Sleepiness at the wheel across Europe: a survey of 19 countries

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SUMMARY

The European Sleep Research Society aimed to estimate the prevalence, determinants and consequences of falling asleep at the wheel. In total, 12 434 questionnaires were obtained from 19 countries using an anonymous online questionnaire that collected demographic and sleep-related data, driving behaviour, history of drowsy driving and accidents. Associations were quantified using multivariate logistic regression. The average prevalence of falling asleep at the wheel in the previous 2 years was 17%. Among respondents who fell asleep, the median prevalence of sleep-related accidents was 7.0% (13.2% involved hospital care and 3.6% caused fatalities). The most frequently perceived reasons for falling asleep at the wheel were poor sleep in the previous night (42.5%) and poor sleeping habits in general (34.1%). Falling asleep was more frequent in the Netherlands [odds ratio = 3.55 (95% confidence interval: 1.97; 6.39)] and Austria [2.34 (1.75; 3.13)], followed by Belgium [1.52 (1.28; 1.81)], Portugal [1.34 (1.13, 1.58)], Poland [1.22 (1.06; 1.40)] and France [1.20 (1.05; 1.38)]. Lower odds were found in Croatia [0.36 (0.21; 0.61)], Slovenia [0.62 (0.43; 0.89)] and Italy [0.65 (0.53; 0.79)]. Individual determinants of falling asleep were younger age; male gender [1.79 (1.61; 2.00)]; driving ≥20 000 km year [2.02 (1.74; 2.35)]; higher daytime sleepiness [7.49 (6.26; 8.95)] and high risk of obstructive sleep apnea syndrome [3.48 (2.78; 4.36) in men]. This Pan European survey demonstrates that drowsy driving is a major safety hazard throughout Europe. It emphasizes the importance of joint research and policy efforts to reduce the burden of sleepiness at the wheel for European drivers.

INTRODUCTION

Drowsy driving is one of the main risk factors for crashes, and is likely responsible for 10–30% of all road traffic accidents (Lyznicki *et al.*, 1998) and a major cause of fatal accidents (Åkerstedt, 2000; Drake *et al.*, 2010; Pack *et al.*, 1995). Nevertheless, the relative importance of sleepiness at the wheel is largely under-reported in published official statistics, where it comprises only about 1–3% of all accidents (Centers for Disease Control and Prevention, 2013; Rosekind, 2005; Stutts *et al.*, 2003). This highlights the need for population-based evidence that can increase awareness of the true burden of drowsy driving.

In the past two decades, a growing number of published studies on the frequency of sleepiness at the wheel in different countries have yielded estimates varying between 20% and 57% (Nabi *et al.*, 2006). Regarding actual sleep-related car accidents, USA National Sleep Foundation's polls have shown a 1-year prevalence of 1% in non-professionals and 1–6% in professional drivers in the USA (NSF's Poll, 2011). Lower estimates (0.2–0.4%) were reported in France (Philip *et al.*, 2010; Sagaspe *et al.*, 2010), whereas a higher frequency was identified (10.4%) in Tokyo (Komada *et al.*, 2010).

Road traffic in Europe is characterized by the fact that millions of drivers cross inner-European borders (EU Commission, Brussels, 2011). Therefore, preventive policies should be coordinated and target the region as a whole beyond national efforts. Such a framework requires that supporting quantitative evidence is obtained at the European level and in a standardized manner. Indeed, most of the previous investigations on the frequency of drowsy driving have been assembled from limited geographical areas, using different study designs and data collection methods, and utilized non-standardized reference periods. In this context, the European Sleep Research Society (ESRS) set up the Wake-Up Bus project in 2013, a wide-range awareness campaign on sleepiness at the wheel at the European level that comprised a media campaign coordinated between European countries, the creation of an expert panel on 'Sleep and Driving', and the organization of the symposium 'Wake up Europe – don't sleep at the wheel' at the European Union Parliament in Brussels. As part of the campaign, the 'Wake-Up Bus Sleep Study' survey collected recent data on sleepiness at the wheel with a wide representation of European countries for comparisons of estimates across different geographical settings, by means of an identical instrument for data collection within a short time frame.

In the present paper, we describe the methods and results of the ESRS Wake-Up Bus Sleep Study conducted in 19 European countries. Specifically, our objectives with the present study were: (i) to describe country-level estimates of the period prevalence of drowsy driving (falling asleep at the wheel in the previous 2 years); (ii) to describe the consequences of falling asleep at the wheel; and (iii) to estimate the associations between falling asleep at the wheel and country of residence, demographic characteristics and sleep-related traits.

MATERIALS AND METHODS

The study was designed by the Wake-up Bus Project Coordination Team with input from an Expert Panel appointed by the ESRS board. Associated members from the Assembly of National Sleep Societies, an ESRS organization that includes more than 7500 members from 30 national sleep societies, were invited by the ESRS to participate in the survey. Nineteen national sleep societies from the following countries agreed to participate: Austria, Belgium, Croatia, Estonia, France, Germany, Greece, Iceland, Italy, Lithuania, Netherlands, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden and Turkey.

Sampling and promotion

The survey targeted the general population of drivers aged 17 years or older by means of an anonymous questionnaire completed online, using a web-based platform for data collection and storage. The questionnaire was translated into the local language of the participating countries (including multiple languages where applicable). Due to feasibility and efficiency issues we opted for non-probabilistic sampling, conducted by means of study promotions across different European and national media, and targeting general or specific population groups. Potential respondents were asked to go online in order to complete the questionnaire.

