Maintenance of wakefulness test: how does it predict accident risk in patients with sleep disorders?

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Introduction

Over the last 30 years, numerous epidemiological studies have highlighted the prevalence of sleepiness while driving and sleep disorders among the general population [1-4]. Sleepiness while driving is one of the major causes of highway accidents and fatal crashes [2,5]. A recent meta-analysis showed that patients reporting sleepiness at the wheel presented a two-fold higher risk of being involved in a car accident compared to drivers without sleepiness while driving [6]. Sleepiness at the wheel can be due to poor sleep hygiene and to sleep disorders including obstructive sleep apnea syndrome (OSAS) or narcolepsy [4,7-13].

While questionnaires are good tools to evaluate the risk of traffic accidents in sleepy patients, objective measures can be useful to quantify the level of sleepiness. Apart from questionnaires, the Multiple Sleep Latency Test (MSLT) and the Maintenance of Wakefulness Test (MWT) are common objective clinical tests for evaluating excessive daytime sleepiness and impaired alertness. The MWT is a validated objective measure of the ability to stay awake for a defined period of time. Its clinical relevance is based on the premise that the volitional ability to remain awake provides important information regarding the ability to stay awake and respond to interventions in disorders associated with excessive sleepiness [14]. As noted by the task force of the American Academy of Sleep Medicine [14], the MSLT is not the best test for investigating alertness in patients. On the other hand, the MWT, which requires patients to fight against sleepiness in a sleep-conducive environment, is better adapted to evaluate the degree of daytime alertness in patients. The MWT is robust, validated for measuring the ability to stay awake in sedative conditions, reproducible and well suited for multicenter studies [15]. Its latency is significantly longer in healthy subjects than in patients with excessive sleepiness due to OSAS [16], and in patients with OSAS after than before treatment [17]. Moreover, its latency in the MWT 40 min protocol predicts simulated and real driving performances in patients with sleep disorders [18-22]. Driving impairment has been quantified in three sleepiness groups (Group #1: mean MWT latency <19 min, Group #2: MWT ≥ 19 and < 33 min, and Group #3 MWT ≥ 33 min, which is considered as the reference non-sleepy group) based on previous publications [18,20-23] which demonstrated these significant cutoffs regarding simulated and real driving performances in untreated and treated patients. Consequently, the MWT may be used to assess an individual's ability to remain awake, when their inability to do so constitutes a public or a personal safety issue. This may be particularly important in patients with OSAS, narcolepsy and other sleep disorders associated with daytime sleepiness, who need to drive or to operate machines when working, or for their personal use [14]. Because sleep-related accidents are becoming an important medical-legal issue, France has now legislated on the processing and dispensing of driving licenses of patients suffering from daytime sleepiness. For non-professional drivers, physicians can use clinical criteria to evaluate a patient's ability to drive once the sleep disorder has been treated. Regarding professional drivers, treatment efficacy needs to be evaluated using a 40-minute MWT, as recommended by the AASM [14]. This test has been selected because it reflects the ability to stay awake and because it is harder to falsify than the MSLT.

Some investigators, however, have questioned its validity in evaluating real-world performances and the risks incurred due to excessive sleepiness [24]. To answer these criticisms, we have conducted studies which showed that abnormally reduced (below 19 minutes) sleep latency on the 40-min MWT correlates with impaired driving in a car simulator [20-22] and in real driving conditions [18-21]. Daytime sleepiness is a public health issue that directly involves physicians. In many countries, physicians are legally liable if they allow sleepy patients to drive a vehicle or operate machinery. Developing objective measures of daytime alertness could provide long-awaited and necessary information on the ability to safely drive in this group of patients. Another important concern is to test the validity of the MWT in professional and nonprofessional drivers in order to reflect the validity of the test, independently of the driving practice of the patients.

After demonstrating that MWT scores correlate with driving performances, the next important question is how does the MWT latency in sleep disorder patients predict the risk of self-reported, sleepiness-related accidents and near-miss accidents. In this study, we tested whether MWT latency discriminates between patients who report driving accidents or near misses in the past year compared to those who do not.

