slept for less than 4 hours over those who slept for 8 hours (Miyata et al., 2010). Philip et al. (2004) found young males (age 20-25) have a faster reaction time than older males (age 52-63), when both were well-rested. Yet, in the same study, after 24 hours of sleep deprivation, only the younger drivers experienced significant impairment in reaction time during simulated driving. Forgoing sleep for 17-19 hours produced similar effects on reaction time and other performance tests as a blood alcohol concentration of 0.05 percent (Williamson & Feyer, 2000). Thus, sleep deprivation does negatively impact driving performance and crash risk, but there are clearly individual differences and possibly differences by age.

Sleep Disorders

Sleep disorders are medical conditions that adversely affect sleep duration, sleep quality, or both. Sleep disorders are common in the general population and in the older adult population. The National Institute of Neurological Disorders and Stroke (NINDS, 2007) reports that at least 40 million Americans suffer from a serious sleep disorder, the most common being sleep apnea, insomnia, and narcolepsy. The NINDS also reports that an additional 20 million Americans have occasional sleeping trouble. According to a study by the National Institute on Aging, one-half of the 9,000 older adults surveyed reported suffering from sleeping trouble (Foley et al., 1995). The American Academy of Sleep Medicine (2008) reports that one-half of adults age 60 and older suffer from insomnia, 20 percent of people age 80 and older suffer from restless leg syndrome (RLS), and 40 percent of all adults snore which may indicate obstructive sleep apnea. In another study of 430 older drivers age 70 and over, 64 percent reported sleeping trouble, 26 percent reported an abnormal score on the Insomnia Severity Index, 20 percent were at risk for sleep apnea and 60 percent were likely to be drowsy in the afternoon (Vaz Fragoso, Araujo, Van Ness, & Marottoli, 2008). Circadian rhythm sleep disorders, periodic limb movement disorder, and REM sleep-behavior disorder can also cause sleep problems in older adults (Neubauer, 1999).

Sleep disorders among drivers are also common in other populations studied. A large study in France surveyed 35,004 highway drivers about sleep disorders and found that 17 percent reported suffering from at least one sleep disorder and 9 percent experienced drowsiness so intense they had to stop driving (Philip et al., in press). Sleep disorders reported by these French drivers included: obstructive sleep apnea (5 percent), insomnia (9 percent), and narcolepsy/hypersomnia (0.1 percent). Approximately 31 percent of respondents reported a near-crash, with one-half of these being sleep-related. Seven percent of respondents reported being in a crash in the past year, with nearly all of these crashes being related to drowsiness.

These studies confirm that sleep disorders are relatively common among the driving population, particularly among older adults. The next sections provide more detail about a few of the more common sleep disorders, including the relationship of these disorders to crash risk: sleep apnea; narcolepsy; and insomnia.

Sleep Apnea

Sleep apnea is a medical condition characterized by repeated complete or partial airway obstructions, which often results in interrupted sleep and daytime sleepiness (National Heart Lung and Blood Institute, 2010). The condition affects at least 18 million Americans according to the National Institute of Neurological Disorders and Stroke (2007). Studies in controlled, on-road conditions show that drivers with sleep apnea exhibit poor driving performance. For example, a study that compared drivers with sleep apnea to healthy controls found that during an on-road test, the sleep apneics drifted out of their lanes more frequently while driving (Philip et al., 2008). Studies using crashes as the outcome measure have also shown that drivers with sleep apnea are more likely to be involved in a car crash than drivers without sleep apnea (Barbe et al., 1998; Findley, Unverzagt, & Suratt, 1988; Haraldsson, Carenfelt, Diderichsen, Nygren, & Tingvall, 1990; Wu & Yan-Go, 1996). One study found that drivers with obstructive sleep apnea (male, mostly obese, average age 49.3) were involved in more than twice as many car crashes as healthy controls (George, Nickerson, Hanly, Millar, & Kryger, 1987). Another study found that out of 554 drivers (average age 49.2 ± 14.3) suffering from heavy snoring and daytime sleepiness, 39 percent reported excessive sleepiness while driving and 25 percent reported instances of falling asleep while driving (Shiomi et al., 2002). In the same study, 448 drivers were diagnosed with obstructive sleep apnea-hypopnea syndrome (OSAHS), while 106 were considered to have primary snoring. The frequency of self-reported drowsy-driving crashes increased with increasing sleep apnea severity, with a 4 percent crash rate reported for primary snorers; a 6 percent crash rate for drivers with mild OSAHS, a 10 percent crash rate for drivers with moderate OSAHS, and an 11 percent rate for drivers classified with severe OSAHS. Other work has found that drivers with moderate to severe sleep apnea syndrome were involved in more crashes than drivers with mild sleep apnea syndrome (Horstmann, Hess, Bassetti, Gugger, & Mathis, 2000). These studies show that sleep apnea is a clear risk factor for decreased driving ability and drowsiness-related crashes and that there is a dose-response relationship between crash risk and disease severity.

Narcolepsy

Narcolepsy, a sleep disorder that affects an estimated 1 in every 2,000 Americans, is characterized by sudden sleep attacks, cataplexy, hallucinations, and sleep paralysis (NINDS, 2010). Narcoleptic patients can suffer an attack at any time, including while driving, which creates an obvious crash risk. Narcoleptics exhibit worse driving performance than other drivers, including those with sleep apnea. A study of 16 narcoleptics (nine male, seven female, mean age of 38±19 years) versus 31 sleep apnea patients (27 male, four female, mean age 45±5.5 years), and 14 control subjects (11 male, 3 female, mean age 43±15 years), found that narcoleptics exhibited significantly worse performances on a simulated driving reaction task than the other two groups (Findley, Suratt, & Dinges, 1999). Narcoleptics are also at greater risk for crashes. In one study, narcoleptics were found to have a higher proportion of sleep-related vehicle crashes when compared to drivers with sleep apnea and drivers with other sleep disorders (Aldrich, 1989). A study of 180 narcoleptic patients found that 66 percent reported falling asleep at the wheel and 67 percent reported near crashes due to falling asleep or drowsiness while driving (Broughton et al., 1981). More recent work has found similar results (Findley et al., 1995; Kotterba et al., 2004; Philip et al., in press).

