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Sleepiness and the risk of road traffic accidents: A systematic review and meta-analysis of previous studies

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ABSTRACT

Objective: To assess whether drowsy driving can increase road traffic accident related deaths and injuries.
Design: Systematic review and meta-analysis.
Data sources: Cochrane Injuries Group Specialized Register, Cochrane Central Register of Controlled Trials, EMBASE, Medline, National Technical Information service, Psychlit, International Road Research Documentation, Transport Research Information Service, and web sites related to the road safety organization were searched; experts were contacted, conference proceedings were hand searched, and relevant reference lists were checked.
Inclusion criteria: We sought to identify all epidemiological studies, published in English language, which assessed the association between fatigued or sleepy driving and the occurrence of car crashes lead to death or injury.
Methods: We conducted a systematic literature review with meta-analysis using PubMed, Google scholar and other valid databases to search for articles published from January 1980 through September 2016 to identify precise effect of drowsy driving on road traffic accidents. For each study odds ratio was calculated, the ratio of event odds in the drivers with drowsy driving divided by the drivers without drowsy driving, which were pooled to obtain an overall estimate using a fixed and random effects models.
Findings: Fourteen articles satisfying inclusion criteria were identified that all of them were included in quantitative synthesis. Pooled odds ratio obtained by fixed and random effect models was 1.29 (95% CI 1.24 to 1.34) and 1.34 (95% CI 1.25 to 1.43), respectively.
Conclusion: Our findings that obtained from meta-analysis (with high level of evidence) suggest a significant association between crash involvement and drowsy driving. It seems that establishment of strategies to reduce any risk factors of road traffic accident such as drowsy driving can be effective in decreasing traffic crashes.

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1. Introduction

Across the globe, road traffic crashes (RTC) are responsible for about 1,200,000 deaths and 50 million annual injuries (Peden & Sminkey, 2004). Based on a study on the global burden of diseases, it is estimated that road accidents ranked eighth in the world in 2010 in terms of years of lives lost due to premature death or disability (Murray et al., 2012).

Drowsy driving, is the dangerous combination of sleepiness and driving or driving while fatigued, and can result from several underlying causes, including excessive sleepiness, changes in circadian rhythm due to shift work, sleep deprivation, fatigue, medications with sedatives and consumption of alcohol when tired. The cumulative effects of these factors have severe effects on performance, alertness, memory, concentration and reaction times (Dernocoeur, 2000; Mahowald & Bornemann, 2006). Sleepy drivers are at increased risk for developing accident and subsequent injuries or death, thus making them an important target group for sleepiness-related interventions.

Sleepiness in drivers is increasingly recognized as an important factor contributing to the burden of traffic related morbidity and mortality (Connor et al., 2002; Gander, Marshall, Harris, & Reid, 2005; Horne & Reyner, 1999). Sleepiness is the second most important factor, after alcohol, in the incidence of single- and multiple-vehicle accidents and yields a significant human and financial cost (Verwey & Zaidel, 1999). Federal data suggests that approximately 15–33% of fatal crashes in the United States of America may be due to drowsy driving (Maia, Grandner, Findley, & Gurubhagavatula, 2013). The cost of drowsy driving has been estimated as $12.4 billion per year by the United States National Highway Traffic Safety Administration. However, as the real extent of the sleep problem is generally agreed to be underestimated, sleepiness actually causes greater loss than what is generally estimated (Zhang & Chan, 2014).

Reports based on comprehensive accident analysis estimate that fatigue is involved in between 10 and 20 per cent of serious road accidents (Phillips & Sagberg, 2013). The proportion of traffic crashes attributable to sleepiness or drowsiness varies across road types and countries, from 3.9% to 33% in the United States, France and Australia (Quera Salva et al., 2014).

Substantial United Kingdom survey, covering 4600 respondents, found that 29% admitted to having felt close to falling asleep at the wheel in the previous year, and 17.9% had accidents during the previous 3 years. Of these, and for those accidents on motorways, about15% were Sleep related vehicle accidents (Horne & Reyner, 1999). Excessive daytime fatigue and sleepiness can increase the risk of driving accidents (Howard, Gaba, Rosekind, & Zarcone, 2002; Ward et al., 2013). The findings of a 2002 poll in Ontario Canada found more than 58% of the study sample of 750 drivers admitted to occasionally operating a vehicle while fatigued or drowsy. Furthermore, an alarming 14.5% admitted to having fallen asleep while driving the previous year, with 2% having had a falling asleep during incident (Smolensky, Di Milia, Ohayon, & Philip, 2011).

Drivers who reported SSS (Stanford Sleepiness Scale) scores greater than 4 (i.e., indicating an impairment of vigilance) had a risk 8 times greater of being involved in car accidents than those who obtained lower SSS scores (Lucidi, Mallia, Violani, Giustiniani, & Persia, 2013).