Methods

This case-control study was conducted between September 2016 and June 2019. Data were collected from four sleep clinics in France: University Hospital of Bordeaux, University Hospital of Montpellier, Sorbonne and Paris Universities (Hôtel-Dieu and Pitié-Salpêtrière). All patients requiring an objective evaluation of excessive daytime sleepiness were given the offer to perform an MWT. This included patients having received medical or non-medical treatment (eg, CPAP) and requiring an objective confirmation of daytime sleepiness improvement. In specific cases involving the ability to drive, the MWT was also performed in before treatment in order to quantify the objective level of the alertness of patients. We did not select patients on their professional or non-professional driving practice in order to obtain the most representative balance between cases and controls. No selection was made regarding the type of disorder or type of treatment in order to make the sample the most representative of a French sleep clinic population. According to the terms of the French ethics law on observational studies which waived written consent, participants were informed of the aim of the study. They were not opposed to the collection of their results. The study was sponsored by a grant from the French Sleep Society (SFRMS) and received the agreement of the ethical committee of the SFRMS. The measures were collected and stored anonymously, according to the recommendations of the French Data Protection Authority, which ensures the ethical use of medical and scientific data collected for research purposes.

Participants

Patients were included if they met the following criteria : (i) age between 18 and 65 years old; (ii) suffering from a sleep disorder for which an MWT was required; (iii) having a driving license for two or more years; (iv) driving 5,000 km (3107 miles) or more per year (in order to have a sufficient observational period to evaluate the accident risk) ; (v) having had no introduction/switch of treatment or just having a minimal change (not impacting the mean level of alertness over the day) of treatment in the past year (titration dose over a month for new patients); (vi) undergoing an MWT for a clinical purpose; and (vii) willing to take part in the study and to complete the questionnaires. All patients included were currently driving, which ruled out those having lost their driving license in the past year for offences or accidents.

Measures

Patients completed a questionnaire exploring whether they had had near misses or actual accidents related to sleepiness and their number in the past year, as well as the Epworth Sleepiness Scale (ESS) on the day of the MWT. Their demographic characteristics, working times, driving habits, frequency of sleepiness at the wheel episodes and types of sleep disorders diagnosed in the sleep clinics were collected. Patients were further categorized as cases when near misses or accidents related to sleepiness occurred in the past year and as controls in the absence of near misses or sleepiness-related accidents in the past year.

The four 40-minute tests of the MWT were completed at 10:00, 12:00, 14:00, and 16:00 and administered by an experienced sleep technologist. Patients were instructed to remain awake as much as possible during the naps. Data were scored manually by experienced scorers. Sleep onset was defined as the first 30 s epoch containing 15 or more seconds of cumulative sleep (including N1, N2, N3 and R sleep). The test was ended after three continuous epochs of stage N1 or 1 epoch of any other sleep stage. The latency of each test was the sleep onset latency or, in the absence of sleep, it was determined as 40 min. The mean latency of the four tests was computed by averaging the latencies of each test (MWT latency).

Statistical analysis

Primary analysis was performed to compare socio-demographic, clinical and driving characteristics between cases and controls and to identify measures associated with cases. Descriptive statistics included frequencies and percentages for categorical measures and means and standard deviations for continuous measures. Univariate analysis was performed using a Chi2 test to compare categorical measures between groups and a t-test for continuous measures, the significance level being set below 5%.

Secondary analysis was performed by comparing frequencies (Khi 2) of "cases" in three *a priori* determined sleepiness groups (Group #1: mean MWT latency <19 min, Group #2: MWT ≥ 19 and < 33 min, and Group #3 MWT ≥ 33 min, considered as the reference, non-sleepy group) based on previous publications which demonstrated these significant cutoffs regarding simulated and real driving performances in untreated and treated patients [18,20-23]. Multivariate analysis was performed using logistic regression modeling for all variables known to be associated with accident risk (age, sex), for prediction of being a case. Odds ratios and their 95% confidence intervals (CIs) are presented to show the association, using Group #3 (MWT latency>33 min) as the reference. The analyses were performed using SPSS software (Version 21 for Mac, PASW Statistics).

Results

Demographical and clinical and characteristics

The flow chart in Figure 1 shows that 377 subjects were screened from September 2016 until June 2019, among which 176 were included (74 cases and 102 controls). Their socio-demographical and clinical characteristics are shown in Table 1. Patients were predominantly male and overweight. They suffered mainly from OSAS, idiopathic hypersomnia, narcolepsy, restless legs syndrome, and insufficient sleep syndrome (in decreasing order of frequency) and were either treated or untreated. In the case group, patients were younger than controls and a higher percentage of them suffered from insufficient sleep syndrome. The other characteristics (marital status, employment, shift/night/daytime working schedule, body mass index, alcohol addiction, use of hypnotics or anxiolytic drugs) did not differ between groups.

