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Original Article

Sleep versus non–sleep-related fatal road accidents

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A B S T R A C T

Objective: To study different factors that are associated with fatal sleepiness-related motor vehicle accidents (FSMVA) and in other types of fatal motor vehicle accidents (FMVA) in Finland.
Methods: All FMVA that were caused by falling asleep at the wheel (FSMVA) during the years 2005–2014 were investigated using OTI (Finnish Crash Data Institute) data. The control group consisted of 136 drivers who died in other types of FMVA in 2013. A total of 258 accidents were investigated.
Results: The mean age of the 122 drivers in the FSMVA group was 44 (standard deviation 19) years; there were 100 men (82%) and 22 women. The mean age of the 136 control drivers was 45 (standard deviation 19) years; there were 116 men (85%) and 20 women. Short sleep time (<6 h) during the previous night before the accident was the most prominent independent risk factor for FSMVA compared to other FMVA ($p < 0.05$). None of the other driver-related factors (diseases, blood alcohol level, illegal drugs, body mass index, medications, age, sex) differed significantly between the two groups.
Conclusion: Short sleep is a major cause of fatal sleepiness-related motor vehicle accidents. Driver health factors such as sleep apnea or acute/chronic diseases as well as use of sedative medications and drugs are known risk factors for FSMVA, but these factors are associated also with other types of accidents. Healthy individuals are at risk for falling asleep while driving if they are sleep deprived. All drivers should be aware of the importance of adequate sleep.

1. Introduction

Falling asleep at the wheel can cause serious road accidents. In addition to the driver and passengers, all other road users are in danger if a driver falls asleep while driving. Based on a national analysis of fatal motor vehicle accidents from 1991 to 2001, 10% of accidents of nonprofessional nonintoxicated drivers were caused by falling asleep while driving [1], and this proportion seems to be rather stable in recent years based on annual reports of the Finnish Crash Data Institute (OTI annual report 2013 and 2014). Seasonal risk factors for accidents involving falling asleep have also been investigated in Finland. Sleepiness-related accidents are especially common in younger drivers between May and August [2,3]. Among military personnel, falling asleep has been the main cause of motor vehicle accidents; these individuals may be exposed to acute sleep deprivation during military service. Students may get insufficient sleep, for example, because of using alcohol or medications to induce sleep [4]. The prevalence of short sleep and sleep debt is highly prevalent in adults aged 25–45 years in France: short sleep, 18%; insomnia, 12%; and sleep debt, 20% [5] The prevalence of insomnia seems to be 1.5 higher in Finland (37.6%) compared to other European countries [6]. Individuals in shift work had insomnia or excessive sleepiness more often than the general population [7].

Previous studies indicate that obstructive sleep apnea (OSA) increases the risk of motor vehicle accidents [8], although in Finland, among truck drivers, OSA did not significantly increase the risk of motor vehicle accidents [9]. Insufficient sleep was reported to be a more significant risk factor in motor vehicle accidents than the apnea–hypopnea index [10] Drivers in accidents involving falling asleep more often have sleep deprivation than those without sleep-related problems [11]. Sleepiness is also often related to medical conditions [12]. In addition to OSA, depression, narcolepsy, and use of sleeping medication or other drugs affecting the central nervous system may cause daytime sleepiness. Alcoholism is also linked to a high prevalence of insomnia [13]. Studies show that use

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of benzodiazepines increases the risk of crash involvement [14]. Driving under the influence of drugs and/or medicine is a major problem in Finland, and drivers using benzodiazepines had a higher risk of death than drivers using amphetamines [15].

2. Methods

2.1. Ethics and study outline

The study plan was reviewed and approved by the Finnish Motor Insurer's Centre.

