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The economic burden of sleepy driving

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Synopsis (195 words).

Driving while sleepy on a regular basis may be due to sleep restriction associated with work schedules or poor sleep hygiene. It may be also associated to sleep disorders like obstructive sleep apnea (OSA) or central hypersomnia, or to sedative drugs.

This review aims to assess the potential consequences of driving sleepy on a regular basis from a societal point of view.

Driving while sleepy on a regular basis first increases the risk of motor-vehicle accidents (MVA), with a related estimate direct cost of \$139.4 billion to \$152 billion per year in the US and 43 € billion to 337 € billion in Europe.

Driving while sleepy on a regular basis also impairs the ability to work, which results in an estimated indirect cost of sleepy driving on society for lost human lives of 2372 \$ billion worldwide per year and an estimated cost of disability for insurance of \$2580 to \$6450 billion worldwide every year.

Driving while sleepy on a regular basis also impacts productivity with an estimated Australian \$1 billion cost in Australia in 2016-17.

Furthermore, driving while sleepy probably also impacts the risk of non MVA occupational accidents and of public disasters.

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 on lost lives, disability, productivity, occupational and civil accidents.
- Sleepy driving is mainly due to sleep restriction associated with work schedules or poor sleep hygiene. However, sleep disorders like obstructive sleep apnea (OSA), central hypersomnia and treatment with sedative drugs have also to be screened.
- We hypothesize that the costs of accidents due to sleepiness in the US could be between \$139 and \$152 billion and in Europe between 43 € and 337 € billion.
- Based on the fact that 1,3 million sleepy drivers including 400,000 people under 25 die on the world's roads every year and 400,000 above 65, we may estimate that the indirect costs of sleepy driving on society is 2372 \$ billion per year.
- Based on the 20 to 50 million sleepy drivers that are injured or disabled, the cost of disability for insurance may be hypothesized to between \$2580 and \$6450 billion every year.
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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 part 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 two hours on long trips, to avoid driving at night, and to sleep adequately on the 24 hours cycle. Drivers have been also informed to see their doctors when they 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.

Regarding the main causes of driving while sleepy, they may be divided in two categories:

- The first and far the much frequent cause of sleepiness at the wheel is a behavioral one.
In most of the industrialized countries, an amount of 20 to 35% of adults are sleeping less than 6 hours per 24 hours [6-8] and are therefore 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 impacting sleep length, with an average reduction of one hour per 24 hours compared to the sleep time of dayworkers [9-11]
 - Connection time between work and home, which increase continuously among big towns and in non-industrialized countries, with workers arriving later and later at home and departing earlier and earlier in the morning, increasing periods of wakefulness on the 24 hours, and impaction sleepiness at the wheel [12-14].
 - Leisure and overuse of screens, smartphones, videogames, late and late in the evening and even at night, disrupting and reducing sleep of not only teens and young adults, but also of more and more older adults [15-17].
- The second one is associated with sleep disorders, which have been well described in this issue and specifically OSA, but also 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 on

- direct costs of driving while sleepy, which include the human and material costs of motor-vehicle accidents (while at work and while driving for leisure) including material loss and hospitalizations and healthcare directly associated with being sleepy.
- Indirect costs on 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 (MVA)

Globally around the world, motor-vehicle accidents (MVA) are the third most common cause of death. However, it touches specifically young adults for whos it is the first cause. Car accidents claim nearly 1.3 million lives every year, according to the Association for Safe International Road Travel [21]. Twenty 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 among young people and the second leading cause of death worldwide among young people aged 5-14. Each year, nearly 400,000 people under 25 die on the world's roads, on average over 1,000 a day. In the U.S., alone, road crashes account for over 37,000 of those fatalities and 2.35 million injuries [21].

The direct costs of accidents

In the US alone, a 2014 National Health Transportation Safety Administration (NHTSA) study showed that motor vehicle crashes had a \$871 billion economic and societal impact on U.S. citizens [22]. This report also shows that in 2013, there were more than 32,000 crash deaths in the US. These deaths cost more than \$380 million in direct medical costs.

