The Economic Burden of Sleepy Driving

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KEYWORDS

• Driving sleepy • Motor vehicle accident • Costs • Productivity • Occupational accidents–economy

KEY POINTS

- The economic burden of sleepy driving includes direct costs of accidents and indirect costs of lost lives, disability, lost productivity, and occupational and civil accidents.
- Sleepy driving is mainly due to sleep restriction associated with work schedules or poor sleep hygiene. Sleep disorders, like obstructive sleep apnea (OSA) and central hypersomnia, and treatment with sedative drugs, however, also have to be screened.
- The authors hypothesize that the costs of accidents due to sleepiness could be in the United States between $139 billion and $152 billion and in Europe between €43 billion and €337 billion.
- Based on 1.3 million sleepy drivers dying on the world's roads every year, including 400,000 under age 25 years and 400,000 above age 65 years, it may be estimated that the indirect cost of sleepy driving on society is $2372 billion per year.
- Based on the 20 million to 50 million sleepy drivers who are injured or disabled, the cost of disability for insurance may be hypothesized to be between $2580 billion and $6450 billion every year.

INTRODUCTION

Driving while sleepy is now widely recognized by health authorities and by general opinion as a major behavioral risk of accidents. Several major public campaigns have been launched on that timely topic in the United States, in Europe, in Australia, and in other parts of the world.[1–5] Public health messages have been extensively given by experts urging drivers to stop for a nap or a break every 2 hours on long trips, to avoid driving at night, and to sleep adequately in a 24-hour cycle. Drivers have been also informed to see their doctors when they have had near-miss accidents or sleepiness at the wheel on a regular basis to investigate and treat potential sleep disorders, such as obstructive sleep apnea (OSA) or central hypersomnia.

The main causes of driving while sleepy may be divided in 2 categories:

- The first and by far the most frequent cause of sleepiness at the wheel is a behavioral one. In most of the industrialized countries, 20% to 35% of adults are sleeping less than 6 hours per 24 hours[6–8] and, therefore, are sleepy during daytime, with a higher risk of sleepy driving. This sleep debt has several determinants, which are
  - Night work and shift work, which are consensually recognized as having an

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impact on sleep length, with an average reduction of 1 hour per 24 hours compared with the sleep time of day workers[9–11]
  - Connection time between work and home, which increases continuously among big towns and in nonindustrialized countries, with workers arriving later and later at home and departing earlier and earlier in the morning, increasing periods of wakefulness in 24 hours and having an impact on sleepiness at the wheel[12–14]
  - Leisure and overuse of screens, smartphones, and videogames later and later in the evening and even at night, disrupting and reducing sleep not only of teens and young adults but also of more and more older adults[15–17]
- The second cause is associated with sleep disorders, which are well described in this issue, specifically OSA; insomnia treated with some kind of long-term sedative treatments; and rare forms of central hypersomnia, such as narcolepsy. All these sleep disorders have been extensively associated with an increased risk of accidents.[18–20]

Whatever the causes of driving sleepy, the burden is similar and may be divided as

- Direct costs of driving while sleepy, which include the human and material costs of motor vehicle accidents (MVAs) (while at work and while driving for leisure), including material loss and hospitalizations and health care directly associated with being sleepy
- Indirect costs of absenteeism, loss of productivity, loss of opportunity, loss of education, loss of income, and impaired quality of life

THE DIRECT COSTS OF SLEEPY DRIVING

Magnitude of Motor Vehicle Accidents

Globally around the world, MVAs are the third most common cause of death. They affect young adults, specifically, however, for whom they are the first cause. Car accidents claim approximately 1.3 million lives every year, according to the Association for Safe International Road Travel.[21] Twenty million to 50 million people are injured or disabled each year as well. More than half of all road traffic deaths occur among young adults. Road crashes are the leading cause of death worldwide among young people and the second leading cause of death among those between 5 to 14 years old. Each year, approximately 400,000 people under 25 die on the world's roads, on average of more than 1000 a day. In the United States alone, road crashes account for more than 37,000 of those fatalities and 2.35 million injuries.[21]

The Direct Costs of Accidents

In the United States alone, a 2014 National Highway Traffic Safety Administration (NHTSA) study showed that MVAs had an $871 billion economic and societal impact on US citizens.[22] This report also shows that in 2013, there were more than 32,000 crash deaths in the United States. These deaths cost more than $380 million in direct medical costs.