All fatal traffic accidents in Finland have been investigated in depth since 1967 based on legislation (law 1512/2016) (Finnish Motor Insurer's Center 2004). Each fatal road and off-road accidents are investigated by multidisciplinary road accident investigation teams (RAITs) in Finland. The investigation teams have expert representation from the police, the field of medicine, vehicle technology, road maintenance, and behavioral sciences. The purpose of investigation is to improve road safety and to find the real causes and risks relating to the accidents. The police investigation on the criminal or juridical aspects of the accidents is conducted separately and individually outside the accident investigation process. In this study, we considered only those accidents with the key event of falling asleep while driving and in which the driver was killed during 2005–2014. We excluded from the study those accidents in which the RAITs had defined fatigue as a background factor but the key event was not falling asleep at the wheel, so that we could only include those accidents in which the driver had most certainly fallen asleep. In fatigue-related accidents, there may be more accidents involving falling asleep than officially identified, and we did not include these cases in the control group. It is likely that in some of the accidents in which fatigue was considered a risk factor, falling asleep was the real cause of the accident. The purpose of the study was not to determine the exact proportion of the accidents involving falling asleep but rather to investigate this in another study. Based on a previous study [2], we know the characteristic signs of accidents involving falling asleep; these include driving off the road from a straight road, in the middle of a curve, or into the opposite lane; excessive speed and no braking marks; uncontrolled turns; less than 6 h' sleep the night before the accident; long driving time (>10 h); driving in the morning at 01:00–06:00 or afternoon 14:00–17:00; and awake time of >16 h. RAITs have been using this information when deciding the key event of an accident as falling asleep. The control group was FMVA from the year 2013 in which driver had been killed (excluding falling asleep, sudden disease attacks, and fatigue-related accidents).

2.2. Statistical analysis

We compared the differences in factors contributing to FSMVA with those in a control group (CGR). We used multivariate logistic regression analysis to identify factors exclusively associated with FSMVA using Stata 14.0 software (StataCorp, College Station, TX, USA). Data included the driver's age and sex, time of accident, type of accident and vehicle, driver's medications, blood alcohol concentration and drug/medication findings in the blood, body mass index (BMI), disease history (Table 1), smoking, use of caffeine, sleep time preceding the night of the accident, and time awake. We compared independently the health-related factors for FSMVA and CGR with the χ^2 test. The driver's blood sample data (including alcohol, drugs, and medication use) and driver's height and weight were collected from the forensic autopsy report. BMI was calculated if the height and weight were available in the accident folder. Health information was collected from accident folders; RAITs are entitled to use all of the existing health records of the drivers. We present a few examples in which the driver's health had posed a background risk for FSMVA. We classified sleep time in three classes: <6 h, 6–7.9 h, and ≥8 h. Drivers were classified as obese (BMI ≥30 kg/m^2) or not obese (<30 kg/m^2).

3. Results

3.1. Demographics

There were 122 drivers (mean age 44 years, standard deviation [SD] 19 years, 82% men) in the FAA group and 136 drivers (mean age 45 years, SD 19 years, 85% men) in the CGR. The proportions of young drivers (age <25 years) were almost the same (20.5% in FSMVA and 23.5% in CGR) (Fig. 1). Senior drivers (age ≥70 years) comprised 13.9% of the FMVA group and 13.2% of the CGR.

Table 1
Health-related factors associated with fatal road accidents.

Health risk	Non–sleep-related accidents	Sleep-related accidents	*p*
No chronic disease	36.0%	34.4%	NS
Cardiovascular disease	21.3%	25.4%	NS
Cerebrovascular disease	2.8%	0.8%	NS
Diabetes	3.7%	4.1%	NS
Metabolic disease	5.1%	8.2%	NS
Neurological disease	5.1%	3.3%	NS
Dementia	0%	0%	NS
Eye disease	0.7%	0%	NS
Central nervous system disease	0%	2.5%	NS
Sleep disorder	**0%**	**7.4%**	**<0.05**
Psychiatric disorder	17.6%	12.3%	NS
Substance/alcohol dependence	8.8%	9.8%	NS
Musculoskeletal disease	5.1%	4.1%	NS
Disability	0%	0%	NS
Insomnia	**0%**	**5.7%**	**<0.01**
Other disease	**8.8%**	**21.3%**	**<0.05**
Obesity	**15.4%**	**24.6%**	**<0.05**
Daytime fatigue	**0%**	**10.1%**	**<0.05**
BAC >0	**32.8%**	**21.7%**	**<0.05**
Psychoactive medication	22.1%	18.9%	NS
Illegal drugs	6.6%	6.6%	NS

Statistically significant differences between the two groups are shown in boldface type. BAC, blood alcohol concentration.