Drivers and sleepiness characteristics

There were as many professional drivers (treated or not in same frequency) in the case group (55.8%, N =40) as in the control group (45.1%, N = 46), p = 0.374), and no difference in the number of kilometers driven per year (cases: 33,633 ± 26,664 km vs. controls: 25,716 ± 18, 684, p = 0.124). Cases reported related to sleepiness a median of near misses of 3 [1-5]. Only 7 cases had had an accident related to sleepiness. Cases were sleepier (according to their score on the ESS and their latency on the MWT) than controls. Figure 2 shows the distribution in three groups (< 11, 11-15, >15 on the ESS) of the frequency of cases and controls.

As many as 37.8% (n=28/74) of cases vs. only 8.8% (n=9/102) of controls reported having experienced sleepiness at the wheel more than once a week ($p < 0.0001$). There was a significant linear relationship between frequency of occurrence of sleepiness at the wheel and the risk of being a case or control (See Figure 3). Lower MWT latency correlated with an increased number of near misses or accidents related to sleepiness and linearly higher MWT latencies correlated with no near misses or accidents related to sleepiness (See Figure 4).

In the multivariate regression analysis of factors explaining accidents or near misses related to sleepiness, patients with MWT latency <33 minutes were at higher risk of being cases. Compared to the reference group (MWT latency >33 min), and after adjustment on age and sex, patients with MWT latency between 19 and 33 minutes had a 3.2- (CI 95%:1.5 – 6.8; p<0.0001) fold increased risk of being a case, and those with MWT <19 minutes had a 5.5- (CI 95%: 2.2 – 13.8, p=0.003) fold increased risk (See Table 2).

Discussion

To our knowledge, this study is the first to analyze the relationship between mean sleep latency on the MWT (MWT latency) with the reported level of sleepiness at the wheel, number of near misses and the occurrence of sleep-related accidents in the past year in patients suffering from sleep disorders. We carefully designed the study to match with clinical practice and included patients treated or not treated in order to cover the entire population requiring MWT. These selection criteria explain the relatively high prevalence of non-sleepy patients in our sample and correspond to the classical patterns of French patients evaluated by the MWT in a sleep clinic. We also included patients with different types of sleep disorders (OSAS, central hypersomnia, restless legs syndrome, insufficient sleep syndrome) treated and untreated to test the face validity of the MWT in a representative sample of patients.

Like other authors [25,26], we found a high frequency (42%) of sleep-related near-misses in the past year. Sleep-related accidents were less frequent in our sample but, as Powell [25] demonstrated, near misses reliably predict the risk of future accidents and therefore can be used to estimate driving impairment in a clinical population. The results show that MWT latency is associated with accident risk, defined here as self-reported sleep-related near misses and sleep-related accidents in the past year. Indeed, we found a linear increase in the accident risk, which increased up to 5-fold in patients unable to maintain wakefulness longer than 19 min on average on the MWT, compared to those able to maintain it longer than 33 minutes. Some MWT sleepy subjects did not report near-miss accidents, which could be due to under-reporting of actual near misses. Fear of losing their license or being instructed to refrain from driving could explain this under-reporting. Nevertheless, we did not find an overrepresentation of controls in the professional drivers. If a prevarication bias was suspected, one would expect a much higher number of controls in the professional group. This is not the case in our results, which suggests that the underreporting of near misses/accidents was low in professional drivers. Another possible explanation for this finding is that the motivation factor during the MWT is lower than during actual driving, where subjects may have traffic accidents. Finally, some subjects could be so sleepy that they were simply unaware of, or did not remember, near-miss events. Nevertheless, just like for other risk factors such as alcohol, there is a strong linear relationship between increasing objective sleepiness and accident risk. In addition to the ability to remain awake, another important dimension of sleep-related risk at the wheel is risky driving behaviors. For example, some patients in the study by Pizza [27] continued to drive while very sleepy whereas others stopped early to prevent driving errors during the driving simulator test. Some of our patients possibly stopped driving when sleepy, which could explain the low rate of near-miss accidents, regardless of their objective level of sleepiness.