Insomnia

Insomnia is defined as difficulty falling or staying asleep and is the most commonly reported sleep disorder, particularly among older adults. Older adults are at an increased risk of being insomniacs with about one-half reporting symptoms of the disorder (Lopez, 2010; Roth, 2007). Given that insomnia disrupts sleep and may cause daytime sleepiness, including while driving, it is related to decreased driving performance and increased incidence of drowsiness-related crashes. Indeed, research shows that older drivers who self-report symptoms of insomnia also report daytime drowsiness and decreased driving abilities, especially at night (Vaz Fragoso et al., 2008). The relationship of insomnia to crash risk, however, is not clear. A study in France found very little difference in driving crashes (9 percent versus 10 percent) and near-crashes (5 percent versus 4 percent) between insomniacs and controls (Leger, Guilleminault, Bader, Levy, & Paillard, 2002). Similar findings were reported in a Canadian study (Daley et al., 2009), which found little difference in motor vehicle crash rates between participants with insomnia, insomnia symptoms but not a definitive diagnosis, and those who considered themselves good sleepers. However, this same study found that of the 33 participants who had been in a motor vehicle crash, eight reported that insomnia was the main cause of the crash. Thus, there is some evidence that insomnia increases crash risk but the evidence is mixed. Further research is needed.

Medical Conditions

A variety of medical conditions can also result in sleepiness that could compromise driving ability. There are too many conditions to cover exhaustively here. Instead we discuss some of the more common conditions. For example, people with Parkinson's Disease (PD) or attention deficit hyperactivity disorder (ADHD) are at risk for daytime drowsiness and, therefore, drowsy driving. Insomnia and restless leg syndrome are commonly reported by patients with PD and could contribute to complaints of daytime sleepiness (Haq, Naidu, Reddy, & Chaudhuri, 2010). A questionnaire completed by 6,620 patients with PD found that 82 percent still had a driver's license, and of those drivers who experienced the sudden onset of sleep while driving, 27 percent reported a near-crash and 28 percent reported an actual crash (Meindorfner et al., 2005). In PD patients, the sudden onset of sleep behind the wheel was associated with older age, being male, longer disease duration, and the use of dopamine agonists (Ondo et al., 2001). Research has shown that drivers with ADHD may become sleepier in a shorter period of time than do drivers without this condition, as they were found likelier to crash in a driving simulator (Reimer, D'Ambrosio, Coughlin, Fried, & Biederman, 2007).

A number of other medical conditions have been linked to sleep problems and daytime drowsiness. Conditions such as cardiovascular, gastrointestinal, neurologic and pulmonary disease may also cause sleep problems in older adults, as can psychiatric disorders, circadian rhythm sleep disorders, periodic limb movement disorder, and REM sleep behavior disorder (Neubauer, 1999). Individuals age 65 and older suffering from a neurological disorder were more likely to fail a standardized road test (Classen et al., 2008). A number of studies have found associations between medical conditions and sleep problems including: HIV/AIDS; rheumatoid arthritis; lung disease; untreated asthma; heartburn; renal disease; depression and anxiety disorder; chronic pain; Lyme disease; menopause; ulcers; obesity; heart disease; migraines; diabetes; stroke osteoporosis; and cancer (Bixler et al., 2005; Bourguignon, Labyak, & Taibi, 2003; Foley, Ancoli-Israel, Britz, & Walsh, 2004; Nokes, Chidekel, & Kendrew, 1999; Ohayon, Caulet, Philip, Guilleminault, & Priest, 1997; Parish, 2009; Stroe et al., 2010; van Mill, Hoogendijk, Vogelzangs, van Dyck, & Penninx, 2010; Vgontzas et al., 1998).

Medications

Many medications can cause drowsiness. Since medication use among older adults is high, the potential side effect of drowsiness is worrisome. A US study of noninstutionalized older adults found that more than 90 percent take at least one medication per week (Gurwitz, 2004). The study also found that polypharmacy was common among older adults, with more than 40 percent using five or more prescription drugs per week and 12 percent using 10 or more drugs per week.

Several classes of medications have been studied to assess their effects on an individual's ability to operate a motor vehicle. For example, Baldock et al. (2005) examined the effect of medication use on driving ability in a sample of 104 drivers age 60 to 92 and found that 60 percent of participants used at least one prescription medication per month and 83 percent suffered from at least one medical condition. Of the 104 drivers, only 44 were taking medications that might impair driving by affecting the central nervous system (CNS). Most of these medications were used to treat depression, heart problems, hypertension, ulcers and acid reflux. To test whether the medication impacted the participants' driving performance, 90 drivers completed an on-road driving assessment, resulting in 76 percent passing, 9 percent passing but being identified as needing lessons, and 16 percent failing. The researchers' general conclusion was that medications that may impair driving were related to driving ability, but not significantly. They also found that the number of medications one is taking does not significantly affect driving ability. Stutts et al. (2003) found 8 percent of drivers in a sleep-related crash reported using medication that could cause drowsiness.

The most common classes of medications that may put one at risk for drowsy driving after use include benzodiazepines, antihistamines, antidepressants and antipsychotics. The following sections examine these drug classes and their effect on driving ability in further detail.

Benzodiazepines

Benzodiazepines are among the most common prescription medications available. Fifteen different types of medication in this class exist and around 100 million prescriptions were written in 1999 (US Drug Enforcement Administration, n.d.). Benzodiazepines are generally used to treat anxiety, muscle spasms, insomnia, and seizures (Jones, Shinar, & Walsh, 2003; Ray, Thapa, & Shorr, 1993).

Commonly prescribed benzodiazepines with long half-lives include diazepam (more commonly known as Valium), flurazepam, and lorazepam. All have consistently been found to impair driving performance, especially during the morning after ingestion and sometimes into the afternoon (Moskowitz & Smiley, 1982; O'Hanlon, Haak, Blaauw, & Riemersma, 1982). O'Hanlon et al. (1982) noted, however, that it may be possible for patients to adapt to long-term treatment of benzodiazepines, which may reduce the drug's effect on driving performance.