Many studies conducted about the role of drowsy driving and risk of traffic injuries throughout the world. In one study conducted by the Sleep Research Center in UK indicates that driver fatigue causes up to 20% of accidents on monotonous roads (Horne & Reyner, 2001), but in another research in UK found slightly lower proportions of sleep related accidents: 9–10% of accidents on all roads, and 15% of accidents on motorways involved driver sleepiness (Maycock, 1995). In another study in New Zealand indicated that population attributable risk for driving with one or more of the acute sleepiness risk factors was 19% (15–25%) (Connor et al., 2002). Also a study of road accidents on two of America's busiest roads indicated that 50% of fatal accidents on those roads were fatigue related (Reissman, 1996). Another study claims that 30–40% of accidents involving heavy trucks are caused by driver sleepiness (Heinzmann, Tate, & Scott, 2008). Additionally, several systematic review and meta-analysis studies were done to assess the relationship between drowsy driving and road traffic accidents during the past years. For example in a study conducted by Conner and his colleagues in 2001, the role of driver sleepiness in car crashes was assessed and evaluated (Connor, Whitlock, Norton, & Jackson, 2001). Also two other systematic reviews were done in USA and Hong Kong entitled "Obstructive Sleep Apnea and Risk of Motor Vehicle Crash" and "Sleepiness and the risk of road accidents for professional drivers", respectively (Tregear, Reston, Schoelles, & Phillips, 2009; Zhang & Chan, 2014).

Due to the impact of sleepiness and fatigue in the incidence of traffic accidents, the quantification of the contribution of fatigue on crashes has important implications for development and prioritization of interventions to prevent deaths and injuries followed by such accidents. Given the current uncertainty about the effect of fatigue on car crash risk, a systematic review and meta-analysis of the international literature has been conducted to generate summaries of the size of the effects.

According to the results of earlier studies, current evidence suggesting that the problem of drowsy or fatigued driving is an important contributor to road traffic accidents, but the magnitude of this effect is unclear and unknown. In other hands we unaware about numeric value of pooled effect size for association between drowsy driving and traffic crashes. As mentioned above, a meta-analysis is presented here of studies of drowsy driving, designed to shed lights on the following questions:

1. Does drowsy driving have an increasing effect on road crashes?
2. What is the precise effect of drowsy driving risk on road crashes?

Throughout this paper the terms ‘sleepiness’ and ‘fatigue’ have been used interchangeably to describe the need to sleep, while recognizing that they may have more precise definitions in other contexts.

2. Method

2.1. Design

Systematic review

2.2. Inclusion criteria

We sought to identify all epidemiological studies which assessed the relation between fatigue in car drivers and the occurrence of car crashes or car crash death or injury. Studies were included in the review if they met four criteria:

1. Article should be published in English language.
2. Cross sectional, retrospective or prospective studies with comparison group.
3. Impact of sleepiness on crash risk should be an output of the article.
4. Sleepiness is represented, examined and measured by one or combinations of the following factors: sleep disorders, acute sleep deprivation, chronic sleep deprivation, sleep fragmentation, excessive daytime sleepiness, insomnia, sleepiness at wheel, sleep quantity and quality, work factors and snoring. These factors are common sleepiness inducements and have received a lot of attention. Other drowsiness related factors were not reviewed.
5. Studies must contain enough information for extraction or estimation of the size of the effect and its 95% confidence interval (CI). The effect size should be in the form of odds ratio relative risk. For studies that claim ‘‘no effect” or ‘‘no significant effect” without offering specific values, they are still included because if not included, the estimated effect size would be greater than it really is. Ways to deal with such data are introduced as part of the meta-analysis.

2.3. Exclusion criteria

The review criteria excluded case reports because they had no comparison group; studies or researches which used more ‘proximal’ outcome measures, such as performance on a simulator; and studies of fatigue in road user groups that potentially have different characteristics from car drivers, such as motorcyclists or truck drivers. Also excluded were studies where the only crash outcome measure was ‘fatigue-related crash’, as this outcome is dependent on a judgment of the driver, witness or the police about the cause of the crash. It seems likely that people with excessive sleepiness from any cause would be likely to attribute their crashes to this problem.

2.4. Search strategy

A computerized search was undertaken of Medline (1980–2016), Science direct (1980–2016), Scopus (1980–2016), EMBASE (1980–2016), Google Scholar (1990–2016), the Cochrane Library and ISI Web of Knowledge. Using keywords: [(drowsy driving OR Drowsiness) AND (Accident OR Crash)], [(sleepiness OR sleeping) AND (Accident OR Crash)], [(fatigue OR tiredness) AND (Accident OR Crash)], [(Driver distraction OR distraction) AND (Accident OR Crash)] Reference lists of identified articles were examined, and proceedings of relevant conferences were hand-searched, for further studies. The websites of institutions involved in research and policy in the areas of road traffic injuries, road safety, injury prevention, drowsy driving and sleep were searched and publication lists obtained where possible. Contact was made with authors and institutions for further information about their research, and to identify other studies. The review was not restricted to peer-reviewed literature or published papers and there were no restrictions regarding date of studies.