Clinical cut point as defined on MWT sleep latencies (ie, <19 minutes) should be interpret as predictors of driving impairment already identified in real driving studies. They should be associated to patients' self-perception of EDS as quantified in sleepiness at the wheel questionnaires to interpret properly fitness to drive. On the other hand, the MWT tests the ability to remain awake and is therefore more reliable in a condition where subjects are supposed not to fall asleep. In our previous studies [18,20-22] in simulated and real-world driving conditions, there was a linear relationship between sleep latency on the MWT and driving impairment, as defined by weaving or inappropriate line crossings. Moreover, we classified MWT scores according to normative values and showed, like Drake [28] with the MSLT, that mean abnormal sleep latencies (<19 min) were strongly associated with driving impairment.

Interestingly, the measure used in our driving studies is an extraction of the near misses considered as strong predictors of accident risk [25]. This new series in a naturalistic prospective setting confirms the relationship between self-reported near misses during day-to-day driving over a one-year period and MWT measures. We also investigated the relationship between self-reported episodes of sleepiness at the wheel (a strong predictor of accidents [6]) and MWT latency and found that an in lab measure can predict the real-world experience of sleepiness at the wheel. Indeed, while there are several subjective measures such as ESS scores and self-reported sleepiness at the wheel, their validity is a recurrent question, especially when legal issues are involved (ie, professional drivers). We previously found that self-reported sleepiness at the wheel [6] had a very linear relationship with the occurrence of near misses and accidents, unlike the ESS which discriminates well very alert or very sleepy patients but is less efficient for patients reporting intermediate sleepiness (scores between 11 and 15). Indeed, several studies have questioned the validity of ESS scores to predict fitness to drive [11,29]. The more objective and linear the measure is, the better is its ability to predict risk. If drivers report sleepiness at the wheel, they should be informed immediately about the severe potential accident risk. If drivers report near misses with or without sleepiness at the wheel, MWT scores can be very informative.

Our results show the clinical coherence of combining subjective and objective measures to predict driving impairment defined by the occurrence of near misses and traffic accidents while sleepy. We show for the first time that clinicians can combine both measures to reinforce their evaluation of accident risk in sleep-disordered patients. This is a valuable finding in a medical context requiring MWT usage, as specified in French law (ie, professional drivers). The current study, along with previous work [18,20-23] suggests that the combination of near misses/traffic accidents with MWT latencies of 19 minutes or less defines a high-risk clinical condition for professional drivers. Our study confirms that MWT latencies above 33 minutes are associated with a low (27%) rate of near misses and accidents, which makes this threshold suitable for a limited risk zone. The driving risk of patients with an MWT score between 33 and 19 min should be more specifically evaluated by self-report of near misses and/or previous sleep-related accidents.

Our study has several limitations. First, we based our results on self-reported near misses and accidents and not on police records. Because of ethical issues, we did not have nominative access to accident reports, so we used a self-reported measure. Second, our sample allowed us to compare cases with controls, but not to analyze the effect of the various medical disorders and treatments, mainly owing to a lack of statistical power. In the future, we need to keep collecting results to better phenotype driving risk according to different types of sleep disorders and treatments. Indeed, MWT latencies may be shorter in patients with treated central hypersomnia than in those with treated OSAS, even though abnormal sleepiness defined by MWT latency below 19 minutes might be a strong marker of accident risk, whatever the sleep disorder. We also excluded patients driving fewer than 5,000 km/year, which may concern many severely impaired patients (ie, narcoleptics or patients remaining sleepy after CPAP treatment). Here again, we wanted our results to be representative of a population which is exposed to driving risk, including for professional reasons. Investigating a group who had lost the ability to drive normal distances/year would have made our results difficult to apply to the general population. We now need to validate the MWT in specific and rare populations. We did not include normal subjects mainly because the MWT concerns patients suffering from sleep disorders and is not used routinely to evaluate the fitness-to-drive of healthy non-sleepy subjects. Finally, the period of the retrospective evaluation over a one year for accident risk is longer than that of subjective sleepiness as measured by the ESS. This could introduce some distortion in the interpretation of the results.