The relationship between benzodiazepine use and impairment of driving performance has been thoroughly studied (see Berghaus & Grass, 1997; Ray et al., 1993; Wilkinson & Moskowitz, 2001). The more than 500 experimental studies on this topic show consistent results: driving performance declines with increased levels of benzodiazepines. Although short half-life benzodiazepines are eliminated faster, they can still be dangerous. O'Hanlon (1992) cited several studies that have found that short half-life benzodiazepines impair driving performance.

Unlike the literature on driving performance, the literature investigating the associations between benzodiazepines and actual crash risk is more limited. Studies with young drivers have generally shown that benzodiazepines increase the risk of a crash (summarized in Ray et al., 1993). Studies with older drivers have found similar results (Hemmelgarn, Suissa, Huang, Jean-Francois, & Pinard, 1997; McGwin, Sims, Pulley, & Roseman, 2000; Neutel, 1995; Ray, Fought, & Decker, 1992; Sims, McGwin, Allman, Ball, & Owsley, 2000). A study in the US, for example, found a 50 percent increase in crash risk among older people who used benzodiazepines (Ray et al., 1992). A Canadian study found that within the first week of using benzodiazepines, there was a 45 percent increased crash risk among older adults who took long half-life benzodiazepines (Hemmelgarn et al., 1997). Crash risk decreased after the first week of use, but still remained 26 percent higher than controls, even after a year of continuous use. Interestingly, for older adults who took short half-life benzodiazepines, no increased crash risk was found. A study of older adults in Alabama found that as compared to control drivers, those taking benzodiazepines were more than five times as likely to be in an at-fault crash (McGwin et al., 2000). Collectively, this body of literature suggests that: (1) older adults taking benzodiazepines are at a higher risk of a crash and should avoid driving for several hours after dosage; and (2) for older adults who drive, only short half-life benzodiazepines should be prescribed, if possible.

Hypnotics

Hypnotic drugs are often taken to treat insomnia. One study of the hypnotic drugs zolpiclone and zolpidem found that these drugs did not significantly impair the driving ability of people age 55 to 65, as tested in a driving simulator (Meskali, Berthelon, Marie, Denise, & Bocca, 2009). The study, however, did note a slight increase in collisions and poorer lane positioning among drivers taking zolpidem compared to zopiclone. The driving effects of the insomnia medications temazepam (a benzodiazepine) and zopiclone (a non-benzodiazepine hypnotic) were tested on a group of older drivers on the morning after a bedtime administration of the drugs (Leufkens & Vermeeren, 2009). Unexpectedly, the study found that driving was significantly impaired in only those drivers who took the shorter acting zopiclone. In a different study, the effects of the insomnia-treating medications zolpidem and temazepam (versus placebo) on driving ability were assessed among 18 women age 35-58 (Partinen, Hirvonen, Hublin, Halavaara, & Hiltunen, 2003). Participants were administered a drug at 2:00 AM and were tested in a driving simulator at 7:30 AM. Results showed that the drugs did not significantly affect driving ability, although two non-placebo drivers recorded a high number of collisions, and those who took zolpidem had slightly more lane deviations when compared to subjects in the temazepam and placebo groups.

Antihistamines

Antihistamines are medications most often used to treat allergies. Many of the older (first and second generation) antihistamines available are known to cause drowsiness, whereas newer (third generation) antihistamines are often marketed as being “non-drowsy” (American Academy of Otolaryngology-Head and Neck Surgery, 2010). Antihistamines are widely available over-the-counter (OTC).

Research shows that the sleep-inducing and sedative properties of this class of drugs may impair driving ability (Verster & Volkerts, 2004). Research on a common OTC second generation antihistamine found that it impaired driving performance for 2-3 hours after taking the medication (Gengo, Gabos, & Miller, 1989; Nakra, Gfeller, & Hassan, 1992; Ray et al., 1993). Non drowsy/sedative antihistamines do not impair cognitive or psychomotor performance (Nicholson, 1986) and do not appear to affect the ability to drive an automobile (Betts, Markman, Debenham, Mortiboy, & McKevitt, 1984).

The relationship between sedation-inducing antihistamines and crash risk has not been firmly established. Studies that have attempted to determine the effect of this type of antihistamine on crash risk among older drivers have found that past users showed a slightly increased risk for an injurious motor vehicle crash, compared to non users (Leveille et al., 1994). However, antihistamines were not found to increase crash risk among the older adults in another study (Ray et al., 1992).

Antipsychotics

Antipsychotics are medications used to treat schizophrenia and other psychiatric disorders. This class of drugs may cause drowsiness; patients taking these types of medications are advised not to drive until they have become accustomed to the drug (National Institute of Mental Health, 2008). Limited research has addressed the effects of antipsychotic medications on driving ability. One study of fatal crashes found a very low incidence (2 of 800) of antipsychotic medication in deceased drivers (Judd, 1985). Another study used a driving simulator to assess the driving ability of schizophrenic who were taking antipsychotic medicine (Wylie, Thompson, & Wildgust, 1993). When 22 schizophrenic drivers were compared to 16 healthy control drivers, drivers with schizophrenia performed significantly worse on brake reaction time and responding to a red light. The researchers noted that it was unclear if driving decrements resulted from the medication or the underlying psychiatric illness.

Antidepressants

Antidepressants may help improve quality of sleep, although side effects may include tiredness and sleep disruption (MedlinePlus, 2010). There are various categories of antidepressant medications, related to their mechanism of action including serotonin-specific reuptake inhibitors (SSRIs;), monoamine oxidase inhibitors (MAO-Is), tricyclic antidepressants (TCAs), and newer serotonion-norepinephrine reuptake inhibitors (Internet Drug News Inc., 2007). There are also newer antidepressants that inhibit the uptake of both serotonin and norepinephrine (SNRIs). Antidepressants can also be classified by whether or not they produce sedation as a side effect. Susceptibility to sedation as a side effect may increase with age (Sanders, 1986).