2.5. Coding of studies

For each included study, information for the following items was extracted: study ID, country where the study was conducted and the sample size. Study ID was recorded as the name of the authors and publication year; sample size was the number of drivers studied. The names of sleepiness inducements and diagnostic criteria were extracted. Information of severity of sleep problem was not extracted as an independent variable but was reflected in the name of sleep problem. For example, one paper distinguished severe and moderate excessive daytime sleepiness and the two situations were recorded as severe EDS and moderate EDS; papers without such discrimination were uniformly recorded as EDS. Studies generally investigated accident experience within a certain time period (e.g. previous year, last 5 years or driving history) and they may only focus on certain types of accidents (e.g. sleepy accident only or multiple-vehicle accident only). Accident data could be gathered through drivers’ self-reports, from company records or from police databases. For each study, the type of effect size used (odds ratio or relative risk), its value, and the confounders controlled (e.g. age) were extracted.

2.6. Quality assessment of studies

The studies which were identified in the search and fulfilled the inclusion criteria were classified by design, and critically appraised by two reviewers independently with regard to selection biases, information biases, confounding, precision and external validity. Quality of articles which were finally imported into the systematic review and meta-analysis was checked with relevant observational studies checklist (STROBE).

2.7. Meta-analysis

To make comparisons between studies and generate summarized effects, other forms of effect sizes were first translated into odds ratios. Approximately all studies except one of them reported odds ratios directly or contained crosstabs from which ORs could be calculated. After performing the above step, uniform effect sizes as well as the confidence intervals for each study could be generated. Odds ratio has a skewed distribution, making it difficult to estimate confidence intervals. One common method to deal with this problem is to carry out all calculations based on a log scale (Log OR) because the logarithmic format of odds ratio is normally distributed. Therefor logarithmic format of odds ratio for all studies was calculated and then exponential value (OR) calculated from log OR.

In thirteen of the included studies in this systematic review, excessive daytime sleepiness has been used as indicator of exposure (related to fatigued or drowsy driving) which has Impact on the incidence of traffic accidents. In these studies, Epworth Sleepiness Scale (ESS) was an indicator for determination of existence and severity of exposure. In some studies, ESS > 10 have been classified as exposed an in other studies drivers with sever situation (based on ESS score) was classified as exposed. It is noted that we calculated SE of OR using P value, Z value and LnOR for one study that has been not reported the SE in its results.

Heterogeneity between studies that met our inclusion criteria evaluated by I^2 test, and we also used funnel plot and eager test to assess presence or absence of publication bias.

3. Results

There were 14 studies that fulfilled the review inclusion criteria, all reported between 1999 and 2016 (see Fig. 1 and Table 2). Thirteen out of the 14 papers were published in past ten years, and all of them were published in refereed journals (e.g. 'Accident Analysis and Prevention', 'Injury Prevention', 'Sleep and Breathing' or 'BMJ'). All except one of the studies had a case-control, survey or cross-sectional design and outcome measure of them was traffic accident in a specified time period (Amra et al., 2012; Connor et al., 2002; Cummings, Koepsell, Moffat, & Rivara, 2001; Gander et al., 2005; Gnardellis, Tzamalouka, Papadakaki, & Chliaoutakis, 2008; Herman et al., 2014; Howard et al., 2004; Karimi et al., 2013; Leechawengwongs, Leechawengwongs, Sukying, & Udomsubpayakul, 2006; Philip et al., 2010; Phillips & Sagberg, 2013; Quera Salva et al., 2014; Sabbagh-Ehrlich, Friedman, & Richter, 2005; Sagaspe et al., 2010; Teran-Santos, Jimenez-Gomez, & Cordero-Guevara, 1999) (see Table 1). The remaining study had a cohort design and serious road traffic accidents as an outcome (Nabi et al., 2006).

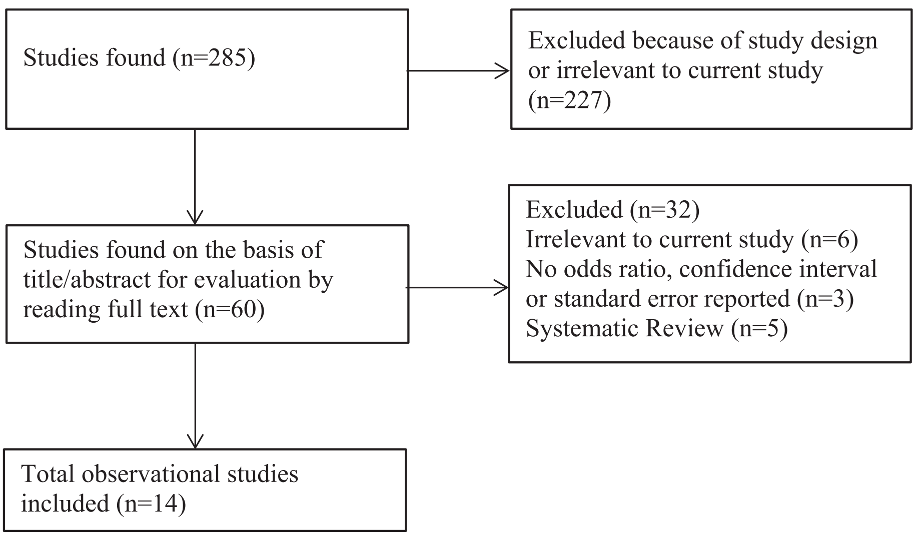

Fig. 1. Flowchart illustrating the literature search and exclusion process.