Because we used inappropriate line crossings, the figures may seem high even for patients who can sustain a high level of alertness. However, we requested the frequency of near misses on a weekly basis, which explains the high figures. Higgins and al. [30], showed that up to 11% of all drivers report sleepiness at the wheel over a year, which probably explains why these sleep-related near misses are quite high in the general population. As our results on subjective measures showed MWT latencies between 19 and 33 minutes, we recommend including objective measures with a clinical interview that probes episodes of sleepiness at the wheel and near misses. Behavioral measures (limited duration of driving, naps before driving and daytime driving) might be reasonable advice in moderately sleepy patients to limit the risk of sleep-related accidents.

Further studies need to be conducted to reinforce the validation of objective measures of driving risk and their relationship with the subjective perception of sleepiness at the wheel or sleepiness scales. Technological devices such as in-car monitoring might provide interesting data on inappropriate line crossings and sleepy driving to complement our present understanding of this issue.

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References

1. Ohayon MM, Caulet M, Philip P, Guilleminault C, Priest RG. How sleep and mental disorders are related to complaints of daytime sleepiness. Archives of Internal Medicine. 1997;157:2645-52.
2. Connor J, Whitlock G, Norton R, Jackson R. The role of driver sleepiness in car crashes: a systematic review of epidemiological studies. Accid Anal Prev. 2001;33:31-41.
3. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med. 1993 Apr 29;328(17):1230-5.
4. Philip P, Sagaspe P, Lagarde E, et al. Sleep disorders and accidental risk in a large group of regular registered highway drivers. Sleep Med. 2010 Dec;11(10):973-9.
5. Hakkanen H, Summala H. Sleepiness at work among commercial truck drivers. Sleep. 2000;23:49-57.
6. Bioulac S, Micoulaud-Franchi JA, Arnaud M, et al. Risk of Motor Vehicle Accidents Related to Sleepiness at the Wheel: A Systematic Review and Meta-Analysis. Sleep. 2017 Oct 1;40(10).
7. Teran-Santos J, Jimenez-Gomez A, Cordero-Guevara J. The association between sleep apnea and the risk of traffic accidents. Cooperative Group Burgos-Santander. N Engl J Med. 1999 Mar 18;340(11):847-51.
8. Masa JF, Rubio M, Findley LJ. Habitually sleepy drivers have a high frequency of automobile crashes associated with respiratory disorders during sleep. Am J Respir Crit Care Med. 2000 Oct;162(4 Pt 1):1407-12.
9. Lloberes P, Levy G, Descals C, et al. Self-reported sleepiness while driving as a risk factor for traffic accidents in patients with obstructive sleep apnoea syndrome and in non-apnoeic snorers. Respir Med. 2000 Oct;94(10):971-6.
10. George CF. Sleep apnea, alertness, and motor vehicle crashes. Am J Respir Crit Care Med. 2007 Nov 15;176(10):954-6.
11. Pack AI, Maislin G, Staley B, et al. Impaired performance in commercial drivers: role of sleep apnea and short sleep duration. Am J Respir Crit Care Med. 2006 Aug 15;174(4):446-54.
12. Pizza F, Contardi S, Mondini S, Trentin L, Cirignotta F. Daytime sleepiness and driving performance in patients with obstructive sleep apnea: comparison of the MSLT, the MWT, and a simulated driving task. Sleep. 2009 Mar;32(3):382-91.
13. Pizza F, Jaussent I, Lopez R, et al. Car Crashes and Central Disorders of Hypersomnolence: A French Study. PLoS One. 2015;10(6):e0129386.
14. Littner MR, Kushida C, Wise M, et al. Practice parameters for clinical use of the multiple sleep latency test and the maintenance of wakefulness test. Sleep. 2005 Jan 1;28(1):113-21.
15. Wise MS. Objective measures of sleepiness and wakefulness: application to the real world? J Clin Neurophysiol. 2006 Feb;23(1):39-49.
16. Bennett LS, Stradling JR, Davies RJ. A behavioural test to assess daytime sleepiness in obstructive sleep apnoea. J Sleep Res. 1997 Jun;6(2):142-5.
17. Poceta JS, Timms RM, Jeong DU, Ho SL, Erman MK, Mitler MM. Maintenance of wakefulness test in obstructive sleep apnea syndrome. Chest. 1992 Apr;101(4):893-7.
18. Sagaspe P, Micoulaud-Franchi JA, Coste O, et al. Maintenance of Wakefulness Test, real and simulated driving in patients with narcolepsy/hypersomnia. Sleep Med. 2019 Mar;55:1-5.
19. Bioulac S, Chaufton C, Taillard J, et al. Excessive daytime sleepiness in adult patients with ADHD as measured by the Maintenance of Wakefulness Test, an electrophysiologic measure. J Clin Psychiatry. 2015 Jul;76(7):943-8.
20. Philip P, Chaufton C, Taillard J, et al. Maintenance of Wakefulness Test scores and driving performance in sleep disorder patients and controls. Int J Psychophysiol. 2013 Aug;89(2):195-202.