In Europe, a recent review estimates the costs of injuries and fatalities due to MVAs per country in relation to the gross domestic product (GDP).[23] Reported costs per fatality vary between €0.7 million per fatality in Slovakia and €3.0 million per fatality in Austria and tend to be higher in Northwest Europe than in South and East Europe. Reported costs per serious injury range from €28,000 in Latvia to €959,000 in Estonia, whereas reported costs per slight injury range from €296 in Latvia to €71,742 in Iceland. When the costs per injury are related to the costs per fatality, they show that the costs of a serious injury range from 2.5% to 34% of the costs of a fatality, although for approximately three-quarters of the countries this figure is between 10% and 20%. The costs per slight injury were 0.03% to 4.2% of the costs of a fatality. The total costs of crashes vary between 0.4% and 4.1% of the GDP.[23]

Differences between countries throughout Europe are also due to methodology, particularly whether the willingness to pay (WTP) method is applied for the calculation of human costs. In countries that use the WTP approach, human costs have a major share (34% to 91%) in the total costs of crashes. In countries that apply an alternative method, the share of human costs in the total costs is much smaller (less than 10%). The standard costs of a fatality are estimated at €2.3 million. These costs mainly consist of human cost (€1.6 million) and production loss (€0.7 million). Costs per serious and slight injury are estimated at 13% and 1% of the value of a fatality. Also, for injuries, human costs are by far the largest cost item. Total costs according to the international guidelines in all European Union (EU) countries individually as well as the EU in total were calculated. For the 28 EU member states, costs are estimated at approximately €270 billion if the results of the value transfer approach are applied. This corresponds to 1.8% of GDP.[23]

The Direct Costs of Accidents Due to Sleepiness

It has been postulated that sleepiness causes 16% of all road MVAs and more than 20% of motorway crashes[24] and that between 30% and 50% of deaths and serious injuries in accidents are caused by sleep-related Road traffic accidents.[25] Based on the previous estimate of the costs of accidents, it may, therefore, be hypothesized that the costs of accidents due to sleepiness in the United States could be between $139.4 billion (16% of $871 billion) and $152 billion (0.4 (between 30% and 50%) × 380 billion).

In Europe, these costs are estimated between €43 billion (16% of €270 billion) and €337 billion (gross national product of Europe €18.774 billion × 1.8%).

The US NHTSA estimates that drowsy driving was responsible for 72,000 crashes, 44,000 injuries, and 800 deaths in 2013. These numbers are underestimated, however, and up to 6000 fatal crashes each year may be caused by drowsy drivers.[26] In 2016, according to the NHTSA, drowsy drivers cost society an estimated $109 billion per year.

In Australia, the cost to the community of drowsy driving road accidents is estimated to be $2 billion every year with MVAs, which may be divided into $530 million due to excessive daytime sleepiness (EDS) related to sleep deprivation, $862 million due to other causes of EDS, and $740 million due to insufficient sleep.[27]

In Brazil, in 2004, there were 97,074 deaths per day and 4.072 deaths per hour, or 1.018 deaths every 15 minutes, resulting from traffic accidents, with a total financial cost of $28.95 billion. Based on sleepiness-attributed accidents rates in Brazil, 17.60 deaths per day or 0.73 deaths per hour are associated with sleepy driving, with a total financial cost of $414,397,997 as a consequence of traffic-related deaths in 2004, a major cause of which was sleepy driving.[28]

The Direct Costs of Accidents Due to Sleepiness in Obstructive Sleep Apnea Patients

There is limited literature trying to assess the cost of EDS or driving sleepy in addition to the other direct or indirect costs of OSA. A Frost & Sullivan report, however, ordered by the American Academy of Sleep Medicine (AASM) in the United States, *Hidden Health Crisis Costing America Billions*, suggests some possible answers.[29] The report estimates that approximatively $12.4 billion was spent in the United States in 2015 diagnosing and treating OSA for the 5.9 million US adults diagnosed with the disease, a larger and more significant investment of approximatively $49.5 billion would be necessary for the 23.5 million individuals with OSA who were undiagnosed at this time. The report compared this direct cost to the indirect ones that result from not being treated. They specifically estimated that the indirect cost of nontreated OSA was $26.2 billion for MVAs, $6.5 billion for workplace accidents, and $86.9 billion per year for lost productivity.[29] Another Frost & Sullivan report ordered by the AASM focused on treated OSA patients. It postulated that treatment induced a 40% decline in workplaces absences and a 17.3% increase in productivity.[30] Thus, treatment would potentially be able to cost-save most of the sleepiness consequences of driving sleepy in OSA patients. It cannot be concluded, however, that all the costs associated to sleepiness at the job in OSA patients are specifically linked to diving sleepy. Only one proportion is responsible, which cannot be exactly calculated.