At the European level, the survey was promoted through the ESRS official website, newsletter and social media. At the country level, promotional media were selected by national representatives according to features such as intended reach, target audience and predicted efficiency. This resulted in country-specific sampling strategies that included promotion by governmental bodies, television and/or radio networks, lay press, scientific and medical societies, drivers associations, patients associations, social media and personal contacts. Table 1 summarizes the promotion strategies adopted in each country.

Questionnaire

During March 2013, the questionnaire was prepared in English by the Expert Panel with input from the Wake-up Bus Project Team. In the final version of the questionnaire (see Appendix 1), the following core information was collected: country of residence; demographic data (age and gender); and annual driving distance. Recent history of falling asleep at the wheel was assessed through the question 'During the last 2 years – have you fallen asleep at the wheel?' If the participant answered affirmatively, he/she was presented with the following question 'If so, what happened?' with the answering options 'Woke up just in time' and 'Had an accident'. In the latter case, the respondent was further questioned on the occurrence of fatalities due to the accident, timing, vehicle, professional driving, type of road, period of non-stop driving before the accident, perceived sleepiness and reasons for having fallen asleep. Regarding sleep-related characteristics, daytime sleepiness was measured through the Epworth Sleepiness Scale (ESS), where scores of 10–15 and 16 or above are indicative of intermediate and high levels of sleepiness, respectively. The STOPBang Questionnaire was used to estimate the risk of obstructive sleep apnea syndrome (OSAS). The STOPBang Questionnaire uses the sum of eight items (gender, age, neck circumference, body mass index, high blood pressure, observed stopped breathing during sleep, tiredness, and snoring) and scores between 3 and 4 are indicative of intermediate risk of OSAS while scores above 4 indicate high risk.

Each country's sleep society was responsible for the translation of the corresponding questionnaire. Versions in the following languages were made available online: Croatian, Dutch, English, Estonian, French, German, Greek, Icelandic, Italian, Lithuanian, Polish, Portuguese, Romanian, Serbian, Slovenian, Spanish, Swedish and Turkish. Validated

Table 1 Summary of survey promotion strategies by country

Country	*Governmental bodies*	*Television/ radio*	*Lay press*		*Scientific societies/ medical resources*		*Drivers' associations*	*Patients' associations*	*Social media*	*Personal contacts*
			Printed	*Online*	*Websites*	*Mailing*				
International					x	x			x	
Austria	x	x	x	x	x	x	x			x
Belgium					x	x				
Croatia						x			x	x
Estonia				x	x		x			
France					x				x	
Germany				x	x		x	x	x	
Greece		x	x			x	x		x	
Iceland				x		x			x	
Italy					x	x	x			x
Lithuania	x	x	x		x					
Netherlands										
Poland					x	x	x	x		x
Portugal			x	x	x	x				
Romania		x		x	x	x			x	
Serbia						x				
Slovenia	x					x				x
Spain	x		x		x					
Sweden		x	x	x	x					x
Turkey										
All countries	4	5	6	7	12	11	5	2	7	5

translations of the ESS and the STOPBang Questionnaire were used when available. Online versions of the questionnaire were created for each language using the eSurvey Creator software. The English version of the questionnaire can be found as Data S1.

The online survey was available at the ESRS website using a dedicated page (http://www.esrs.eu/sleepstudy.html). Promotion of the study in each country publicized or linked to that landing page, where respondents could choose to complete the questionnaire in one of the 18 languages. The questionnaire was anonymous, but browser ID and cookies were saved to allow resuming participation at a later time and to reduce multiple participations from the same individual. The questionnaire was presented to each respondent in a sequence of up to 21 screens. Apart from questions whose answer was conditional on previous items, all variables were defined as required fields. The questionnaire included a variable number of items ranging from 16 to 33, depending on the individual's responses for gender, previous history of falling asleep at the wheel and occurrence of an accident. The resulting database was stored and exported from www.esurveycreator.com.

Participation

Data collection for the present report refers to the period from 15 July to 6 September 2013. In that period, 14 904 questionnaires were initiated at the web-based platform, of which 12 783 were completed and submitted. Among those, we excluded questionnaires completed by individuals who reported living in countries other than the participating ones (41 from Switzerland, five from the UK and 140 from other countries). Of the remaining 12 597, we additionally excluded 163 respondents who reported having driven <1 km in the previous year, leaving a final sample of 12 434 questionnaires eligible for statistical analysis.

Data analysis

Descriptive statistics are presented for all variables or scores asked in the questionnaire. We present pooled results as well as estimates stratified by country of residence. The statistical significance of differences in proportions was calculated using the Chi-squared statistic. The frequencies of the main outcomes (having fallen asleep at the wheel in the previous 2 years and having had an accident as a consequence of falling asleep in the same period) were compared over categories of potential determinants (country of residence, gender, age, distance driven in the previous year, average daytime sleepiness measuring using the ESS, and probability of OSAS measured using the STOPBang Questionnaire). We used adjusted odds ratios (OR) and 95% confidence intervals (95% CI) obtained by logistic regression to estimate the magnitude of the associations between exposures and the main outcome of having fallen asleep at the wheel in the previous 2 years. Because we expected a higher degree of correlation between any two individuals in the same country than between any two from different countries due to differences in sampling strategies or other country-level factors, we have included a country-level random effects term in the logistic regression models.

In order to reduce the impact of selection bias due to differences between source populations and/or different recruitment methods in comparing the frequency of falling asleep between countries, ORs were adjusted for age, gender and distance driven in the previous year. To calculate ORs for countries we used the mean of all samples as the reference class. Due to comparatively small sample size ($n = 167$), we did not have sufficient statistical power to present adjusted estimates for the risk of accident.

A number of issues arising from intended or unintended differences in questionnaire design between languages required corresponding adjustments to the analysis in order to improve comparability. Those options are presented below.