21. Philip P, Sagaspe P, Taillard J, et al. Maintenance of Wakefulness Test, obstructive sleep apnea syndrome, and driving risk. Ann Neurol. 2008 Oct;64(4):410-6.
22. Sagaspe P, Taillard J, Chaumet G, et al. Maintenance of wakefulness test as a predictor of driving performance in patients with untreated obstructive sleep apnea. Sleep. 2007 Mar 1;30(3):327-30.
23. Philip P, Chaufton C, Taillard J, et al. Modafinil improves real driving performance in patients with hypersomnia: a randomized double-blind placebo-controlled crossover clinical trial. Sleep. 2014 Mar 1;37(3):483-7.
24. Bonnet MH. ACNS clinical controversy: MSLT and MWT have limited clinical utility. J Clin Neurophysiol. 2006 Feb;23(1):50-8.
25. Powell NB, Schechtman KB, Riley RW, Guilleminault C, Chiang RP, Weaver EM. Sleepy driver near-misses may predict accident risks. Sleep. 2007 Mar;30(3):331-42.
26. Sagaspe P, Taillard J, Bayon V, et al. Sleepiness, near-misses and driving accidents among a representative population of French drivers. J Sleep Res. 2010 Dec;19(4):578-84.
27. Pizza F, Contardi S, Mondini S, Cirignotta F. Simulated driving performance coupled with driver behaviour can predict the risk of sleepiness-related car accidents. Thorax. 2011 Aug;66(8):725-6.
28. Drake C, Roehrs T, Breslau N, et al. The 10-year risk of verified motor vehicle crashes in relation to physiologic sleepiness. Sleep. 2010 Jun;33(6):745-52.
29. Connor J, Norton R, Ameratunga S, et al. Driver sleepiness and risk of serious injury to car occupants: population based case control study. BMJ. 2002 May 11;324(7346):1125.
30. Higgins JS, Michael J, Austin R, et al. Asleep at the Wheel-The Road to Addressing Drowsy Driving. Sleep. 2017 Feb 1;40(2).

Table 1. Demographical and clinical characteristics in patients having had (cases) or not (controls) a near miss or actual driving accident in past year

	Cases	Controls	P value
N	74	102	
Socio-demographical characteristics			
Age (years)	41.1 ± 10.7	46.0 ± 11.8	*0.006*
Women, N (%)	26 (35.6)	26 (26.8)	*0.242*
Marital status (%)			*0.242*
Married	33 (46.6)	57 (55.9)	
Single	15 (20.5)	23 (22.5)	
Divorced	10 (13.0)	11 (10.8)	
Workers, N (%)	53 (71.6)	73 (71.6)	*0.994*
Work shift, N (%)			*0.527*
Diurnal work	38 (51.4)	56 (54.9)	
Nocturnal work	1 (1.4)	5 (4.9)	
Shift work	14 (18.9)	12 (11.7)	
Clinical characteristics			
Body mass index (kg/m^2)	28.0 ± 6.8	29.2 ± 6.6	*0.948*
Epworth sleepiness score	14.3 (+/- 4.8)	9.3 (+/- 5.5)	*0.000*
Alcohol addiction, N (%)	2 (2.7)	2 (2)	*0.083*
Use of anxiolytic/hypnotics N (%)	4 (5.4)	4 (3.9)	*0.627*
OSAS, treated and untreated, N (%)	37 (48.1%)	58 (58.9%)	*0.290*
OSAS treated with CPAP or DO, N (%)	24 (64.8%)	41 (70.6%)	*0.647*
Narcolepsy, N (%)	5 (6.5%)	8 (7.8%)	*0.780*
Idiopathic hypersomnia, treated and untreated, N (%)	17 (22.1%)	23 (22.5%)	*1.000*
Idiopathic hypersomnia, treated drug, N (%)	14 (82%)	17 (74%)	*0.707*
Insufficient sleep	7 (9.1%)	2 (2%)	*0.040*

Restless legs syndrome	6 (7.8%)	6 (5.9%)	*0.765*
Objective measure of excessive sleepiness			
Mean MWT latency	27.0 (+/-11.1)	33.9 (+/- 8.6)	*0.000*

DO: dental orthosis; CPAP: continuous positive airway pressure; OSAS: obstructive sleep apnea syndrome.