Table 1
Coding information.

Variable coded	Codes meaning
Detection method	AHI = apnea-hypopnea index; ESS = Epworth Sleepiness Scale; MAP = multivariable apnea prediction; PCFA = Past crash due to falling asleep; EFAW = Ever fell asleep at the wheel; HSAD = History of sleep apnea diagnosis; SMN = Snore most nights; GS = Gasp in sleep; SSS = Stanford sleepiness scale; SPH = Sleep in previous 24 h; MSSQ = Moderate to severe sleep quality; SD = Sleep disorder; FWD = Fatigue while driving; BQ = Berlin Questionnaire; SR = Self-report; SRP = Sleep-related problems; WIS = 7 days/week insufficient sleep; SST = Sleepiness scale for TRIP; ASP = Amount of sleep in the previous 24 h; OSAS = obstructive sleep apnea symptom; VAS = VAS sleepiness score (cm); FAW = Falling asleep at the wheel; TSAS = Triad of sleep apnea symptoms; SC = Sleep complaints; FAWD = Falling asleep while driving
Confounders controlled	A = age, B = sex, C = socioeconomic status, D = ethnicity, E = alcohol consumption, F = use of recreational drugs, G = Road surface, H = Miles driven by driver time, I = vehicle speed, J = average traffic speed, K = body mass index, L = reported high blood pressure, M = Working related variables, N = Marital status, O = Pathologies, P = Stimulant effect of coffee, tea or cola, Q = Education , R = income, S = vehicle type , T = day and time of crash, U = Overnight travel
Sleep problems	AS = acute sleepiness; EDS = excessive daytime sleepiness; I = Insomnia; PSQ = poor sleep quality; SA = sleep apnea; SD = sleep debt; S = Snoring; CS = Chronic sleepiness; SBR = Sleep-disordered breathing risk;
Accident type	1 = any types of accidents; 2 = single accident; 3 = multiple accident; 4 = casualty accident; 5 = injury accident; 6 = fatal accident; 7 = serious accidents; 8 = near-miss sleepy accidents
Effect size	OR = Odds Ratio; RR = Rate Ratio

The sample size of studies included in this review varied from 101 to 35,004 subjects. Also the effect size reported in these studies for association of drowsy driving and road traffic accidents varied from OR = 1.0 to OR = 11.1

Most of the studies have used different methods such as regression models, matching and restricting to control the potential confounders. Potential confounders that were considered for adjustment in the studies entered to our review were including age, gender, alcohol consumption and duration of driving. For extra information see Table 2.

Table 2
characteristics of studies included in this review.

ID	Country	Sample size	Study design	Risk factor	Detection method	Effect size	Accident type	Confounders controlled
Teran-Santos et al. (1999)	Spain	254	Matched Case-control	SA	AHI $\geq$ 5 AHI $\geq$ 10 AHI $\geq$ 15	OR = 11.1 OR = 7.2 OR = 8.1	1	A, B
Cummings et al. (2001)	USA	399	Matched Case-control	SA, S, EDS	PCFA EFAW HSAD SMN GS ESS	OR = 5.9 OR = 1.6 OR = 2.9 OR = 1.7 OR = 1.0 OR = 1.6	1	G, H
Connor et al. (2002)	New Zealand	1159	Case-control	AS, CS, EDS	SSS = 2–3 SSS = 4–7 SP TSAS	OR = 1.7 OR = 11.0 OR = 2.7 OR = 1.4	1	A, B, C, D, E, H, I, J
Sabbagh-Ehrlich et al. (2005)	Israel	160	Cross sectional	PSQ	MSSQ	OR = 2.9	6, 5	H, K, L
Harris et al. (2005)	New Zealand	5368	Cross sectional	EDS, PSQ	ESS MSSQ	OR = 1.13 OR = 1.31	1	A, B, D, E, H
Leechawengwongs et al. (2006)	Thailand	4331	Survey	EDS	ESS	OR = 1.68	1	No
Gnardellis et al. (2008)	Greece	1366	Cross sectional	AS, EDS, CS	FAW FWD	OR = 1.76 OR = 1.49	2	No
Philip et al. (2010)	France	35,004	Survey	EDS, SA, I	ESS = 11–15 ESS > 15	OR = 2.22 OR = 5.00	4, 5	N, O
Sagaspe et al. (2010)	France	4774	Survey	EDS, I	ESS $\geq$ 11	OR = 1.67	1	A, B, O, P
Amra et al. (2012)	Iran	9	Cross sectional	EDS, SA, S	SR WA	OR = 1.50 OR = 2.0	2, 4	A, B, E
Phillips and Sagberg (2013)	Norway	8249	Survey	EDS	SRP	OR = 2.20	5	A, H, Q
Karimi et al. (2013)	Sweden	101	cross-sectional	SA, EDS	ESS > 10	OR = 5.78	1	No
Herman et al. (2014)	New Zealand	883	Case-control	EDS, PSQ, SA	SST = 2–4 ASP < 6 h OSAS	OR = 5.7 OR = 5.9 OR = 2.9	5, 6	A, B, D, E, R, S, T
Quera Salva et al. (2014)	France	3051	cross-sectional	EDS, PSQ, I, S	ESS = 11–15 ESS > 15 VAS	OR = 2.7 OR = 5.7 OR = 1.4	8	A, B, K, T
Ruiz et al. (2015)	Brazil	205	cross-sectional	EDS, PSQ	SC FAWD	OR = 1.54 OR = 3.02	1	U