Use of sedating antidepressants is consistently associated with deterioration in a wide variety of vehicle-handling skills (Clayton, Harvey, & Betts, 1977; Hindmarch, 1988; Ramaekers, 2003; Seppala, Linnoila, Elonen, Mattila, & Maki, 1975; Smiley, 1987). For example, utilizing an in-traffic driving test, sedating antidepressants significantly impaired lateral position control and speed control compared to a placebo (Louwerens, Brookhuis, & O'Hanlon, 1984). Non-sedating antidepressants typically do not impair driving skills, except possibly at high doses (Lococo & Staplin, 2006; Ray et al., 1993; Walsh, de Gier, Christopherson, & Verstraete, 2004; Wilkinson & Moskowitz, 2001).

Studies have also found that sedating antidepressants increase crash risk among older adults (Leveille et al., 1994; Ray et al., 1992). In two studies, older adults with current prescriptions of sedating tricyclic antidepressants had more than twice the risk for injury-crashes, compared to older adults without these prescriptions (Leveille et al., 1994; Ray et al., 1992). A strong dose-response effect has also been found, with crash risk increasing as dosage levels of the drug increased. In one study, older drivers with high-dose prescriptions had nearly three times the risk for injury crashes, compared with nonusers (Leveille et al., 1994). Another study of older drivers found that the crash risk associated with taking 125 mg of amitriptyline (a popular sedating tricyclic antidepressant) daily resulted in five times the crash risk associated with a dosage of 25 mg of amitriptyline (Ray et al., 1992).

Work Schedules

Several studies have found that the type of job one holds, as well as the schedule and hours worked, can have an effect on driving ability. The National Sleep Foundation (2010) states that working over 60 hours a week increases crash risk by 40 percent. In a survey of 1,000 New York residents, respondents who reported a strenuous work life, including working extra hours and varying shifts, were more likely to report drowsy driving in the previous year (McCartt et al., 1996). Similarly, a survey of 1,366 Greek drivers, ranging in age from 19-65 years, also found that working extra hours and varying shifts increased crash risk (Gnardellis, Tzamalouka, Papadakaki, & Chliaoutakis, 2008).

Shift work (i.e. working hours and shifts outside the standard workday) is considered a risk factor for drowsy driving. Those entering into shift work from a standard work day increase their risk of sleep problems, as well as their risk of falling asleep at work (Akerstedt, Nordin, Alfredsson, Westerholm, & Kecklund, 2010). A New York study found night-shift and rotating-shift workers were likely to be sleep-deprived (<6 hours sleep) and at a greater risk for a car crash (Ohayon, Smolensky, & Roth, 2010). Scott et al. (2007) found that, out of a sample of 895 nurses, 596 reported driving drowsy at least once over a span of 4 weeks, and 30 said they drove drowsy following every shift. These nurses doubled and tripled their risk of drowsy driving by working shifts longer than 12.5 hours or experiencing drowsiness while on the job, respectively. Night-shift nurses were also at an increased risk, with 136 of 171 nurses driving drowsy at least once over the 4 week study period. Findings from a study on interns showed that each extended shift worked increased the intern's crash risk by 9.1 percent and his or her monthly risk of crashing during the drive home by 16.2 percent; interns working five or more extended shifts per month significantly increased their risk of falling asleep at the wheel (Barger et al., 2005). House staff workers on-call every fourth night experienced more occurrences of falling asleep while stopped at a traffic light and falling asleep while driving than faculty members undisturbed at night (Marcus & Loughlin, 1996). This study found 49 percent of the house staff subjects to have fallen asleep at the wheel, with 90 percent of these occurrences happening post-call.

Drowsy driving may be a particularly salient issue for commercial drivers, who also work extended shifts at varying times across the 24-hour day. McCartt et al. (2000) interviewed 593 commercial truck drivers at truck stops to inquire about drowsy driving. Of the 593 truck drivers, 61.3 percent reported driving at least 100,000 miles annually, 79.6 percent reported trips that lasted 3 days or more, and 70.5 percent a schedule that changed daily. When asked about falling asleep while driving, 47.1 percent said they had, with 25.4 percent reporting that it happened at least once in the last year. According to this study, older truck drivers were at an increased risk of a drowsy driving crash. Not all studies of older commercial vehicle drivers agree. A detailed literature review of drowsiness-related crashes among commercial vehicle drivers reported that when compared to young drivers, older drivers were found to be safer in some studies, less safe in others, and not different from younger drivers in other studies (Duke, Guest, & Boggess, 2010). In another study of male heavy goods commercial vehicle drivers age 20-60, snoring at night (a symptom of obstructive sleep apnea), obesity, large neck size, and higher Epworth Sleepiness Scale scores were associated with increased risk of a crash (Maycock, 1997). A study of 154 bus drivers found that 14 percent experienced sleepiness while driving on a regular basis, 33 percent sometimes experienced sleepiness, and 77 percent reported they felt so sleepy they had to stop driving at least one time (van den Berg & Landström, 2006). Respondents reported that sleepiness came about during early morning hours (3:00 AM and 6:00 AM) and at the end of a long trip. The drivers reported that lack of sleep, sleep quality and work hours were the most significant causes of sleepiness (van den Berg & Landström, 2006). A survey of 4,331 commercial bus and truck drivers found that 33 percent of crashes were related to drowsy driving (Leechawengwongs, Leechawengwongs, Sukying, & Udomsubpayakul, 2006). The study also reported that 75 percent of drivers reported drowsy driving, 28 percent reported micro sleeps while driving, and 45 percent experienced EDS. Studies have also addressed the causes of drowsiness among commercial drivers. In a study of 2,342 commercial drivers, 60 percent reported probable sleep-disorders and another 16 percent reported diagnosed sleep apnea (Howard et al., 2004). Other drivers reported shifting schedules, use of antihistamines, and use of analgesics as the cause of sleepiness.