Table 2. Regression analysis of measure associated with accident risk

	Total (n)	Case: Yes (n)	%	OR (CI 95%)	P value
MWT latency					
> 33 min	95	26	27	reference	-
19-33 min	49	26	53	**3.2 (1.5 – 6,8)**	0.000
< 19 min	32	22	69	**5.5 (2.2 – 13.8)**	0.003
Age				0.96 (0.93 – 0.99)	0.026
Sex					ns

Figure 1. Flow chart

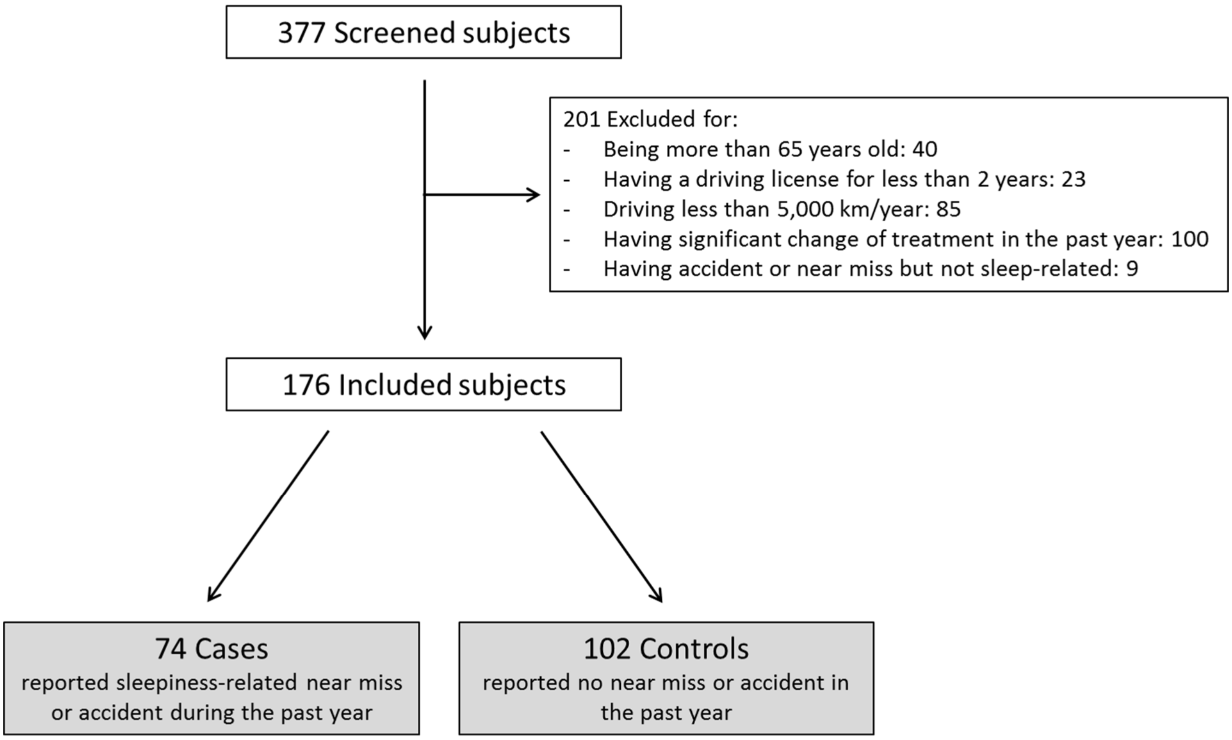

Figure 2. Percentage of Cases/Controls for the three ESS categories

Cases/controls percentage in each ESS group.
Khi2(2) Z=29,9; (P=0.000).
Cases = near misses or traffic accidents related to ESS scores.
Controls = absence of near misses or traffic accidents in past year.