Forest plot of all studies entered into the meta-analysis based on Fix model to describe association between drowsy driving and road traffic accidents is shown in Fig. 2. Based on the results summarized in this forest plot, the overall estimate of odds ratio measure is 1.29 with confidence interval of 1.24 to 1.34. In the other hand, based on fixed meta-analysis model chance of road traffic accident occurrence in sleepy drivers is 1.29 times higher than those driving without sleepiness. As you see in Fig. 2, among studies assessed by meta-analysis, Howard study and Karimi study had maximum (53.25%) and minimum weight (0.18%), respectively.

We also assessed the heterogeneity of studies by I^2 test. Given that the test result for heterogeneity was significant ($P = 0.007$), we conducted random effect model of meta-analysis. Forest plot of random effect meta-analysis model is detailed in Fig. 3. According to the results of random effect meta-analysis model numeric value of overall OR was 1.34 (95% CI: 1.25 to 1.43). In this model similar to the fixed effect meta-analysis model, studies whit maximum and minimum weight were Hoard (10.73) and Karimi (1.90), respectively. The values of overall OR, 95% CI for OR and P- value to both models (fixed and random) are summarized in Table 3.

We also conducted two subgroup meta-analyses. Separated meta-analysis to extract pooled OR for association between apnea and traffic injuries, indicated apnea was significantly associated with traffic injuries ($OR = 1.53$, $P < 0.001$). Another subgroup analysis was related to the studies that used ESS as sleepiness index, the results showed chance of traffic injury in tired/sleepy drivers with ESS > 11, in 5 studies that used ESS, was 1.27 times more than normal drivers ($P < 0.001$) (Fig. 4).

In this study, we also used funnel plot to check the existence of possible publication bias. Fig. 5 shows the results of potential publication bias assessed by funnel plot. As you see in Fig. 5, asymmetry in Funnel plot shows some sort of publication bias has occurred. The correspondent test of funnel plot, eager test, also emphasize on occurrence of publication bias ($P = 0.02$).