- The item ‘Do you often feel tired, fatigued or sleepy during the daytime?’ present in the original version of STOPBang was not included in the questionnaire. It was replaced by a dichotomous variable that resulted from the individual’s score in the ESS: present if the ESS score was above the cut-off of 10 and absent if the score was 10 or below. Additionally, the item neck circumference was not asked if the respondent selected the female gender. Therefore, we restricted the calculation of OSAS risk to male respondents.
- On items collected as string variables, such as weight, height, neck circumference and distance driven, ranges for plausible values were applied. All extreme values were omitted from the analysis.
- In the Spanish version of the questionnaire, the main outcome considered was ‘Did you ever feel sleepy at the wheel in the last 2 years?’ instead of ‘Did you ever fall asleep at the wheel in the last 2 years?’ Spanish data on that item were excluded from the pooled analyses.
- In Austria, Estonia and Germany, distance driven in the previous year was asked only to respondents of one gender. Missing data were assumed to be at least 1 km based on the low probability of no driving history found in other countries.
- In the Estonian version of the questionnaire, the ESS was included only for those participants who reported not having had an accident due to falling asleep. For the remaining participants data were considered missing.

RESULTS

Sample characteristics

Demographics and annual driving distance

The final sample included 12 434 valid questionnaires. The median number of questionnaires submitted by country of residence was 466, and varied between 49 in the Netherlands and 2313 in France.

Young respondents (defined as an age between 17 and 30 years) accounted on average for one-fifth of the country samples, whereas on average half of respondents were 31–50 years old and about 1% were older than 70 years old. The highest proportion of young respondents was found in Serbia and the lowest in Slovenia (52.5% and 6.6%, respectively). Participants over 70 years old were more represented in Germany (9.6%), and were absent from samples from Estonia, Lithuania, the Netherlands and Turkey. Overall, the sample included slightly more women than men (56.6% versus 43.4%). Women were clearly more represented in Slovenia, Belgium and Iceland (women:men ratio over 2), and less represented in Spain and Estonia (ratio: 0.4). The prevalence of obesity (from self-reported height and weight) varied from 6% in Croatia and Slovenia to more than 20% in Estonia, Germany, Greece, Iceland and Romania.

Regarding reported driving distance in the year prior to the questionnaire, Austria and Germany had the lowest proportion of respondents who reported driving <5000 km (about 10%), while Sweden and the Netherlands had the highest frequency of low-intensity drivers (about 50%). Respondents driving over 20 000 km per year were more common in the Lithuanian and Austrian samples (about half), and less common in Croatia, Serbia and Turkey (under 20%).

Sleep-related characteristics

The prevalence of a high level of daytime sleepiness (ESS score above 15) varied from 1% (Turkey, Croatia and Serbia) to 8% in Austria, France, Poland and Portugal. Sleepiness scores of 16 or higher were significantly more frequent among younger respondents, as well as in female drivers.

In men, the prevalence of intermediate to high OSAS risk varied from approximately 45% in Slovenia and Italy to over 75% in Serbia, Germany and Sweden. The risk of obstructive sleep apnea among men increased significantly with age.

Falling asleep at the wheel

Fig. 1 shows the distribution of countries categorized by quartiles of the crude prevalence of the main outcome, having fallen asleep at the wheel in the previous 2 years. The median frequency of falling asleep was 17% (95% CI: 12.4; 21.9), varying between 6.1% in Croatia and 34.7% in the Netherlands. Fig. 2 shows the estimates of associations between country of residence and falling asleep at the wheel after adjustment for age, gender and distance driven in the previous year. Using the mean value of the overall sample as the reference category, the odds of falling asleep were substantially and significantly higher in the Netherlands [OR = 3.55 (95% CI: 1.97; 6.39)] and Austria [OR = 2.34 (95% CI: 1.75; 3.13)]. The frequency was also significantly higher, albeit with lower magnitude in Belgium [OR = 1.52 (95% CI: 1.28; 1.81)], Portugal [OR = 1.34 (95% CI: 1.13;

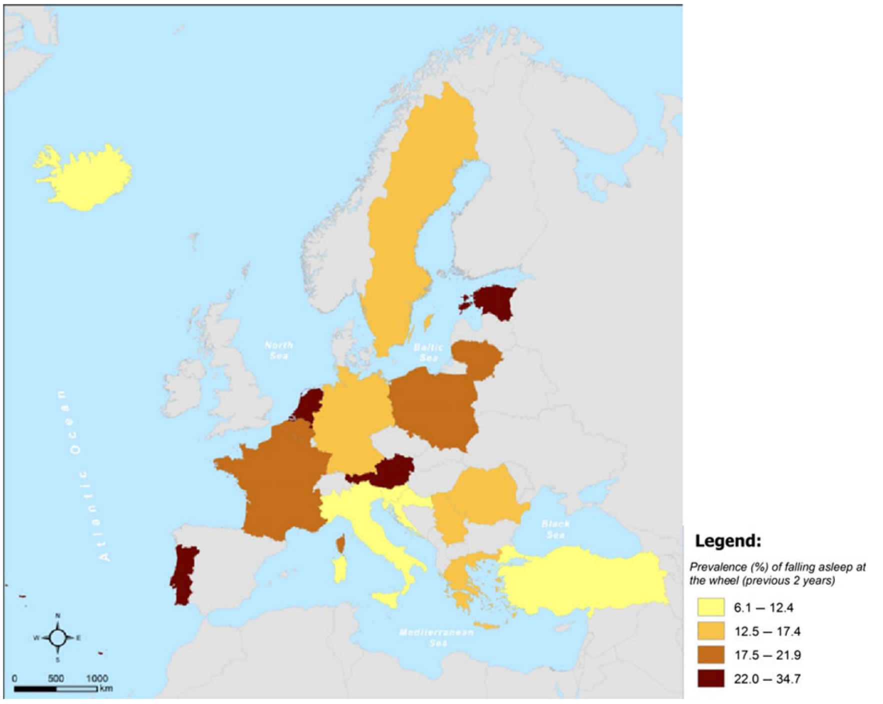

Figure 1. Prevalence (%) of drivers reporting a history of having fallen asleep at the wheel during the previous two years, data shown by country. Prevalence data from Spain are missing.