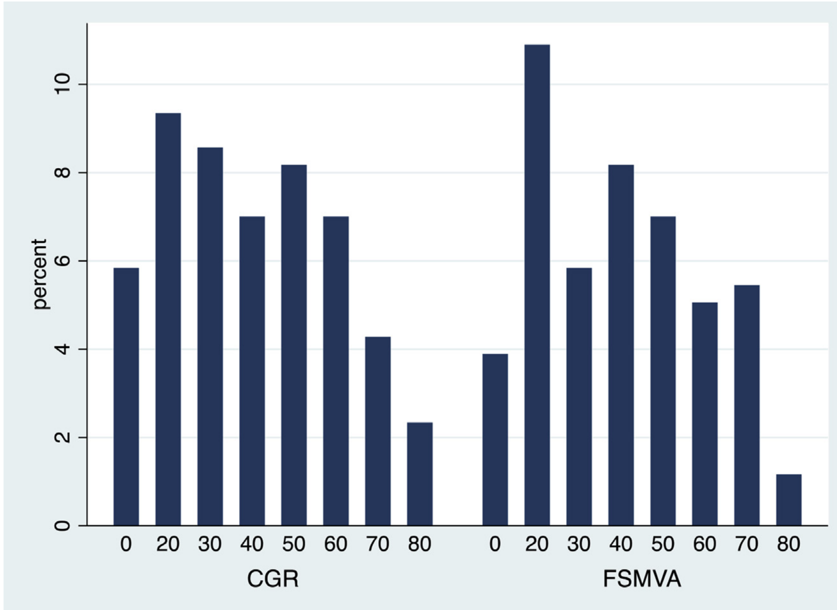

Fig. 1. Age group distribution in the control group (CGR) and in the group with motor vehicle accidents involving falling asleep (FSMVA).

3.2. Logistic regression analysis

In this study we used three models (Table 2). In model 1 we used only short sleep as an explanatory variable. In model 2 we used short sleep, BMI, sex, and age, and in model 3 we added duration of time awake before accident (TAWBA) and blood alcohol concentration. Based on multivariate logistic regression analysis, only short sleep time was an independent factor for FSMVA. Seven drivers in the FSMVA group had a TAWBA of >21 h, and the CGP did not have any drivers with equal awake time; therefore, statistical analysis related to TAWBA was not feasible. Model 3 included age, sex, BMI, and short sleep time (<6 h the preceding night). In this analysis, sleeping less than 6 h was statistically significantly associated with FSMVA (odds ratio [OR] = 9.45; 95% confidence interval [CI] = 1.49–59.97). Sleep-related health conditions (sleep disorder, daytime fatigue, insomnia) could not been analyzed because these factors were not found in any of the drivers in the CGR. Analyses show that driver BMI as a continuous or classified variable was not associated with accidents involving falling asleep. Five of the seven heavy vehicle drivers in FSMVA were obese (BMI ≥30 kg/m^2) and one was overweight (BMI = 27.4 kg/m^2). In one case, information for calculating BMI was not available. Of the drivers in FSMVA, 75% (n = 92) had health-related background factors and in the CGR 68% (n = 93) of drivers had at least one health-related background factor (alcohol or drug use, medical condition, central nervous system medication, sleep-related disorder). The variable “other diseases” is the only variable that differed between FSMVA drivers and the CGR, according to the χ^2 test. In addition, this variable was not significant in logistic regression models when short sleep was included. The “other diseases” variable comprises various medical conditions such as acute infectious diseases (eg, respiratory infections) and cancers (eg, the case of a young healthy man with acute mononucleosis falling asleep while driving). Another example of “other diseases” involved an individual in the final stage of cirrhosis of the liver. The prevalence of obesity was higher in FSMVA (24.6% vs 15.4%), but obesity is not significant in logistic regression models. Sleeping time was known in 33.6% of the FSMVA drivers and in 27.9% of the CRP.