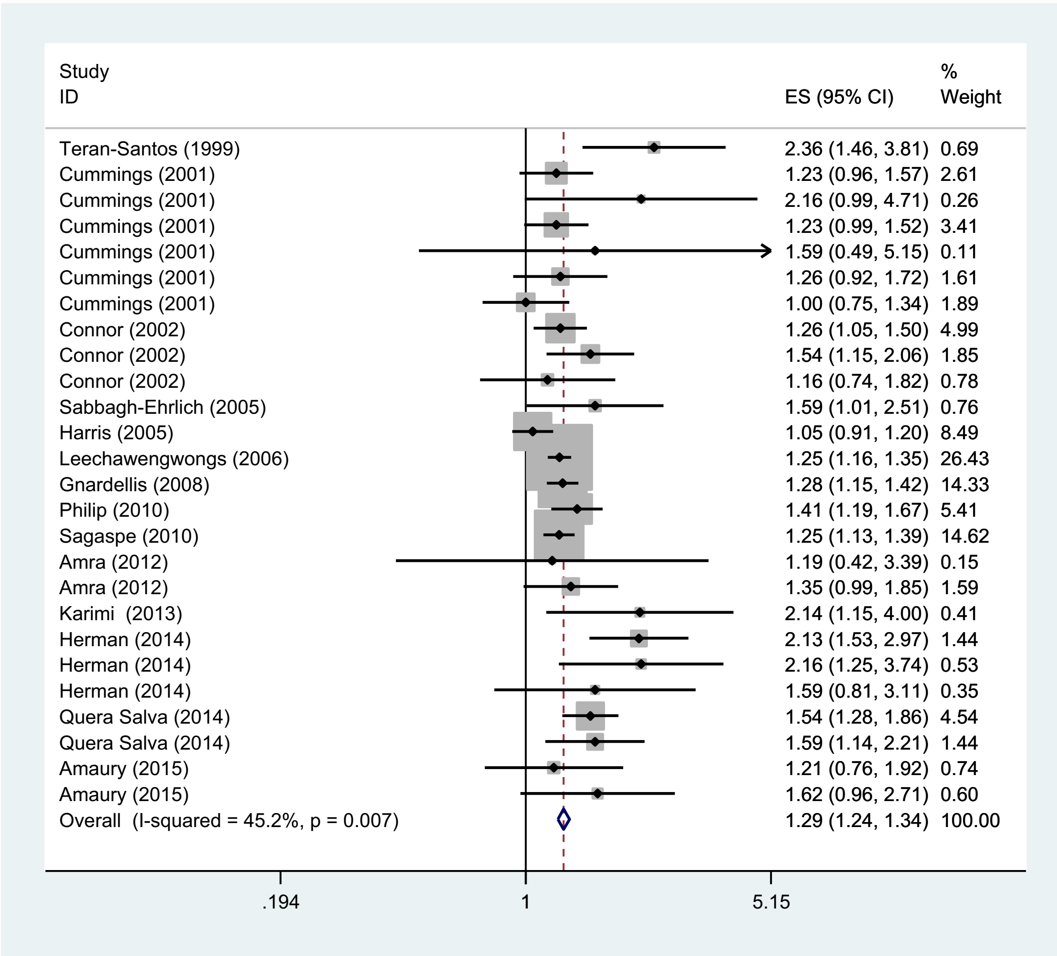

Fig. 2. Forest plot of all studies describing association between drowsy driving and road traffic accidents (fixed effect model). OR indicates odds ratio; CI, confidence interval. Heterogeneity chi-squared = 45.63 (d.f. = 25) p = 0.007. I-squared (variation in ES attributable to heterogeneity) = 45.2%. Test of ES = 1: z = 12.47 p = 0.000.

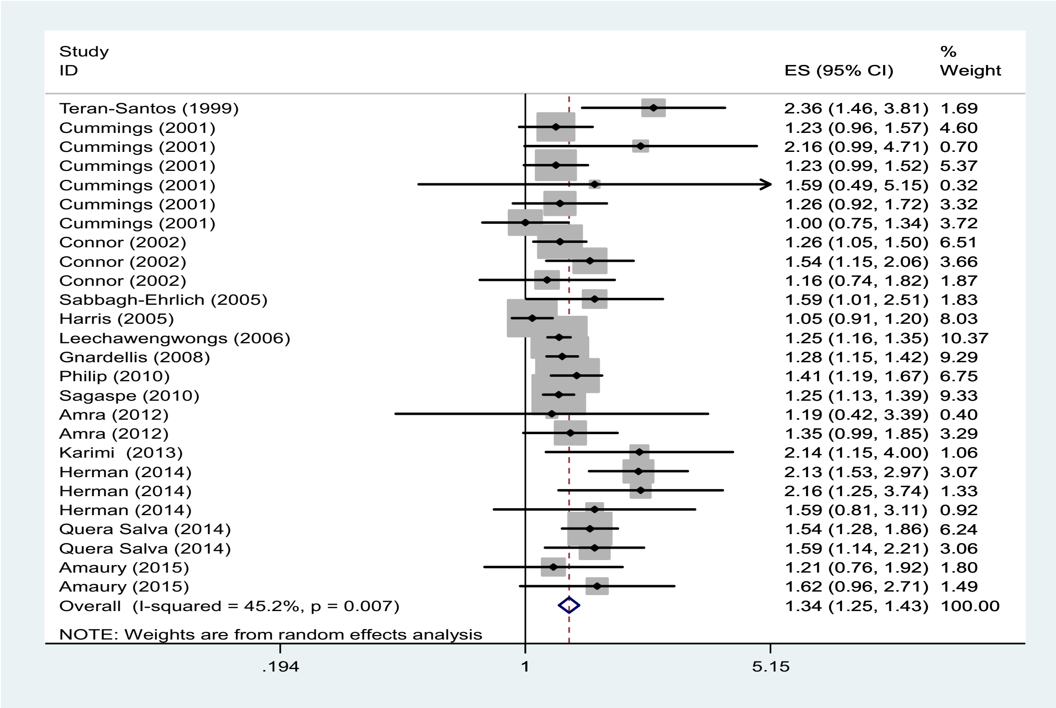

Fig. 3. Forest plot of all studies describing association between drowsy driving and road traffic accidents (random effect model). OR indicates odds ratio; CI, confidence interval. Heterogeneity chi-squared = 45.63 (d.f. = 25) p = 0.007. I-squared (variation in ES attributable to heterogeneity) = 45.2%. Estimate of between-study variance Tau-squared = 0.0098. Test of ES = 1: z = 8.54 p = 0.000.

Table 3
The value of overall OR, 95% CI for OR and P- value in meta-analysis (Fixed and random models) of studies assessed relation between drowsy driving and risk of RTA.

Method (Model)	Pooled estimation (OR)	95% CI		Z- value	P- value	No. of studies
		lower	Upper			
Fixed model	1.29	1.24	1.34	12.47	0.000	14
Random model	1.34	1.25	1.43	8.54	0.000	14

4. Discussion

Results of our review indicated that there was a significant statistical association between drowsy driving and risk of road traffic accident. Meta-analysis of studies included in present study showed that numeric value of OR (as selective measure of association in this review) for this relation based on fixed and random model was 1.29 and 1.34, respectively.