Circadian Rhythm

Circadian rhythm refers to the body's internal rhythms that are roughly 24 hours in length (National Institute of General Medical Sciences, 2010). The body's master clock, located in the suprachiasmatic nuclei (SCN) of the anterior hypothalamus, modulates several of these rhythms, including sleepiness and alertness. Attempting to perform during a time when one's circadian rhythm is signaling that the body should be sleeping could be a risk factor for a drowsiness-related crash. As people age, the circadian rhythm tends to change, with older people going to bed and waking earlier. Indeed, drowsy driving crashes are more frequent at night, but also occur at other times. A survey of US drivers found that drowsiness behind the wheel occurred between the hours of 6:00 AM and 5:00 PM for 35 percent of drivers, while 28 percent felt drowsy between 12:00 AM and 6:00 AM, and 17 percent between 5:00 PM and 9:00 PM (Royal, 2003). A study of English drivers found drowsy driving crashes to be highest in the mid-afternoon and in the early morning between 2:00 and 3:00 AM (Horne & Reyner, 1995). A study in North Carolina found that drivers in sleep-related crashes were more likely to report driving between 12:00 AM and 6:00 AM (Stutts et al., 2003). Other work in New York found that 60 percent of drivers who were in drowsy driving crashes had their crash between the hours of 11:00 PM and 7:00 AM (McCartt et al., 1996). Studies that have considered older adults, however, find that this age group tends to have drowsiness-related crashes in the mid-afternoon rather than at night (Horne & Reyner, 1999; Pack et al., 1995; Summala & Mikkola, 1994). This is not surprising given that older adults tend to do most of their driving during the daytime.

Personality

An individual's personality traits may increase his or her likelihood of experiencing daytime sleepiness. Mastin et al. (2005) found neuroticism to be linked with higher self-reported feelings of sleepiness and poorer performance on a behavioral task. Other work has shown that sleep-deprived extraverts became more impaired than sleep-deprived introverts on a cognitive vigilance task (Smith & Maben, 1993).

There is also some evidence that a person's personality may affect the likelihood of a drowsy driving crash. For example, one study of 26 people age 22-55 assessed driving performance in a driving simulator to assess driving performance, drowsiness, and personality (Verwey & Zaidel, 2000). Participants drove for 135 minutes on a simulated two-lane highway at night with light traffic. The participants completed a questionnaire prior to the simulated driving test that included questions about medication use, driving experience and behavior, and personality. None of the participants used medication that might affect driving, and they were not allowed to consume coffee or alcohol prior to the driving test. The researchers measured eye-closures (a measure of drowsiness) and lane/road departures. The study found that participants who were categorized as having an extraversion-boredom personality trait showed more drowsiness and had significantly more road departures than those who were classified as introverted. Other work has also found that extraverts may be more likely to be in drowsy driving crashes (e.g. Thiffault & Bergeron, 2003a; Wijesuriya, Tran, & Craig, 2007)

Alcohol Use

The dangers of alcohol use and driving are well known. What is less well-known is that drowsiness can produce decrements in driving ability that are similar to the effects of alcohol (Powell et al., 2001). For example, forgoing sleep for 18.5 or 21 hours has produced the same types of driving performance decrements as blood alcohol concentrations (BAC) of 0.05 and 0.08 percent (Arnedt, Wilde, Munt, & MacLean, 2001; Fairclough & Graham, 1999). Drowsiness combined with alcohol use can greatly reduce driving ability. Driving ability has been shown to decrease in sleep-deprived subjects after they ingest alcohol (Arnedt, Wilde, Munt, & MacLean, 2000; Horne, Reyner, & Barrett, 2003). Among a survey of 2,335 drivers, males with a BAC of 0.001g- 0.049g percent felt sleepier than those with a BAC 0.05g percent or greater or those who had not ingested any alcohol (Wilson, Fang, Cooper, & Beirness, 2006). Low doses of ethanol combined with sleep deprivation (4 hours of sleep) increased sleepiness, reaction time, and driver impairment in young men 21-35 years old (Roehrs, Beare, Zorick, & Roth, 1994). Alcohol has been found to affect sleepiness especially in the early afternoon (i.e. 1:10 p.m.) versus in the early evening in young women

(Horne & Baumber, 1991). Even without sleep deprivation, ingesting even small quantities of alcohol in the afternoon can be dangerous, particularly if one is sleep-deprived. One study found that sleep deprivation plus alcohol resulted in greater decline in driving performance than either one alone and that drivers did not always realize how much sleepier they had become due to alcohol consumption (Horne et al., 2003).

Lifestyle

The lifestyle one leads could influence the likeliness of driving drowsy. For example, Papadakaki et al. (2008) surveyed 1,366 Greeks age 19-65 years, and found that married people, women, experienced drivers, and older drivers were less likely to drive drowsy. The same study found that those whose lifestyles included "amusement", "sports" and being a "workaholic" were more prone to drowsy driving, daytime sleepiness, and getting less sleep at night. The researchers also found lifestyle practices relating to "religion" (i.e. fasting, going to church, etc**)** were associated with a lesser risk of drowsy driving. Philip et al. (2010) also found that unmarried people were at increased risk for drowsy driving. The 2003 *Sleep and Aging* poll found older adults who exercised less than once a week were more likely to suffer from a sleep disorder, sleep trouble, and daytime sleepiness (National Sleep Foundation, 2010). Smoking tobacco was also found to be a risk factor for excessive daytime sleepiness (Bixler et al., 2005).

Drowsy Driving Countermeasures

In response to the long-time recognition that drowsy driving is a risk factor for crashes (Williams, 1931), several countermeasures have been developed to alleviate the problem. These countermeasures have met with varied success. Here we review some commonly used countermeasures for drowsy driving.

Common Practices

People report engaging in a number practices believed to help keep them awake when they are experiencing drowsiness while driving. In one survey of 750 drivers, the most commonly reported practices to combat drowsiness were rolling down a window and listening to the radio, while the least reported practice was taking a rest (Vanlaar et al., 2008). A different survey of more than 3,000 drivers found that people reported the following practices: stopping to take a walk (54 percent); turning on the stereo (52 percent); opening a window (47 percent); drinking coffee (45 percent); and talking to vehicle passengers (35 percent)(Anund, Kecklund, Peters, & Akerstedt, 2008). This same study also found that older drivers were more likely to report measures such as stopping for a nap or to get coffee. Although these practices are very common, many do not improve the driving performance of a drowsy driver (see e.g., Reyner & Horne, 1998).