3.3. Role of sleep-related health conditions

Sixteen drivers in FSMVA had a diagnosed sleep disorder (sleep apnea, narcolepsy), daytime fatigue, or insomnia listed as a background risk, however none of the drivers in the CGP group had any sleep disorders. Sleep apnea had been diagnosed in three of the drivers in the FSMVA group, and two of them did not use continuous positive airway pressure (CPAP) although they had a CPAP device. One driver had experienced excessive daytime sleepiness with involuntary sleep attacks. The reason for his sleepiness was unknown. Forensic autopsy data information about neck size and waist circumference was not available.

Table 2
Logistic regression models for sleep-related fatal accidents.

	Univariate model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 (fully adjusted) OR (95% CI)
Sleep <6 h	**3.81 (1.22–11.85)**	**4.94 (1.13–21.54)**	**9.45 (1.49–59.97)**
Men vs women		1.21 (0.31–4.74)	1.13 (0.26–4.99)
Age		1.00 (0.97–1.03)	1.00 (0.96–1.03)
BMI ≥30 kg/m^2		1.81 (0.50–6.58)	1.25 (0.31–4.99)
BAC			0.46 (0.18–1.19)
TAWBA			1.71 (0.73–4.02)

Statistically significant odds ratios are shown in boldface type. BAC, blood alcohol concentration; BMI, body mass index; CI, confidence interval; OR, odds ratio; TAWBA, duration of time awake before accident.

3.4. Crash types and times of accidents

Head-on collisions (51.6% vs 44.1%) and drift-off accidents (46% vs 32.4%) are more common in FSMVA. Drivers were more likely to drive a light vehicle (passenger car) in the FSMVA group than in the CGP (87.7% vs 67.6%). Drivers were driving a heavy vehicle in 5.7% in the FMVA group and 2.9% in the CGR. All accidents were most likely to occur from 12:00 to 17:59 (FSMVA 41% and CGP 42.7%). During the early morning hours (03:00–05:59), 14.8% of FSMVA occurred and 7.4% of the CGR. The peaks of FMVA were during 03:00–05:59 and 12:00–17:59. During the summertime (May–August), 49.3% of accidents occurred in the CGR and 48.4% in the FSMVA group. The majority of the drivers died on the site of the accident before receiving first aid (FMVA 86.1% vs CGP 81.6%).

3.5. Alcohol/substance use and medications

Of all drivers, 21.7% (26/120, two with missing data) in the FSMVA group had alcohol in the blood (blood alcohol concentration >0) vs 32.8% (43/131, five with missing data) in the CRP ($p = 0.048$). In all, 18.9% of FSMVA drivers had a medication that could affect alertness (opioids, antipsychotics, sedatives, antihistamines) and 22.1% in the CGR ($p > 0.05$). In 6.6% of the drivers in both groups, individuals were found to be under the influence of drugs (amphetamine, cannabis, cocaine, opioids), or drug metabolites were found in the blood or urine. Caffeine was found in 45.1% of drivers in the FSMVA group and 40.4% in CGR (no data: 38.5%/43.4%). The prevalence of smoking or nicotine use was almost the same (21.3% in the FSMVA group and 19.9% in the CGR).