THE INDIRECT COSTS OF ACCIDENTS DUE TO SLEEPINESS

The "Value" of Human Life

Apart from the direct costs of accidents, the worst impact on society due to accidents is the loss of human beings potentially involved in the future economic network of their countries. One human life is priceless. Aside from the methodology of WTP, described previously, insurance companies and public authorities also traditionally base their estimates on the price of 1 human life after an accident. It is estimated by the total income a person would have earned in a total lifetime until age 60s. Then, when a person under 25 dies on the road, this means 35 years of income is lost. The individual yearly income varies extensively from one country to another depending on the national gross product income of each country and each socioprofessional category. In the United States, the average lifetime earnings for college graduates was estimated to be $2.4 million in 2017.[31] In Europe, the standard costs of a fatality for an adult is €2.3 million.[32] After age 65, the insurance companies usually apply a senior discount rate, which takes more account of the moral impact of death on those nearest than of the economic impact. For household people in the United States, the average compensation was estimated to be $80,000.[32]

The Indirect Costs of Sleepy Driving on Lost Human Lives

Part of the 1.3 million are dying including 400000 under 25 age and 400000 above 65 age, it may be estimated, based on Western values of life, that the indirect costs of sleepy driving to society are $(600{,}000 \times 2.3 + 400{,}000 \times 2.4 + 400{,}000 \times 0.08) = \$2372$ billion.

The Indirect Costs of Sleepy Driving on Disability

In Western developed countries, another method of assessing human cost values is to estimate how much insurance companies must pay to give 1 year of quality life to disabled or injured people. For a long time, it has been estimated at $50,000 or less. New research, however, has proposed that in the United States, that figure was far too low. Recently, Princeton University economists have demonstrated that the average value of a year of quality human life was actually closer to approximately $129,000 per year.[33] Based on the 20 million to 50 million people who are injured or disabled, the cost of disability for insurance may be hypothesized at $2580 billion to $6450 billion every year.

The Indirect Costs of Driving While Sleepy on the Loss of Productivity

Driving while sleepy may affect productivity in different ways besides the one of Motor vehicle accidents at work, discussed previously.

- First, it may be hypothesized that a sleepy driver drives more slowly and makes mistakes on the itinerary, which may have consequences on the delivery of goods by the driver. It is difficult to accurately assess how this delay may affect productivity. Delays caused by late shipments, however, can slow down an assembly line's productivity. Inevitably money is lost because employees who are not working at their top speed and efficiency cost money. The production time is longer, because additional time is spent waiting for shipments, all the while having employees on the clock for hours or days longer than they should be. What is more, there are higher inventory costs because of these delays. There is a timeline and a budget for each good production project, and there should be confidence in the ability to accomplish them quickly and in a streamlined fashion. If engaged with a dependable supplier, these additional costs created by low productivity can be avoided.
- Moreover, if a customer's orders are delayed due to late shipments from suppliers, souring important relationships and ultimately decreasing customer satisfaction are risked. If clients are continuously forced to wait for their orders due to late shipments, they might take their business to competitors. Losing customers means losing out on money, which critically affects the bottom line.

The authors did not find any literature on the cost of sleepy driving on productivity. They did find, however, recent works on driving while sleepy at work, which may help in understanding the magnitude of this burden. A survey of 2189 truck drivers was recently made by researchers of the Safety and Health Assessment and Research for Prevention program, of Washington State, enquiring about the perception of associated with work-related injury. Daytime sleepiness, pressure to work faster, driving less than truckload, and having a poor composite score for safety perceptions all were associated with increased likelihood of work-related injury.[34]

In Australia, Bruck[27] also estimated the cost of loss productivity not only due to driving sleepy but also due to injuries promoted by EDS. Based on the results of Safe Work Australia (2015) and the average annual earnings in Australia in 2013, it was estimated that the productivity has an impact on per workplace injury due to EDS-sleep debt would be equivalent to 1.22 times the average annual earnings of the general population. This was estimated to cost Australian $1 billion in 2016 to 2017. In another recent Australian national survey, the aim was also to test the relationship between sleep duration and disorders, sleep health and hygiene factors, and work-related factors and errors at work in Australian workers. A group of 512 workers provided responses to the question, "Thinking about the past 3 months, how many days did you make errors at work because you were too sleepy or you had a sleep problem?"[35] Work errors related to sleepiness or sleep problems were found 11.6 times higher ($P<.001$) in those who snored, 7.0 times higher in short ($\leq$5 h/night) sleepers ($P<.021$), and 6.1 times higher in those staying up later than planned most nights of the week ($P<.001$). It may, therefore, be hypothesized that sleepy drivers may also have an impact on safety and productivity in the workplace through increased sleepiness-related errors.