Caffeine Consumption & Napping

Caffeine intake and/or napping can help fight drowsiness and may be helpful to counteracting sleepiness behind the wheel. In response to one survey, experts in the fields of driving, fatigue, and traffic safety chose measures such as letting a passenger drive for a few hours while one naps and stopping to nap for an hour or more as the most recommended to combat driver fatigue (Nguyen, Jauregui, & Dinges, 1998). Following these, the study respondents recommended stopping for a 30-45 minute nap, stopping for a 10-20 minute nap, stopping to consume caffeine and talking to a passenger. Caffeine has been shown to improve simulated driving ability in young adults (Biggs et al., 2007). Slow-release caffeine has been shown to decrease driving errors (i.e. lane drifting, crashes) made by young (age 20-25) sleep-deprived drivers (De Valck & Cluydts, 2001). However, caffeine effects have been shown to be short-lived (Reyner & Horne, 2000). In this study, the authors found that 200 mg of caffeine decreased young drivers' sleepiness for about 30 minutes if they were not sleep-deprived and only for about 2 hours if they were sleep-deprived. Other work has shown that caffeine intake could even improve wakefulness and reaction times following alcohol use (Liguori & Robinson, 2001). Caffeine combined with a short nap may be even more effective in decreasing daytime drowsiness (Hayashi, Masuda, & Hori, 2003). Afternoon sleepiness while driving was found to be reduced by 200 mg of caffeine and eliminated by caffeine consumption plus a 30 minute nap (Reyner & Horne, 1997). Energy drinks (which contain caffeine) may also be useful in counteracting drowsiness while driving. When young, sleep-restricted drivers were given 500 ml of an energy drink, they committed fewer lane crossing errors in simulated driving than before consuming the energy drink (Horne & Reyner, 2001). Although this research shows that caffeine may be beneficial for counteracting drowsy driving in some circumstances, caffeine can also disrupt and decrease the quality of sleep when consumed too close to bedtime (Drapeau et al., 2006).

Treatments for Sleep Disorders

Given that untreated sleep disorders increase the likelihood of a drowsy driving crash, proper treatment of these conditions will likely reduce drowsy driving. A telephone interview of 50 drivers with sleep apnea found that treatment with nasal continuous positive airway pressure (nasal CPAP) reduced the number of automobile crashes that patients experienced (Findley, Smith, Hooper, Dineen, & Suratt, 2000). Researchers have estimated that treating sleep apnea with CPAP can potentially save 1,000 lives and prevent more than 500,000 crashes per year (Sassani et al., 2004). Patients with obstructive sleep apnea were found to have significantly improved driving performance after treatment with CPAP (George, Boudreau, & Smiley, 1997). Taking a 2-hour nap was found to only temporarily improve alertness in narcoleptic patients (Helmus et al., 1997). Severe narcoleptics already being treated with medication may find further symptomatic benefit from the addition of scheduled daytime naps in reducing their daytime drowsiness (Rogers, Aldrich, & Lin, 2001). The drug modafinil may reduce excessive daytime sleepiness in narcoleptics (Golicki, Bala, Niewada, & Wierzbicka, 2010) and the risk of RLS patients suddenly falling asleep may be decreased by dopaminergic medications (Möller et al., 2006). A survey of 24 RLS patients taking pramipexole, a dopamine agonist, found that none of the treated patients experienced sleep attacks, although 11 did report ongoing daytime drowsiness (Stiasny, Möller, & Oertel, 2000). A review of RLS found the sudden onset of sleep in RLS patients due to dopaminergic medications to be low or not experienced in three studies (Earley & Silber, 2010). Although certain medications and good sleep hygiene may reduce the likelihood of daytime drowsiness in patients with narcolepsy and restless leg syndrome, further research is needed to determine whether these treatments improve the patients' driving performance. Insomnia causes difficulty with sleep initiation or maintenance, which can result in daytime drowsiness, potentially leading to drowsy driving. With treatment, individuals with insomnia may be able to get better sleep and counteract their daytime drowsiness. However, as previously discussed, the potential medication side effect of sedation must be considered when pharmacologic treatment for insomnia is prescribed. In one study, eszopiclone improved the sleep of subjects with insomnia without impairing driving ability (Boyle, Trick, Johnsen, Roach, & Rubens, 2008). Older adult sufferers of insomnia may benefit from keeping a "sleep diary" to keep track of sleep duration, quality of sleep and related factors (Roszkowska & Geraci). With this sleep diary, the authors believed that older patients could improve their sleep hygiene (e.g. avoiding heavy meals near bedtime) and hence reduce their symptoms of insomnia. Good sleep hygiene and 45 minutes of morning bright light treatment were found to help older adult sufferers of insomnia (Kirisoglu & Guilleminault, 2004). Though these non-medication treatments of insomnia have shown to improve older adults' quality of sleep, further research is needed to determine whether these approaches translate to increased road safety.

Lifestyle

An individual's daily lifestyle can influence his or her likelihood of drowsy driving. Maintaining a set sleep schedule and refraining from nicotine, alcohol, meals, and exercise before bedtime are lifestyle practices that can help reduce sleep deprivation and drowsiness (Kushida, 2006). An active lifestyle could lead to better sleep in older adults, and in turn, a decreased risk of drowsy driving. A study of 741 men and 365 women diagnosed with sleep apnea, showed that lack of exercise was associated with increased excessive daytime sleepiness (Basta et al., 2008). A study of physically active versus sedentary older women showed that those women active in walking and dancing four times a week or more experienced a longer, better quality and less disturbed night's sleep (de Castro Toledo Guimaraes, de Carvalho, Yanaguibashi, & do Prado, 2008). Further studies found that older adults with mild sleep problems can benefit from low to moderate exercise regimens (King, Oman, Brassington, Bliwise, & Haskell, 1997; Li et al., 2004), and in older adults suffering from insomnia, aerobic exercise may help improve their sleep (Reid et al., 2010). Music may help as well, as a study in Taiwan of 60 adults age 60-83 found listening to soothing music at bedtime improved sleep quality (Lai & Good, 2005). Good sleep hygiene, exercise and soothing music may increase sleep quality, however, more research is needed to determine whether these tactics may reduce the risk of a drowsy driving crash.