Based on our systematic review and meta-analysis, drowsy driving increase road crashes by 1.29 to 1.34 times higher than driving without sleepiness, but there are difficulties in determining the level of sleep related road traffic accidents because there is no simple, reliable method for an investigating police officer to determine whether fatigue or sleepiness was a factor in an accident, and if it was, what level of fatigue (sleepiness) the driver was suffering. These results in varying estimates of the level of sleep related accidents, and in particular, evidence based on accident reports usually produces lower estimated values than research based on high level and in-depth studies.

According to the results of earlier studies, young drivers (aged 16–29 years), shift workers and people working long hours, commercial drivers (those who drive high number of miles and drive at night, and have also been found to be at a high risk for sleep disorders), people with untreated sleep disorders such as obstructive sleep apnea (Garcia-Borreguero, Larrosa, and Bravo, 2003) and business travelers (frequent travelers who may be suffering from jet lag and crossing time zones, spending long hours behind the wheel or getting too little sleep) are high-risk groups for the occurrence of traffic accidents caused by sleepiness (Ebel, 2013; Herman et al., 2014; Swanson, Drake, & Arnedt, 2012).

Calculation of pooled odds ratio as valid effect size index is main advantage of our review. Based on previous study's findings, there were discrepancies about quantitative role of drowsy driving and road traffic accidents. Based on previous studies although sleepiness is a main contributor of traffic accidents especially among heavy truck drivers but non earlier mentioned

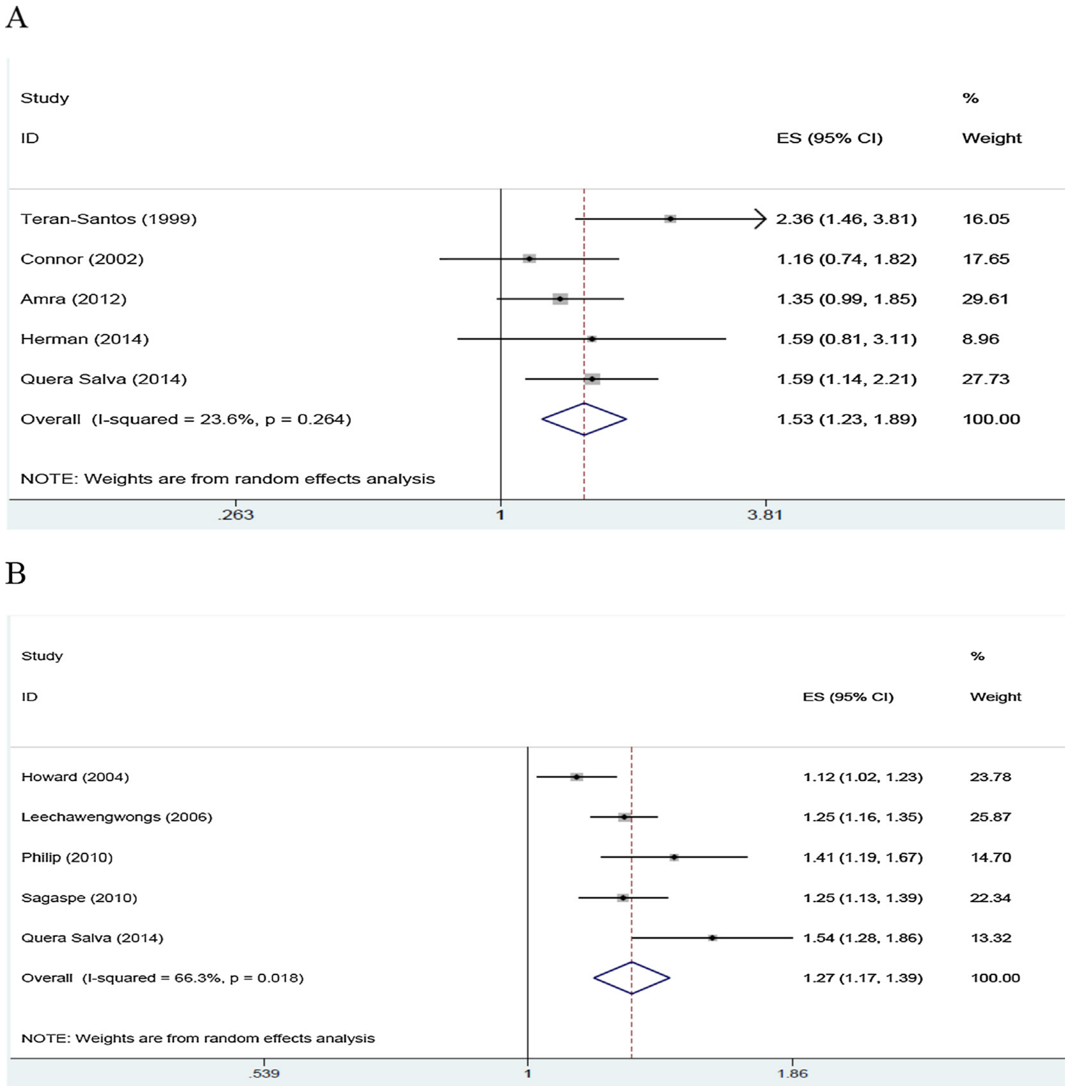

Fig. 4. Forest plot of sub group analyses; A: Association between apnea and traffic injury B: Association between sleepiness and traffic injury in studies that used ESS index. OR indicates odds ratio; CI, confidence interval.