4. Discussion

Acute sleep insufficiency (sleeping <6 h on the previous night) was the only independent factor identified in relation to FMVA drivers compared to the CGR. All the drivers (n = 7) with extended wakefulness time (>21 h) fell asleep while driving. Our study confirms a previous study finding that sleep disorders and sleepiness at the wheel are risk factors for traffic accidents [16]. Based on the findings, we can assume that TAWBA is probably a risk factor for FSMVA even though we were not able to perform a statistical analysis. Sleep is vital for brain energy levels [17]. A high proportion of all the drivers in all of the accidents had health-related risk factor(s). Alcohol and drugs had a major role in both the FSMVA group and CGR, but substance abuse was not an independent factor related to FSMVA compared to CGR; alcohol played a larger role as a background risk factor in the CGR. Only a few of the drivers in the FSMVA group had sleep-related conditions, and obstructive sleep apnea (OSA) was diagnosed in only three of these drivers. Based on this study, OSA is not a significant cause of FSMVA. Taking into account the previous population studies in Finland, it is likely that sleep-related conditions are underrepresented in this study, based on the fact that OSA is underdiagnosed in the population. Obesity is a major risk factor for OSA [18]. The prevalence of obesity was higher in the FSMVA group, with one of four drivers being obese; however, the real prevalence is likely higher because in about 30% of the cases BMI data could not be calculated. Obesity is a known risk for traffic accidents [19,20]. Obesity is associated, for example, with chronic inflammation [21] and inflammatory mediators [22]. Excessive daytime sleepiness among obese individuals is a complex topic, and OSA is only one reason for this [23]. Moreover, a high-fat diet, high sympathetic activity, hormones, and cytokines are associated with daytime sleepiness [24]. Sleep-related medical conditions were not found in any of the drivers in the CGR; this is because fatigue-related accidents were excluded from this study. However, benzodiazepines were found in the blood of 18 drivers in the CGR, and many of these drivers may have had some kind of sleep disorder. If the fatigue-related accidents had been in the CGR, these variables may had been statistically significant in a logistic regression model. Motorcyclists are almost absent from FSMVA. Driving a motorcycle may require more attention from the driver, and this may have protective effect on falling asleep. The prevalence of smoking was more or less the same compared to that of the male adult population in Finland. The CGR contained road suicides, and among these incidents the use of alcohol and drugs is common [25]. This may partly explain why alcohol seems to be a more frequent risk factor in the CGP than in the FSMVA group. The prevalence of all accidents was higher in summertime, and also FSMVA occurred more in the summertime; this phenomenon has also been identified in a previous study [2]. Pharmacological treatment of insomia in drivers with daytime sleepiness is somewhat controversial. Benzodiazepines and benzodiazepine-like Z-drugs (eg, zopiclone and zolpidem) increase sleep duration [26], but they (especially zopiclone) [27] may also be associated with an increased risk of traffic accidents [28,29]. Mean weekly sleep duration among highway drivers has decreased in France between the years 1996 and 2011 [30], and it seems that drowsy driving has been an increasing challenge to traffic safety.

An notable finding was that in all fatal accidents in this study, the drivers died almost immediately and in any case before the arrival of an ambulance. At the end of the year 2012, the average age of the passenger car used in traffic in Finland was 10.9 years (Trafi; Finnish Transport Safety Agency). Newer cars are safer for drivers than older cars; especially in accidents involving falling asleep, vehicles with advanced passive features can reduce the consequences of the accident.

The major strength of the present study is the comprehensive countrywide accident investigation in Finland, which makes it possible to identify both the immediate and background risks of FMVA and the circumstances of the accidents with good precision. Accident investigation includes every FMVA on the road. Health records and forensic autopsy information allows one a chance to analyze true health-related risk factors for FMVA. The most important limitation of the study is the number of accidents involving falling asleep and the lack of information on sleeping time preceding the night of the accident in the majority of the cases (sleeping time was known in 33.6% of FSMVA cases and 27.9% of CGR). Forensic autopsy data about neck size and waist circumference were not available, so the possible prevalence of OSA in accidents involving falling asleep could not be assessed adequately. In the present study, the duration (quantity) of sleep was significant factor, but data on sleep depth (ie, quality) was often not available.

The key factor (falling asleep while driving) was determined by road accident investigation teams. It is possible that some sudden disease attacks or other fatal accidents actually, however, involve falling asleep. We excluded from the CGR those accidents with a background risk of fatigue because it is almost sure that these accidents include those caused by falling asleep. The purpose was to exclude the source of error from the CGR.

5. Conclusion

The present study confirms the conception of sleep deprivation as major cause of fatal automobile accidents and confirms the results of a previous study in Finland: Partinen suggested in 2004 that the proportion of sleepiness-related road accidents is between 4.8% and 30% [2]. The present study confirms that sleep deprivation is an independent health-related factor in FSMVA compared to the rest of FMVA. Anyone can fall asleep unintentionally after sleep deprivation. Drivers should be more aware of risks to traffic safety related to sleep deprivation. As a simple general rule, one should sleep at least 6 h before starting to drive for a long period of time.

Conflict of interest

The authors declare that they have no conflict of interest.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2018.04.017.

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