Shift Work Schedule

Those with a non-traditional work schedule may be able to reduce drowsiness by sleeping at opportune times (such as late night, early morning, or in the afternoon), shortening shifts, eliminating double shifts, or rotating schedules from night to day (Caldwell, 2001). However, in another study, taking a 40-minute mid-shift nap break at 3:00 AM did not improve medical staff's simulated driving ability after their shift over those who did not nap (Smith-Coggins et al., 2006). However, ingesting caffeine combined with a nap helped those working a night-shift (Schweitzer, Randazzo, Stone, Erman, & Walsh, 2006). A review of the literature on shift and night work found that countermeasures such as bright light therapy and melatonin can help adjust the circadian rhythm; the use of hypnotics (e.g. zopiclone) and/or physical exercise can help improve sleep quality; a quick nap or ingesting caffeine before a night shift can help increase alertness and performance (Pallesen et al., 2010).

Nurses often work demanding schedules that can produce daytime drowsiness. A program for reducing daytime drowsiness among nurses was recently evaluated (Scott, Hofmeister, Rogness, & Rogers, 2010). Forty-seven nurses participated in the program, which educated them on the topics of sleep loss and deprivation, enhancing sleep quality, and the use of naps and caffeine. The program succeeded in reducing daytime drowsiness and improving sleep quality, sleep duration, and alertness.

Countermeasures to help sleepiness in professional drivers have also been studied. For example, a 3-hour afternoon nap improved alertness in long-haul nighttime professional drivers (Macchi, Boulos, Ranney, Simmons, & Campbell, 2002). Leger et al. (2009) found that bright light pulses and naps benefitted shift work drivers, reducing their drowsiness while driving. Other work found bright lights to decrease nighttime workers sleepiness (Sadeghniiat-Haghighi, Yazdi, Jahanihashemi, & Aminian, 2010). Exercise may also be effective in enhancing nighttime workers' alertness (Sato et al., 2010).

Technology

A number of technological countermeasures that could impact the drowsy driving problem have been developed. Broadly, these technologies fall into three categories: drowsy driver detection; alertness maintenance; and crash warning systems. Drowsy driver detection technologies are a class of devices designed to detect and warn when a driver is becoming dangerously sleepy behind the wheel. The main challenge with these systems is being able to automatically determine when a driver is drowsy. As described in a recent review (May & Baldwin, 2009), a number of methods have been used with varying success including: frequency of eye blinks and other eye movements (Adachi et al., 2007; Akerstedt, Ingre, et al., 2010; Dinges & Grace, 1998; Grace, 2001; Verwey & Zaidel, 2000; Wierwille, Lewin, & Fairbanks, 1996); head nodding (Hartley, Horberry, Mabbott, & Krueger, 2000); deadman switches (Ogilvie, Wilkinson, & Allison, 1989); pulse rate (Hirata, Nishiyama, & Kinoshita, 2009; Hu, Bowlds, Gu, & Yu, 2009); electroencephalogram (EEG) (Rimini-Doering, Altmueller, Ladstaetter, & Rossmeier, 2005); and driver behavior, particularly measures of time-to-lane crossing (Verwey & Zaidel, 2000). Based on their synthesis of the literature, May and Balwin (2009) concluded that eye closure and lane crossing were the most useful measures for the early detection of drowsy driving, although some work shows that EEG detection may be promising (Rimini-Doering et al., 2005).

Alertness maintenance technology is designed to increase driver alertness by increasing the overall demands of driving without disrupting the primary task of safely operating the vehicle (Oron-Gilad, Ronen, & Shinar, 2008). These technologies can either work in combination with drowsy driver detection technology or be engaged at the driver's discretion. A number of experimental systems have been developed. For example, Verway and Zaidel (1999) developed and evaluated a "gamebox" device where drivers could play simple games by interacting with the device via speech. In a simulator study, the researchers found that while traveling long distances, those using the device reported less drowsiness and experienced few driving crashes compared to controls. A study in California addressed the effectiveness of an interactive language learning system on helping drowsy drivers stay awake (Takayama & Nass, 2008). The driving simulator study found that the system reduced drowsiness, but only in the condition when the system was interactive. Recent work from Israel has addressed the effectiveness of alertness maintaining tasks (Gershon, Ronen, Oron-Gilad, & Shinar, 2009; Oron-Gilad et al., 2008). These researchers have tried several types of tasks including: interactive trivia; choice reaction time; and working memory. The researchers found that the choice reaction and working memory tasks were neither effective at reducing drowsiness nor liked by the drivers. The trivia task, on the other hand, was found to prevent driving performance decrements, increased arousal, increase alertness, and was liked by the drivers. The benefits, however, were only found when the driver engaged in the task. None of these tasks have been tested specifically with older drivers.

Crash warning system technology can also positively impact drowsy driving by preventing crashes that result from drowsiness. These technologies use radars and cameras positioned around the vehicle to determine the locations of other traffic and lane pavement markings. When a potentially hazardous situation arises, the system warns the driver. More advanced systems not only warn the driver, but also take over partial control of the vehicle's operation to avoid the hazard. For example, the 2008 models of the Volvo S80, V70 and XC70 have a crash warning system with "auto brake;" that is, the system will detect an impending forward collision and apply the brakes for the driver if he or she fails to do so. There are two main crash warning systems that seem particularly useful for drowsy driving: forward collision warning and lane departure warning systems.