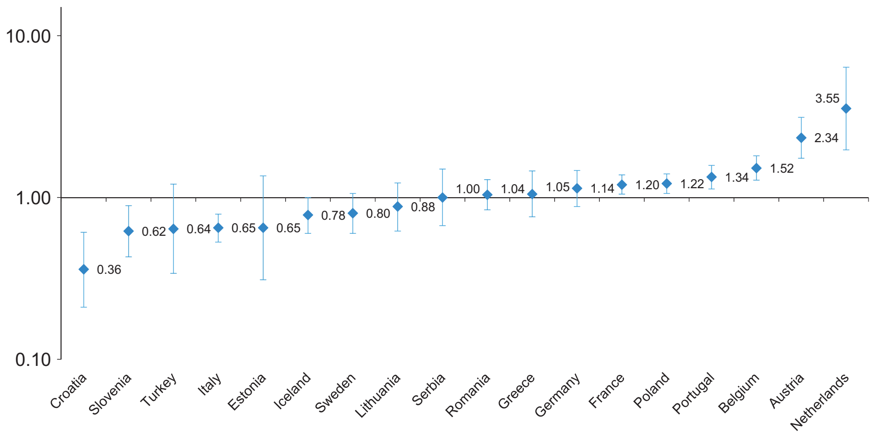

Figure 2. Associations (odds ratios and 95% confidence intervals) between country of residence and having fallen asleep at the wheel in the previous two years (adjusted for age, gender and distance driven in the previous year).

1.58)], Poland [OR = 1.22 (95% CI: 1.06; 1.40)] and France [OR = 1.20 (95% CI: 1.05, 1.38)]. In Croatia, Slovenia and Italy, the odds of falling asleep were significantly lower [$OR_{Croatia}$ = 0.36 (95% CI: 0.21; 0.61); $OR_{Slovenia}$ = 0.62 (95% CI: 0.43; 0.89); OR_{Italy} = 0.65 (95% CI: 0.53, 0.79)]. In the remaining countries, no significant differences in odds were found. After categorizing countries according to participation rates, we obtained similar mean frequencies of falling asleep at the wheel between groups, as follows: 18.2% in countries with <30 participants per million population (Turkey, Netherlands, Germany, Spain, Italy, Greece and Serbia), 18.4% in those with 30–70 participants per million (Romania, France, Austria, Sweden, Poland and Croatia) and 18.6% in countries with more than 70 participants per million (Lithuania, Belgium, Portugal, Slovenia, Estonia and Iceland).

Table 2 presents the prevalence estimates for falling asleep at the wheel, and for road traffic accidents due to falling asleep in each country. Accidents due to drowsy driving were more frequent in Estonia and Austria (2.7% and 2.6%, respectively), and less frequent in the Netherlands and Turkey (0.0%), $P < 0.001$ between all countries. Considering only respondents who reported having fallen asleep, the median proportion of episodes of falling asleep that caused an accident was 7.0% (95% CI: 4.5; 7.2). This proportion was highest in Italy and Estonia (11.1% and 10.4%, respectively), and lowest in Iceland (1.4%) followed by Belgium, France, Lithuania and Sweden (approximately 5%).

Overall, of the 167 accidents reported in the whole sample, 13.2% involved at least one person receiving hospital care and 3.6% involved at least one fatality. As for the time of day of reported accidents, the observed distribution was significantly different from random (Chi-squared *P*-value: 0.002): there was a peak between 15:00 and 16:00 hours (26.8% of all accidents) and a smaller elevation in the early morning, between 04:00 and 08:00 hours (21.4% of accidents; Fig. 3). The vast majority of vehicles driven at the time of the accident

Table 2 Number and proportion (%) of respondents who fell asleep at the wheel in the previous 2 years, and who had an accident due to falling asleep in that period, by country

	Falling asleep at the wheel					*Accident due to sleepy driving*				
	No		*Yes*			*No*		*Yes*		
Country	n	%	n	%	P	n	%	n	%	P
Austria	225	65.8	117	34.2 (29.2, 39.5)	<0.001	333	97.4	9	2.6 (1.2, 4.9)	<0.001
Belgium	745	78.1	209	21.9 (19.3, 24.7)		944	99.0	10	1.0 (0.5, 1.9)	
Croatia	217	93.9	14	6.1 (3.4, 10.0)		230	99.6	1	0.4 (0.0, 2.4)	
Estonia	188	73.7	67	26.3 (21.0, 32.1)		248	97.3	7	2.7 (1.1, 5.6)	
France	1866	80.7	447	19.3 (17.7, 21.0)		2292	99.1	21	0.9 (0.6, 1.4)	
Germany	629	82.9	130	17.1 (14.5, 20.0)		750	98.8	9	1.2 (0.5, 2.2)	
Greece	204	82.6	43	17.4 (12.9, 22.7)		244	98.8	3	1.2 (0.3, 3.5)	
Iceland	514	87.6	73	12.4 (9.9, 15.4)		586	98.8	1	0.2 (0.0, 0.9)	
Italy	1006	88.2	135	11.8 (10.0, 13.8)		1126	98.7	15	1.3 (0.7, 2.2)	
Lithuania	192	81.7	43	18.3 (13.6, 23.8)		231	99.1	2	0.9 (0.1, 3.1)	
Netherlands	32	65.3	17	34.7 (21.7, 49.6)		49	100.0	0	0.0 (0.0, 7.3)	
Poland	1589	79.3	415	20.7 (19.0, 22.5)		1964	98.0	40	2.0 (1.4, 2.7)	
Portugal	849	77.7	244	22.3 (19.9, 24.9)		1074	98.3	19	1.7 (1.0, 2.7)	
Romania	559	82.8	116	17.2 (14.4, 20.2)		666	98.7	9	1.3 (0.6, 2.5)	
Serbia	139	83.2	28	16.8 (11.4, 23.3)		165	98.8	2	1.2 (0.1, 4.3)	
Slovenia	282	89.8	32	10.2 (7.1, 14.1)		311	99.0	3	1.0 (0.2, 2.8)	
Spain	–	–	–	–		503	97.5	13	2.5 (1.3, 4.3)	
Sweden	407	87.3	59	12.7 (9.8, 16.0)		463	99.4	3	0.6 (0.1, 1.9)	
Turkey	76	88.4	10	11.6 (5.7, 20.3)		86	100.0	0	0.0 (0.0, 4.2)	