In Europe, a recent review interestingly estimates the costs of injuries and fatalities due to MVA 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 North-West 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 we relate the costs per injury to the costs per fatality, it shows that the costs of a serious injury range from 2.5% to 34% of the costs of a fatality, though for about three quarters of the countries this figure is between 10% and 20%. The costs per slight injury was 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 Gross Domestic Product (GDP) [23].

Differences between countries throughout Europe are also due to methodological differences, 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 EU countries individually as well as the EU in total were calculated. For the 28 EU member states, costs are estimated at about €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 MVA 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 RTAs [25]. Based on the previous estimate of the costs of accidents, it may be therefore hypothesized that the costs of accidents due to sleepiness in the

US could be between \$139.4 billion (16% of \$871 billion) and \$152 billion (0.4 (between 30-50%) x 380 billion).

In Europe, these costs are estimated between 43 € billion (16% of 270 € billion) and 337 € billion (GNP of Europe 18774 billion x1,8%).

The US National Highway Traffic Safety Administration by itself estimates that drowsy driving was responsible for 72,000 crashes, 44,000 injuries, and 800 deaths in 2013. However, these numbers are underestimated and up to 6,000 fatal crashes each year may be caused by drowsy drivers [26]. In 2016, according to the National Highway Traffic Safety Administration (NHTSA), drowsy drivers cost society an estimated \$109 billion dollars per year.

In Australia, the cost to the community of drowsy driving road accidents is estimated to be \$2 billion every year with an MVA, 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 97074 deaths per day, 4.072 deaths per hour, or 1.018 deaths every 15 minutes resulting from traffic accidents, with a total financial cost of US \$28.95 billion. Based on sleepy attributed accidents rate in Brazil 17.60 deaths per day or 0.73 deaths per hour are associated to sleepy driving with a total financial cost of US \$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 OSA patients

There is limited literature trying to assess the cost of excessive daytime sleepiness, or driving sleepy beside the other direct or indirect costs of OSA. However, an interesting “Frost and Sullivan” report ordered by the American Academy of Sleep Medicine in the US (AASM) “Hidden health crisis costing America billions” brings some possible answers [29]. The report estimates that approximatively \$12.4 billion was spent in the US in 2015 diagnosing and treating OSA for

the 5.9 million US adults diagnosed with the disease, a larger and more significant investment of approximately \$49.5 billion would be necessary for the 23.5 million individuals with OSA who were undiagnosed at this time. Interestingly the report compared this direct cost to the indirect ones that result from not being treated. They specifically estimated that the indirect cost of non-treated OSA was \$26.2 billion for MVA, \$6.5 billion for workplace accidents and \$86.9 billion per year for lost productivity [29]. Another “Frost and Sullivan” report ordered by the AASM focused on recently treated OSA patients. They postulated that treatment induced a 40% decline in workplaces absences and 17,3% increase in productivity [30]. Thus treatment would be potentially able to cost save most of the sleepiness consequences of driving sleepy in OSA patients. However, we do not conclude that all the costs related to sleepiness at the job in sleepy OSA patients are associated with sleepy driving. 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 worse impact on society due to accidents is the loss of human beings that have been potentially involved in the future economic network of their countries. One human life is priceless. Beside the methodology of willingness to pay, we have described previously, insurance companies and public authorities also traditionally base their estimates on the price of one human life after an accident. It is estimated by the total income the person would have earned in his total life until his sixties. Then, when a people 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 (NGP) of each country and each socio-professional category. In the US, 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 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 US, the average compensation was estimated to be \$80,000 [32].

The indirect costs of sleepy driving on lost human lives.

Based on the fact that 1,3 million, including 400,000 people under 25 years, die on the world's roads every year and 400,000 above 65, we may estimate, based on western values of life, that the indirect costs of sleepy driving to society is $(600,000 \times 2.3 + 400,000 \times 2.4 + 400,000 \times 0,08)$ 2372 \$ billion.

The indirect costs of sleepy driving on disability.

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

The indirect costs of driving while sleepy on the loss of productivity.

Driving while sleepy may affect productivity by different ways beside the one of MVA (at work) we have previously discussed.