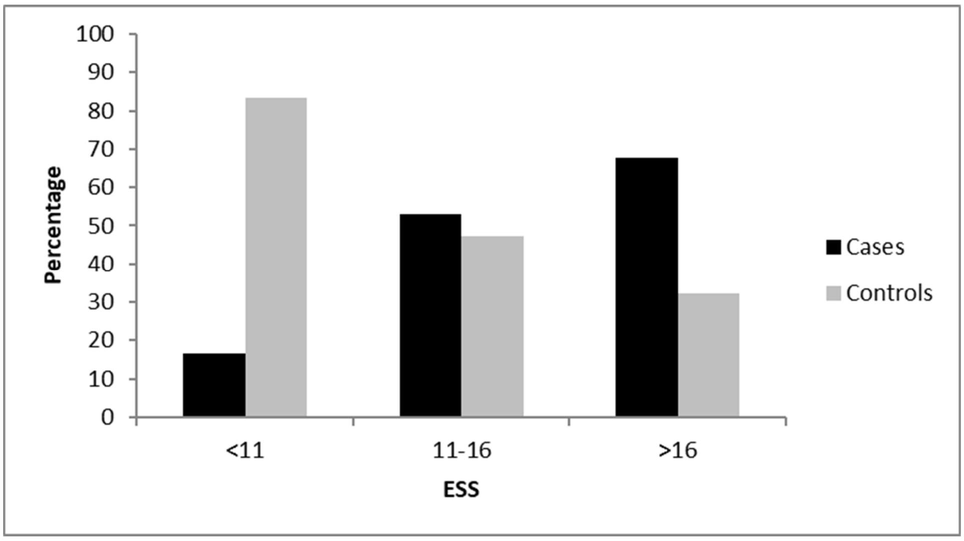

Figure 3. Percentage of Cases/Controls for the four categories of severity of sleepiness at the wheel

Cases/controls percentage according to severity of sleepiness at the wheel.
Khi2(3) Z=51,9; P=0.000.
Cases = near misses or traffic accidents related to sleepiness in past year.
Controls = absence of near misses or traffic accidents in past year.

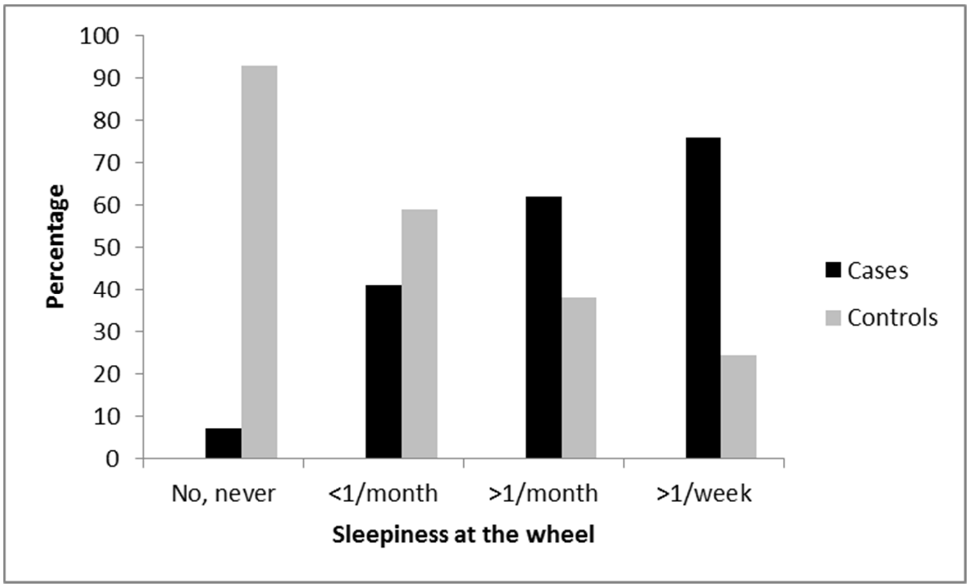

Figure 4. Percentage of Cases/Controls for the three MWT Latency categories

Cases/controls percentage in each MWT-defined sleepiness group.
Khi2(2) Z=20,2; P=0.000.
Cases = near misses or traffic accidents related to sleepiness in past year.
Controls = absence of near misses or traffic accidents in past year.