–, No data available for this item.

were cars (over 90% in the overall sample). The proportion of respondents who were driving during working hours at the time of the accident was 43.7%. At the time of the accident most respondents were driving on major roads, like motorways or intercity roads (56.3%), followed by town/city roads (25.7%) and then by other roads (18.0%).

Driving more than 2 h before the sleepiness-related accident was more prevalent in Estonia and Poland (71.4% and 40.0%, respectively), but never reported in Belgium, Croatia, Iceland, Lithuania, Serbia and Slovenia (0.0%). Accidents due to falling asleep at the wheel were accompanied by drivers' reporting feeling 'somewhat sleepy' or 'very sleepy' in over 80% of cases in the majority of countries. Regarding the reasons perceived by respondents for falling asleep at the time of the accident (Fig. 4), the most frequently reported were poor 'sleep in the previous night' (42.5%) and 'poor sleeping habits in general' (34.1%), followed by 'feeling unwell' (18.6%) and 'having been driving for a very long time' (16.2%). Importantly, over 8% of drivers attributed the accident to the use of medication.

Determinants of falling asleep

Table 3 shows the frequency of our main outcomes (falling asleep and having an accident) according to age, gender, distance usually driven, daytime sleepiness and OSAS risk.

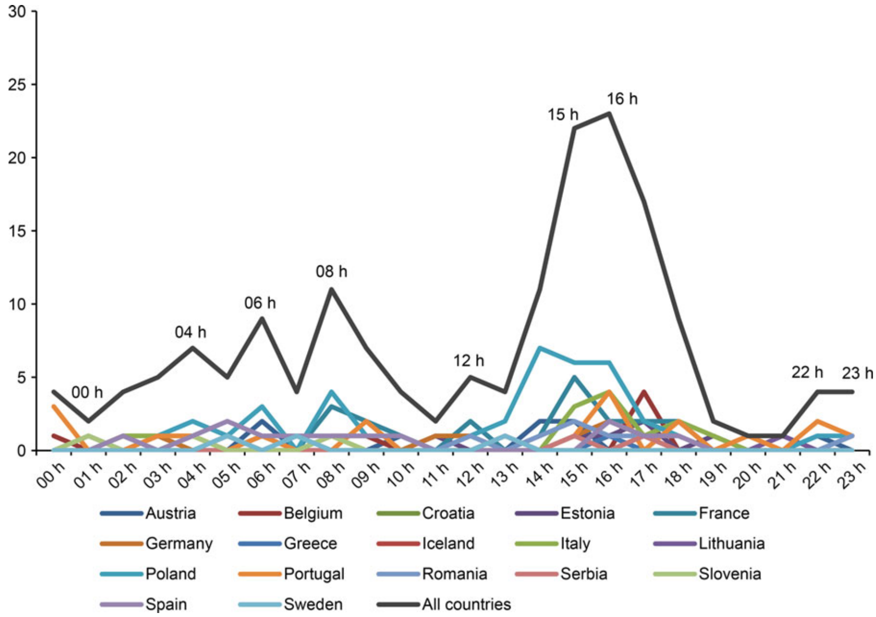

Figure 3. Distribution of the absolute number of accidents by time of day (n = 167 accidents in 17 countries except Turkey and Netherlands where no accidents were reported, chi squared test, compared to random distribution: P = 0.002).

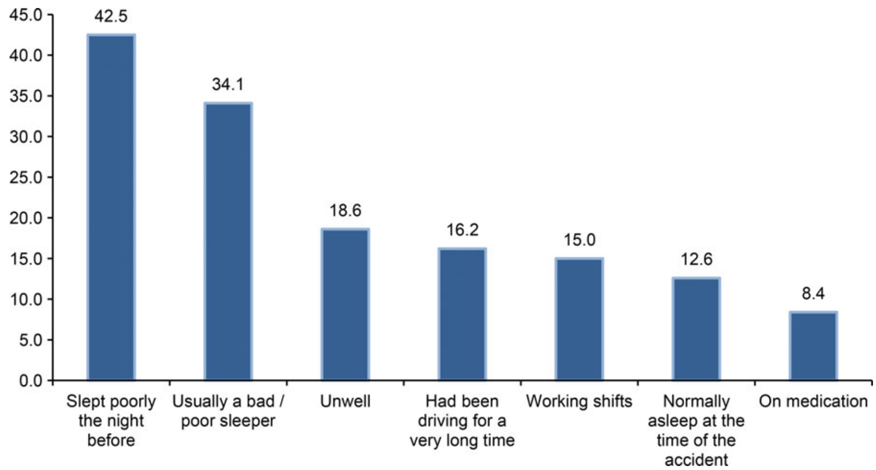

Figure 4. Proportion (%) of respondents by perceived reasons for falling asleep at the time of accident (multiple options were possible, n = 167 accidents).