studies reported the effect size for the association between drowsy driving and traffic accidents. In this study for first time, we calculated the pooled odds ratio for association between sleepiness and traffic accidents.

As a result, traffic accidents still can be considered as a major health problem, it seems that establishment of strategies to reduce any risk factors of road traffic accident such as drowsy driving can be effective in decreasing traffic crashes. According to the most expert opinion and some prior studies, the best practice for reduction of drowsy driving crashes is to get adequate sleep on a regular basis, practice good sleep habits, and to seek treatment for sleep problems, should they arise (Hirata, Nishiyama, & Kinoshita, 2009; Jordan, McSharry, & Malhotra, 2014; Schmidt et al., 2009). In addition, other studies addressed that measures such as: getting a good night's sleep before a long drive, getting off the road if driver notice any of the warning signs of fatigue, getting nap (finding a safe place to take a 15 to 20-minute nap) and consuming caffeine (to increase alertness) could be effective (Sassani et al., 2004; Verwey & Zaidel, 1999; Ward et al., 2013; Weinbroum, 2003). In a review study conducted by Hashemi Nazari et al. indicated that some interventions such as talking to passengers, face washing, listening to the radio, no alcohol use, limiting the driving behavior at the time of 12 p.m.–6 a.m., changes in the environment can be used to cope with traffic accidents resulted from drowsy driving (Nazari, Moradi, & Rahmani, 2017).

It should be noted that major limitation of our systematic review was missing of non- English published papers. Also limitations of the included studies were: most of the published studies for assessment of relationship between sleepiness while driving and risk of road crashes were observational, particularly cross-sectional studies, and these types of the studies provide low level of evidence to ascertain relation of exposure and outcome. Reliance on self-report of crash involvement as an

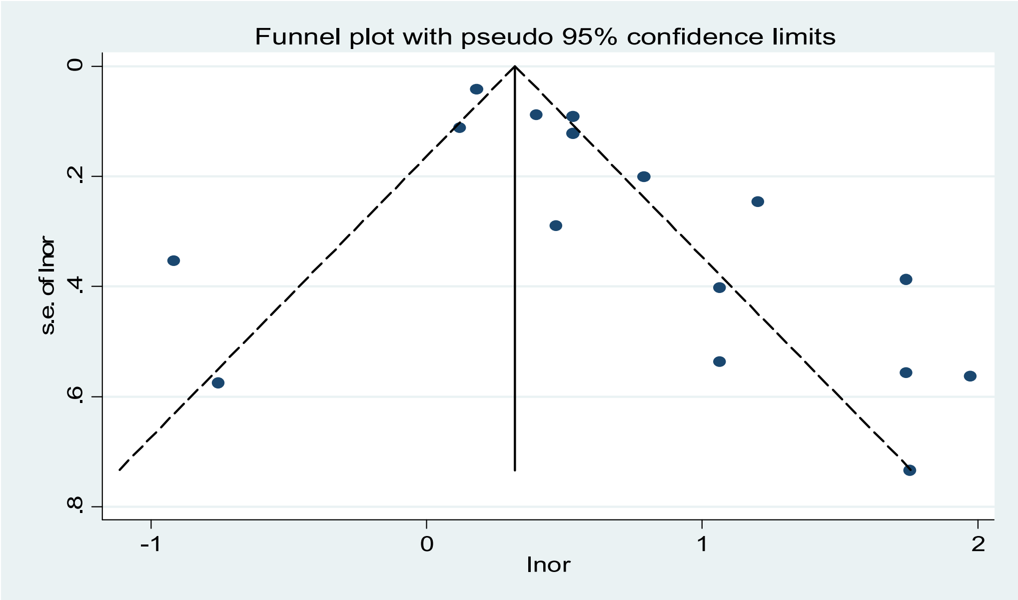

Fig. 5. Funnel plot to assessing possible publication bias in studies published for association between drowsy driving and road traffic accidents.

outcome variable is another limitation in most of the studies included in the review. Besides, all of the studies entered in our review were observational studies, hence the result of this meta-analysis can be used in determining overall associations between drowsy driving factor and a past crash event and it can neither ascertain whether factors associated with having had a crash is predictive, nor can it determine the association between these factors and crash severity. Similarly, we know little about the circumstances preceding and surrounding these incidents.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2018.09.013.

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