- First, it may be hypothesized that a sleepy driver drives more slowly, that he makes mistakes on his itinerary, and that it may have consequences on the delivery of goods by the driver. It is difficult to accurately assess how this delay may affect productivity. However, delays caused by late part shipments can slow down an assembly line's productivity. One is also inevitably losing money because employees, who are not working at their top speed and efficiency, cost money. The production time will be longer, since one will have to spend additional time waiting for shipments, all the while having employees on the clock for hours or days longer than they should be. What's more, there will be higher inventory costs because of these delays. There is a timeline and a budget for each good production project, and one should be confident in the ability to accomplish it quickly and in a streamlined fashion. If one engages a dependable supplier, these additional costs created by low productivity can be avoided.
- Moreover, if one is delaying a customer's orders due to late shipments from suppliers, one is risking souring important relationships and ultimately decreasing customer satisfaction. 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.

We did not find any reference on the cost of sleepy driving on productivity. However, we did find recent works on driving while sleepy at work, which may help us in understanding the magnitude of this burden. An interesting survey of 2189 truck drivers was recently made by researchers of the Safety and Health Assessment and Research for Prevention (SHARP) Program, of Washington State, USA 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 were all associated with increased likelihood of work-related injury [34].

In Australia, Bruck also estimated the cost of loss productivity not only due to driving sleepy, but due to injuries promoted by excessive daytime sleepiness (EDS) [27]. Based on the results in Safe Work Australia (2015) and the average annual earnings in Australia in 2013, it was estimated that the productivity impacts per workplace injury due to EDS-SD would be equivalent to 1.22 times the average annual earnings of the general population. This was estimated to cost Australian \$1 billion in 2016-17. 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 three 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 ($p < 0.001$) in those that snored, 7.0 times higher in short (≤ 5 hours/night) sleepers ($p < 0.021$), and 6.1 times higher in those staying up later than planned most nights of the week ($p < 0.001$). It may therefore be hypothesized that sleepy drivers may also impact safety and productivity in the workplace through increased sleepiness-related errors.

Finally, Redecker et al. also recently analyzed 60 articles on workplace Interventions made to promote sleep health and an alert, healthy workforce [36]. They suggest that employer-sponsored efforts can improve sleep and sleep-related outcomes at the workplace. They conclude that when employers encourage better sleep habits and general fitness, it 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 amount of MVA accidents may be considered as 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 a 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 our knowledge was made in Australia, where the adjusted prevalence of work injuries due to EDS was estimated to be 60,681 cases in 2016-17. Thus, the health system costs attributed to inadequate sleep were estimated to be \$620 million [27].

Beside this single estimate, multiple reports have clearly shown how professional drivers were concerned by 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:

- the distance from the last shipment of more than 1,000 km [OR] = 1.54
- and 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]. However, it is not sure 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, high), driving duration (short, long), and time of day/circadian influences (afternoon, nighttime) of driving. The analysis confirmed that sleepy driving was considered a risky driving behavior but not as risky as high levels of speeding ($P < .05$). The results suggest a lack of awareness or appreciation of circadian rhythm functioning, particularly the descending phase of circadian rhythm that promotes increased sleepiness in the afternoon and during the early hours of the morning [39].

Beside accidents at work, a larger group again of professionals are simply using their car to go to work, and accidents in the way and/or back from work, are considered in many countries as “occupational” or “work accidents”. Due to the urban development and the need of having larger homes outside cities centers, workers are driving more and more every day and therefore reduce their sleep time, which is one of the determinants of sleep debt around the world. The farther you live from work, the less you sleep, the longer you drive, and the highest the risk of sleepiness related accidents. In a specific survey enquiring about sleeping at the wheel on French highways, with the same questionnaire 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 reports some spectacular public accidents in which sleepiness is considered as a significant risk factor.

Decades ago the National Sleep Commission in the USA has 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 a.m., overnight shift workers failed to respond quickly because they were sleepy.
- The nuclear plant disaster at Chernobyl, which took place at 1:30 a.m., is also 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 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 is also a crucial issue as they have also to face jet-lag, long extended shifts and sometimes stressful climate conditions [42-43]. However, no specific cost has been reported in our knowledge to piloting while sleepy and associated accident risk.

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