The prevalence of falling asleep at the wheel decreased with age, although with borderline significance in crude analysis, while the prevalence of accidents was highest in the oldest age group. Overall, country-level factors (random-effects) accounted for 6% of the total variance observed in the outcome; this proportion decreased to 5% after gender, age and distance driven were included in the model. In multivariate analysis, after adjustment for gender and distance driven in the previous year, the odds of falling asleep at the wheel remained significantly higher in the youngest age groups when compared with those over 70 years old: OR = 1.56 (95% CI: 1.06; 2.29) in drivers aged up to 30 years; 1.56 (95% CI: 1.06, 2.28) from 31 to 50 years; and 1.67 (95% CI: 1.13, 2.47) from 51 to 70 years.

Regarding gender, the prevalences of falling asleep at the wheel and of related accidents were significantly higher among men. The association between gender and falling asleep maintained significance after adjustment for age group and distance driven in the previous year: OR = 1.79 (95% CI: 1.61; 2.00).

The frequency of falling asleep at the wheel increased significantly in a dose–response manner with the distance driven in the previous year: 10 000–19 999 km [adjusted OR = 1.36 (95% CI: 1.16; 1.58)] and 20 000 km or more [adjusted OR = 2.02 (95% CI: 1.74; 2.35)]. Among respondents who drove ≥20 000 km, the frequency of accidents was significantly higher.

Daytime sleepiness assessed by the ESS was significantly and positively associated with falling asleep and with reporting an accident. The association with falling asleep maintained significance after adjustment for age group, gender and distance driven: OR = 2.71 (95% CI: 2.43; 3.03) for ESS scores of 10–15; and 7.49 (95% CI: 6.26; 8.95) for scores above 15.

Among men, the prevalence of falling asleep at the wheel, as well as the prevalence of accidents due to falling asleep,

Table 3 Associations between respondents' characteristics and falling asleep at the wheel and accidents due to falling asleep (previous 2 years)

	Falling asleep at the wheel						*Accident due to falling asleep (whole sample)*					*Accident due to falling asleep (respondents who fell asleep)*				
	No		*Yes*				*No*		*Yes*			*No*		*Yes*		
	n	%	n	%	P	*Adjusted OR* (95% CI)*	n	%	n	%	P	n	%	n	%	P
Gender																
Female	6012	85.4	1029	14.6	<0.001	1 (ref)	6985	99.2	56	0.8	<0.001	913	94.5	53	5.5	0.018
Male	3869	71.7	1524	28.3		1.79 (1.61, 2.00)	5280	97.9	111	2.1		1165	92.0	102	8.0	
Age (years)																
17–30	2056	80.3	504	19.7	0.088	1.56 (1.06, 2.29)	2521	98.5	38	1.5	<0.001	415	92.4	34	7.5	<0.001
31–50	4875	78.8	1308	21.2		1.56 (1.06, 2.28)	6108	98.8	74	1.2		1058	94.0	68	6.0	
51–70	2718	79.6	697	20.4		1.67 (1.13, 2.47)	3375	98.8	40	1.2		578	93.8	38	6.2	
>70	231	84.3	43	15.7		1 (ref)	259	94.5	15	5.5		26	63.4	15	36.6	
Distance driven (km)																
<5000	2219	86.4	350	13.6	<0.001	1 (ref)	2540	98.9	28	1.1	0.005	282	91.9	25	8.1	0.697
5000–9999	1352	86.4	213	13.6		0.99 (0.81, 1.21)	1552	99.2	13	0.8		178	93.2	13	6.8	
10 000–19 999	3085	80.7	737	19.3		1.36 (1.16, 1.58)	3780	98.9	42	1.1		619	93.9	40	6.1	
≥20 000	2526	70.3	1066	29.7		2.02 (1.74, 2.35)	3525	98.2	66	1.8		832	93.3	60	6.7	
ESS score																
<10	6516	86.1	1050	13.9	<0.001	1 (ref)	7513	99.3	52	0.7	<0.001	795	94.2	49	5.8	0.545
10–15	2971	72.3	1139	27.7		2.71 (2.43, 3.03)	4037	98.2	73	1.8		971	93.5	68	6.5	
>15	391	52.8	349	47.2		7.49 (6.26, 8.95)	710	96.0	30	4.0		308	92.5	25	7.5	
OSAS risk (in men)																
Low	1585	77.0	473	23.0	<0.001	1 (ref)	2033	98.8	24	1.2	<0.001	343	93.5	24	6.5	0.253
Intermediate	1437	70.9	590	29.1		1.83 (1.54, 2.18)	1981	97.8	45	2.2		465	92.1	40	7.9	
High	653	63.0	383	37.0		3.48 (2.78, 4.36)	998	96.3	38	3.7		309	90.1	34	9.9	

*Mixed effects logistic regression model including a random effect for country. Odds ratios are adjusted for gender, age and distance driven in the previous year.
CI, confidence interval; ESS, Epworth Sleepiness Scale; OR, odds ratio; OSAS, obstructive sleep apnea syndrome.

increased significantly with the risk of OSAS (as measured by the modified STOPBang questionnaire score). A dose–response association between OSAS risk and falling asleep at the wheel was found even after adjustment for potential confounders: OR = 1.83 (95% CI: 1.54; 2.18) for intermediate OSAS risk; and OR = 3.48 (95% CI: 2.78; 4.36) for high OSAS risk, respectively. We tested an interaction term between ESS and OSAS risk, which was not statistically significant.