Finally, Redeker and colleagues[36] also recently analyzed 60 articles on workplace interventions made to promote sleep health and an alert, healthy workforce. They suggest that employer-sponsored efforts can improve sleep and sleep-related outcomes at the workplace. They conclude that employers encouraging better sleep habits and general fitness results in self-reported improvements in sleep-related outcomes and may be associated with reduced absenteeism and better overall quality of life.[36]

THE BURDEN OF SLEEPY DRIVING IN THE RISK OF OCCUPATIONAL AND PUBLIC ACCIDENTS

Occupational Accidents

There are few data specifically devoted to the cost of occupational accidents associated with driving while sleepy. A large number of MVAs may be considered work or occupational accidents. Some groups of professionals are particularly at risk, such as truck drivers and bus drivers, who often cumulate several risk factors for driving while sleepy: night-shift work, long periods of work, insufficient environmental conditions to get restorative sleep, and sleep disorders such as OSA. It is, therefore, difficult to separate formally the cost of accidents at the workplace from the cost of accidents in the entire population. The only estimate in the field to the authors' knowledge was made in Australia, where the adjusted prevalence of work injuries due to EDS was estimated to be 60,681 cases in 2016 to 2017. Thus, the health system costs attributed to inadequate sleep were estimated to be $620 million.[27]

Besides this single estimate, multiple reports have clearly shown how professional drivers were concerned about being sleepy at the wheel.

In Brazil, a recent survey was performed in 670 professional male truck drivers, with a mean age of 41.9 (±11.1) years. The prevalence of sleepiness while driving was 31.5%. The following working conditions were significantly associated with sleepiness while driving regardless of other working or behavioral characteristics, age, and sleep duration:

- A distance from the last shipment of more than 1000 km (odds ratio [OR] = 1.54)
- A formal labor contract with a productivity-based salary (OR = 2.65)[37]

In Sweden, it has also been shown that shift-working bus drivers frequently struggle to stay awake and thus countermeasures are needed in order to guarantee safe driving with split-shift schedules.[38] It is not certain, however, that professional drivers are sufficiently aware of the risk of driving while sleepy. Three hundred Australian drivers recently completed a questionnaire that assessed crash risk perceptions for sleepy driving, drink driving, and speeding. Additionally, the participants' perceptions of crash risk were assessed for 5 different contextual scenarios that included different levels of sleepiness (low and high), driving duration (short and long), and time of day/circadian influences (afternoon and nighttime) on driving. The analysis confirmed that sleepy driving was considered a risky driving behavior but not as risky as high levels of speed ($P<.05$). The results suggest a lack of awareness or appreciation of circadian rhythm functioning, in particular the descending phase of circadian rhythm that promotes increased sleepiness in the afternoon and during the early hours of the morning.[39]

Besides accidents at work, a larger group, again of professionals, are simply using their car to go to work, and accidents on the way to and/or back from work are considered in many countries as occupational or work accidents. Due to urban development and the need for larger homes outside city centers, workers are driving more and more every day and, therefore, reducing their sleep time, which is one of the determinants of sleep debt around the world. The farther they live from work, the less they sleep, the longer they drive, and the higher the risk of sleepiness-related accidents. In a specific survey enquiring about sleeping at the wheel on French highways, with the same questionnaire used in regular highway drivers (2196 in 1996 and 3545 in 2011), it has been shown that drivers have reduced their mean weekly sleep duration over 15 years and have a higher risk of sleepiness at the wheel.[40]

Public Accidents

The media frequently report on spectacular public accidents in which sleepiness is considered a significant risk factor.

Decades ago, the National Commission on Sleep Disorders Research in the United States highlighted the role of sleepiness in several environmental health disasters in history,[41] including

- The Three Mile Island nuclear power plant incident, which occurred at 4:00 AM; overnight shift workers failed to respond quickly because they were sleepy.
- The nuclear plant disaster at Chernobyl, which took place at 1:30 AM, also is linked to human error influenced by sleepiness.
- Sleep loss is thought to have played a role in the Exxon Valdez oil tanker spill and the Space Shuttle Challenger accident (where managers at the flight center were known to be working irregular hours on very little sleep). These and other accidents, both small scale and large scale, highlight the potentially devastating consequences of being drowsy or sleeping at the wheel or on security monotonous conditions.

Fatigue and sleepiness in airplane pilots also are crucial issues because they face jet lag, long extended shifts, and sometimes stressful climate conditions.[42,43] No specific cost has been reported, however, to the authors' knowledge, on piloting while sleepy and associated accident risk.

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