Forward Collision Warning

Forward collision warning systems use forward radar sensors to determine the distance between cars. When this distance begins to get too small, the system will warn the driver using some signal (usually a combination of a light and sound) and, in some systems, take over partial control of the vehicle. Studies have investigated the safety benefits of forward collision warning systems by placing drivers in simulated conditions where vehicles appeared suddenly in front of them (Cotté, Meyer, & Coughlin, 2001; Kramer, Cassavaugh, Horrey, Becic, & Mayhugh, 2007; Maltz & Shinar, 2004). These studies found that: driver acceptance was high when the system did not give too many false alarms (giving alerts when they were not appropriate); older drivers were more forgiving of false alarms; older drivers benefited as much as or more than younger drivers; and older participants drove more slowly than younger drivers and maintained longer headways from the next vehicle. In a test-track study, Dingus et al.(1997) found that older drivers maintained longer headways when compared to young drivers. The headways for older drivers did not change as false alarms increased, indicating that older drivers were more tolerant of false alarms. The largest field operational test to date on forward collision warnings system use was conducted by the University of Michigan Transportation Research Institute (UMTRI) and General Motors Corporation (Ervin et al., 2005). In this study, 96 people were given vehicles with a forward collision warning system to drive as they normally would for 1 month. One-third of these subjects were age 60-70. In general, older drivers were likely to view the system favorably and the system improved safety for all drivers. Forward collision warning systems have not been tested specifically with drivers who are drowsy.

Lane Departure Warning

Lane departure warning (LDW) systems are designed to help drivers avoid drifting off the road by providing a warning to the driver when the vehicle moves over a dashed or solid lane edge boundary without the use of a lane-change signal (LeBlanc et al., 2006). LDW systems use cameras pointed at the roadway on each side of the vehicle and video-analysis software to determine the vehicle's lane position. Alerts are usually directionally-linked so that a drift to the right is accompanied by a light, sound, or seat vibration in the right portion of the vehicle. A simulator study in Germany investigated whether an LDW system could help prevent drowsy-driving crashes (Rimini-Doering et al., 2005). After eating a rich meal, 63 healthy young males drove the simulator for up to 2.5 hours on a route with little stimulation. Collectively, the drivers had several hundred micro-sleep episodes. The study found that when using the LDW system, there was a significant reduction in the number, time, length, and area of lane departure events. There also seem to be safety benefits when LDW systems are used in natural driving. In an investigation of 78 people (26 of whom were age 60-70) in Michigan using a LDW system in over 83,000 miles of driving, LeBlanc et al. (2006) found that the system induced drivers to stay closer to the center of the lane, use their turn signals more often when changing lanes, and reduced the frequency of lane excursions. People also liked the system. A LDW system would have great benefit for older drivers, particularly those who are taking medications that can produce drowsiness.

Conclusions

This review documents several causes and correlates of drowsy driving. Drowsiness while driving may be due to monotonous roadways, lifestyle choices, working long, rotating, or night shifts, personality traits such as neuroticism and extraversion, circadian rhythm effects (e.g. driving between midnight and 6:00 AM), consuming alcohol, sleep disorders and deprivation, medications and various medical conditions. Each of these factors has been found to be a risk factor for sleepiness and/or drowsy driving, but most studies were conducted on young to middle-aged adults. More research is needed to determine to what extent these factors affect older drivers.

Methods also exist that individuals can use in an attempt to counteract drowsiness while driving. Those sleepy while behind the wheel often fight the sleepiness by turning up the stereo or rolling down the window, yet these methods have been found to be ineffective. Should individuals feel drowsy while driving, this review found that the best practice is to stop driving and get some sleep. If this is not possible, drinking caffeine and/or stopping for a short nap, can help to alleviate sleepiness. Alertness-maintaining tasks, such as interacting via speech with an in-vehicle device, can also help drivers improve alertness and decrease crash risk. In-vehicle drowsiness-detection technologies that warn drivers before they experience a crash have been tested and may be beneficial to drivers. All of these countermeasures may help to counter drowsiness and decrease crash risk; however, studies have mostly been performed on younger subjects. More research is needed to better understand the effectiveness of these countermeasures on older drivers.

Drivers aware of their potential daytime drowsiness can seek treatments to prevent being sleepy behind the wheel. Those suffering from drowsiness-inducing medical conditions may be able to reduce their daytime sleepiness with certain medication. Nasal continuous positive airway pressure can reduce the number of crashes that sleep apnea patients experience. Certain medications can help reduce drowsiness for other sleep disorders as well; dopaminergic medications have been found to help restless leg syndrome patients, eszopiclone can improve the sleep quality in insomnia patients, and modafinil can reduce EDS in narcoleptics. Treatment becomes even more effective when combining medications with proper sleep hygiene (e.g. taking scheduled naps), leading to improvement in individuals' alertness. Bright-light therapy (to adjust the circadian rhythm) can help to reduce drowsiness while driving for shift workers. Napping before work can help shift-workers as well, but may not be effective for medical staff napping mid-shift. Exercise regimens and soothing music at bedtime were found to improve the sleep quality of older adults. Though these countermeasures are promising for older adults regarding sleep quality and EDS, more research is needed on this population to better understand if certain medications, exercise, napping, and music translate to decreased risk of drowsy driving.

Drowsiness is caused by many different factors and situations, and can be combated in different ways. Research has shown that sleep disorders, medical conditions and medications, shift work, circadian rhythm, personality traits, alcohol use and lifestyle choices to be causes of daytime sleepiness and could lead to a drowsy driving crash. However, the vast majority of studies have been conducted on younger or middle-aged adults. Clearly, older drivers are at a special risk; older adults are more prone than younger adults to experience drowsiness from numerous medical conditions and medications in addition to possible circadian rhythm effects, abnormal work schedules, roadway conditions, and other sleepiness causes. The co-presence of causes and correlates of drowsiness in individuals may put anyone at risk, but the risk is likely increased for older drivers. Therefore more research is needed on these areas and the countermeasures that may be most effective for the older adult population. Although medications and other treatments have been shown to improve the sleep quality of older adults, research is needed to determine whether these treatments result in a decreased risk of a drowsy driving crash. Understanding the prevalence of drowsy driving among older adults, and the causes and correlates of drowsy driving in this population, is imperative for developing effective measures that reduce the chances of a drowsy driving crash among older drivers.

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