DISCUSSION

In this study conducted over 19 European countries, we found the average prevalence of a recent history of falling asleep at the wheel to be 17%. After adjustment for individual characteristics, falling asleep was more frequent in the Netherlands and Austria, followed by Belgium, Portugal, Poland and France. Lower odds were found in Croatia, Slovenia and Italy. Frequencies were similar to the mean sample in the remaining nine countries. The main predictors of falling asleep at the wheel included male gender, high amount of driving exposure and elevated risk for OSAS. To our knowledge, this is the first large European multi-national study addressing the burden of drowsy driving within European countries.

Falling asleep at the wheel was quite prevalent, with estimates varying between 6 and 35%, and resulting in a 17% median across countries. These results are consistent with previous estimates obtained in several studies (Nabi *et al.*, 2006; Sagaspe *et al.*, 2010). In comparison, severe sleepiness in the previous year occurred in 29% of UK drivers (Maycock, 1997). Differences between countries in the frequency of falling asleep were likely confounded by characteristics of samples, as supported by our finding of an attenuation of the odds of falling asleep between countries after adjustment for age, gender and distance driven. Indeed, young people and men have been found to be more prone to drowsy driving (Åkerstedt and Kecklund, 2001; Horne and Reyner, 1995, 1999; Pack *et al.*, 1995; Phillips and Sagberg, 2013) when compared with the elderly. This pattern was also observed in our study. Another expected finding was the excess risk for sleeping behind the wheel associated with high annual driving distance. Our finding is consistent with data showing that higher exposure to driving is associated with an increased likelihood of falling asleep (Sagaspe *et al.*, 2008).

In line with previous research, we found that individuals with an increased likelihood of daytime sleepiness and sleep disturbance like OSAS were more likely to report an episode of falling asleep at the wheel (Alonderis *et al.*, 2007; Barbé *et al.*, 1998; Teran-Santos *et al.*, 1999). This highlights both subjective daytime sleepiness and relevant sleep disorders as important determinants of sleep-related accidents. However, we did not collect thorough data on usual sleep duration or other sleeping habits. Detailed analysis of reasons for sleepy driving may require more comprehensive studies in random samples of European drivers. Likewise, due to feasibility issues we were not able to collect information on important causes of drowsy driving that may have confounded the present associations, such as the use of psychoactive substances (e.g. alcohol and other drugs).

Regarding road traffic accidents as a result of sleepiness at the wheel, the average prevalence of 7% among those who fell asleep is consistent with previous findings in other settings (Philip *et al.*, 2010; Sagaspe *et al.*, 2010). The majority of accidents occurred in the time windows 04:00–08:00 hours and 15:00–16:00 hours, which seems to precede road traffic intensity peaks in Europe: 08:00–10:00 hours and 17:00–19:00 hours (INRIX Driving Intelligence, 2013). This dissociation suggests that at least some of the risk of accident was independent of traffic density. Factors like time on task and time of the day may reflect the joint action of both the circadian and homeostatic variation of sleep pressure, which may cause an increase in the probability of sleepiness at the wheel (Horne and Reyner, 1995). In the present setting, cross-country comparisons would be useful as our survey spans very diverse latitudes. Ideally, time of day, month of the year and latitude of the location of accident should be assessed to analyse accident risks in relation to individual circadian phase and the degree of daylight exposure. However, this set of information was not available in our survey.

We also found that more than half of all accidents occurred when individuals had been driving for <2 h, as reported in an Australian study (Fell, 1995). This result suggests that other explanations than fatigue may determine the risk of drowsy driving, namely the presence of severe sleep deprivation or untreated OSAS. Indeed, subjects who reported accidents within the first 2 h of driving had a higher daytime sleepiness score than the remaining individuals involved in accidents. Even though this difference was not statistically significant, it may argue for a more detailed investigation of sleep habits and symptoms and signs of sleep disorders in the analysis of sleepy driving. Another argument in favour of sleep deprivation as an underlying cause of daytime sleepiness was our finding that over one-third of participants reported having slept poorly the previous night. Being usually a poor sleeper has previously been described as a reason for having fallen asleep at the wheel (Dijk and Czeisler, 1995; Dongen *et al.*, 2003). Another interesting finding is the fact that most of the drivers continued driving despite being aware of their sleepiness, which is consistent with reports from other studies (Maycock, 1997; McCartt *et al.*, 1996; Connor *et al.*, 2001; Reyner and Horne, 1998). This finding may indicate a lack of knowledge, or of consideration, about the risks of sleepiness while driving. At the same time, it highlights the important role that specific prevention measures could have for reducing the rate of future accidents.

Another potential cause for drowsy driving was identified in the use of medication in more than 8% of the participants involved in these accidents. This finding is noteworthy and may reflect very different scenarios between countries, in agreement with the major geographic variations in the consumption of sedative-hypnotic medication, varying from 3.75 DDD/1000 inhabitants-day in Lithuania to 82.19 in Belgium. However, our sample size regarding this variable did not allow enough statistical power to estimate the significance of differences between countries in reporting medication as a cause of accident, which is why only aggregate data were reported here.

Finally, working shifts as the cause of the accident was reported by a fraction of participants, a finding supported by previous studies (Rogers *et al.*, 2001; Swanson *et al.*, 2012). An additional important remark is our finding that one in every six accidents resulted in serious injuries or death, which confirms the deadly rate of accidents when sleep is involved.

Several methodological strengths in our study have to be mentioned. First, this is to our knowledge the first study using a questionnaire translated to more than 16 languages for the assessment of sleepiness at the wheel. This unique approach enabled us to map the prevalence and associated factors across major parts of Europe. Second, the questionnaire was assembled by an international expert panel addressing not only the frequency but also the relevant risk factors for drowsy driving. Third, dissemination of the questionnaire was supported by National Sleep Societies, giving the study a broad acceptance in each country. Finally, analysis of data was performed in order to present relevant findings at both national and European levels. However, a number of limitations need also to be considered. One major limitation is the lack of random selection of participants. In order to overcome barriers for participation as well as to allow the recruitment of a large sample within a short time frame, the study opted for group-level promotion of the survey and for an internet-based data collection platform. Those options improved feasibility but limited an accurate characterization of the sampling frame – in theory composed of all drivers over 17 years old who were informed about the study and had access to the internet. This produced a non-probabilistic sample in the sense that we cannot estimate a sampling fraction as we have no objective information on the coverage of promotion media. Samples originated from this method can hardly be considered representative of the general population even if participation is optimal, which limits the confidence in the statistical inference of results to the source population. This aspect is particularly important for prevalence estimates in each country. Additionally, there was heterogeneity between countries with regard to the type of media and specific strategies for dissemination, as well as to the intensity of the diffusion effort. The final sample size, which is partly a reflection of that effort, varied substantially between countries, and evoked differently powered estimates for each setting. Internet access was in itself an additional selection factor that varied substantially between settings. In 2012, the proportion of individuals with internet access varied between 45% in Turkey and 96% in Iceland (International Telecom Union, 2012). The fact that the sampling strategy required internet access and, to a varying extent, use of social media in each country is likely to have produced some degree of selection bias that we may hypothesize to have caused under-representation of lower socioeconomic strata in each country.

If we assume that the extent of sampling bias is comparable between countries or that adjustment for individual characteristics is at least partially effective in overcoming such bias, then the method could provide a useful insight into risk variation between countries. In the present analysis we did compare the frequencies of drowsy driving between countries, and provided estimates adjusted for age, gender and distance driven in the previous year. In order to test whether selection bias could be related with sample size, we performed a separate analysis where countries were grouped according to the rate of participation, and we found that prevalence estimates for drowsy driving did not differ between those groups. This analysis strongly indicates that any potential bias at the national level was not markedly influenced by sample size.

Secondly, participation is always a critical issue in population research. In particular, web-based surveys may produce major biases that are hardly quantifiable without data on non-participants. In interpreting the present results, it should be taken into account that the self-selection of people who are particularly aware or sensitive to the issue being studied may depend on the probability of having a previous history of drowsy driving or road traffic accidents. Moreover, our results may be affected by survivor bias, in that driver fatalities are by definition excluded from our sampling method.

With regard to the validity of information, we cannot exclude possible recall bias, whereby drivers who did have accidents may be more likely to report having fallen asleep than those who had less serious outcomes. Additionally, as in any survey involving sensitive issues, social desirability may play an important role in the responses given by participants regarding behavioural characteristics. In this particular case, cultural differences between countries may have influenced the validity of responses, thus explaining some of the observed inter-country variability.

A third aspect to consider is the calendar period of data collection. The survey was conducted during summer months, which due to work schedules may have influenced the available sampling frame as well as the degree of self-selection in responses.

The above-mentioned limitations are certainly important. Nevertheless, it is relevant to note that the frequencies of drowsy driving obtained in the present survey are similar to previous estimates obtained in other studies, which provides external validation to our results (Gander *et al.*, 2005; Maycock, 1997; Papadakakia *et al.*, 2008; Sagaspe *et al.*, 2010). Additionally, beyond frequency estimates, our data may provide an important picture of associations between individual factors and driving habits, and a history of drowsy driving across a large number of European countries.

In the present study we estimated that, in two-thirds of the countries, over one in each six individuals had fallen asleep at the wheel in the previous 2 years. Despite differences in crude frequency, we found common determinants of falling asleep at the wheel between countries, which provides a rationale for common preventive policies at the European Union level. The importance of sleep disorders in the context of driver safety has been officially recognized by the establishment of a working group on driving and OSAS by the Transport and Mobility Directorate of the European Commission. This working group prepared a report containing recommendations regarding the provision of driving licenses to patients with established OSAS, which has been published by the Commission (McNicholas, 2013). This report stresses the importance to public safety of identifying patients with OSAS with significant risk of accident, but also stresses the safety of patients receiving effective treatment. The report also makes recommendations regarding screening strategies to identify patients at risk of having OSAS based on easily obtained subjective and objective data, and also highlights the importance of educating key stakeholders in the field of road safety, such as the police and members of the road transport industry. The report has been endorsed by the Driving Licence Committee of the Directorate, and resulted in a revision to Annex 111 of the Driving Licence Directive relating to OSAS [Directive 2006/126/EC (2014)], which specifies that patients with moderate or severe OSAS associated with sleepiness should not be issued a driving license unless the disorder is adequately treated.

The present study also reinforces the need for the inclusion of fatigue-related issues in official accident investigations in order to get more accurate and realistic official numbers. This information will provide a better understanding of the dimension of the problem, help to adjust preventive measures, as well as promote more research in the field.

In conclusion, our study is the first Pan European multicentric multinational survey on the assessment of frequency and risk factors for sleepiness at the wheel for both short- and long-distance drivers. Our results clearly demonstrate that drowsy driving is a major driving safety hazard in all European countries.

Our data further emphasize the importance of joint scientific efforts supporting both basic and clinical sleep research for a reduction of the burden of sleepiness at the wheel for European drivers.

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APPENDIX 1. NATIONAL REPRESENTATIVES AS STUDY COLLABORATORS

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[Note: Correction added on 10 February 2015 after initial online publication on 12 January 2015. Appendix 1 has been amended to include details for Austria and Belgium, which were accidentally omitted.]

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:
Data S1. English Version.