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Original Article

A systematic review of the effect of various interventions on reducing fatigue and sleepiness while driving

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ABSTRACT

Purpose: To identify and appraise the published studies assessing interventions accounting for reducing fatigue and sleepiness while driving.

Methods: This systematic review searched the following electronic databases: Medline, Science direct, Scopus, EMBASE, PsycINFO, Transport Database, Cochrane, BIOSIS, ISI Web of Knowledge, specialist road injuries journals and the Australian Transport and Road Index database. Additional searches included websites of relevant organizations, reference lists of included studies, and issues of major injury journals published within the past 15 years. Studies were included if they investigated interventions/exposures accounting for reducing fatigue and sleepiness as the outcome, measured any potential interventions for mitigation of sleepiness and were written in English. Meta-analysis was not attempted because of the heterogeneity of the included studies.

Results: Of 63 studies identified, 18 met the inclusion criteria. Based on results of our review, many interventions in the world have been used to reduce drowsiness while driving such as behavioral (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. etc), educational interventions and also changes in the environment (such as rumble strips, chevrons, variable message signs, etc). Meta-analysis on the effect of all these interventions was impossible due to the high heterogeneity in methodology, effect size and interventions reported in the assessed studies.

Conclusion: Results of present review showed various interventions in different parts of the world have been used to decrease drowsy driving. Although these interventions can be used in countries with high incidence of road traffic accidents, precise effect of each intervention is still unknown. Further studies are required for comparison of the efficiency of each intervention and localization of each intervention according to the traffic patterns of each country.

Introduction

Road traffic accidents (RTAs) are amongst the most common accidents causing death every year.[1,2] Due to their importance, the WHO designated "Safe Roads" as the theme of the World Health Day 2004 and addressed the decrease in RTAs by 2020 as its 21st objective.[3] Based on the study of the global burden of diseases, it is estimated that RTAs have ranked eighth in the world in 2010 in terms of Years of Lives Lost (YLL) due to premature death or disability.[4] Drowsiness and fatigue are introduced as the main risk factors for occurrence of traffic accidents and deaths. Considering the raised mortality statistics due to RTAs worldwide despite the decrease in some countries, the General Assembly of the United Nations (UN) passed a global plan for the decade of action (from 2011 to 2020) for road safety and requested all members to take steps to lower RTAs through implementing preventive measures.[5]

Sleepiness results from the sleep component of the circadian cycle of sleep and wakefulness, restriction of sleep, and/or interruption or fragmentation of sleep.[6] Sleepiness causes auto crashes

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because it impairs performance and can ultimately lead to the inability to resist falling asleep at the wheel.[7] Although sleeping is the most effective way to reduce sleepiness, in some situation continuing to driving is unavoidable and it seems we need some interventions to deal with drowsy driving.

Drivers, particularly professional drivers are at high risk of sleepiness due to a combination of several factors including shift work and obstructive sleep apnea/hypopnea syndrome (OSAHS). Previous studies shown that driver fatigue is a significant cause of traffic accidents and is believed to account for 20%–30% of all vehicle accidents.[8] Many experts agree that this is a conservative estimate and the actual contribution of fatigue to RTAs may be much higher. In addition to having potentially catastrophic personal consequences, fatigue-related accidents have a substantial financial burden, particularly in accident that occurs at night and also in situations in which driving hours are very long and varied.[9]

According to the study which conducted by MacLean and his colleagues,[10] 29%–55% of drivers report feeling drowsy while driving, 11%–31% report having fallen asleep at the wheel, and 4%–12% report having had a crash due to sleepiness. Drowsiness is the second most important factor, after alcohol, in the occurrence of single and multiple vehicle accidents and yields a significant human and financial cost. Accidents caused by driver fatigue, or more precisely, driver lapses of attention caused by sleep deprivation, are often particularly severe as the drowsy driver may not take evasive action to avoid the severity of a potential collision.[11]

Several factors can account for fatigue and drowsy driving. Different physiological and psychophysiological processes can be linked to fluctuations of activation, arousal, alertness and vigilance. Based on existing evidences, among factors that influence RTAs the role of human factors is very dominant. Human factors in vehicle collisions include all factors related to drivers and other road users that may contribute to a collision such as: driver behavior, visual and auditory acuity, decision-making ability, and reaction speed. In fact, due to the complex and systemic nature of human function precise extraction or isolating of all factors contributing in a traffic crash is very difficult in a single study. Indeed, in order to reach a better understanding and isolating causal role of fatigue or sleepiness, as human factors contributing in road crashes, we need to conduct experimental studies, but implementation of such studies have ethical issues.[12]

As mentioned earlier, drowsy driving is a serious problem that leads to thousands of automobile crashes each year. Due to the impact of sleepiness and fatigue in the incidence of RTAs, a study on the intervention programs to deal with this issue can be effective in reducing the incidence of these events. To address this need, the authors decided to conduct a systematic review on effectiveness of interventions to reduce drowsy driving with two objectives: (1) identify effective interventions to reduce sleepiness while driving and (2) determine the true effect size of each intervention that has influence on reducing drowsiness while driving.

Materials and methods

We sought to identify all the epidemiological studies which examined the effect of different interventions to reduce accidents related to fatigue and drowsiness. The question addressed in this systematic review was designed based on PICOs rules (In our study PICO were as follows: participants = drivers, intervention or exposure = any intervention or exposure to reduce drowsiness, comparison group = drivers without the defined exposure/intervention in the study, outcome = decrease of road crashes related to drowsy driving). The question selected was: what interventions are being used to reduce fatigue or sleepiness while driving? Studies were included in the review if they evaluated the effect of one or more interventions in drivers to reduce sleepiness while driving.

The review criteria therefore included all observational or interventional studies that investigated the effect of one or more interventions on decreasing sleepiness while driving. We excluded case reports, studies using 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 truck drivers or motorcyclists.

Search strategy and selection criteria

We followed a standard protocol for doing systematic review: a computerized search was undertaken of Medline (1980–2015), Science direct (1980–2015), Scopus (1980–2015), EMBASE (1980–2015), PsycLIT (1990–2015), transport and road websites (to 2015). The Cochrane Library, BIOSIS and ISI Web of Knowledge were also searched in February 2015. Reference lists of identified articles were also 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 safety, injury prevention and sleep were searched and publication lists were obtained where possible. The review was not restricted to published or peer-reviewed literature and there were no restrictions regarding date of studies.

Electronic databases were searched using following keywords: sleepiness and accidents, fatigue and accidents, drowsiness and accidents, driver fatigue, sleepiness, and their synonyms. Other combined key words used to find appropriate papers in two major databases (Medline and EMBASE) were summarized as follows:

A: ("drowsy driving" OR "Sleep Stage" OR "Stage, Sleep" OR "Stages, Sleep") AND ("Road accident" OR "Traffic Accidents" OR "Accident, Traffic" OR "Traffic Accident")
B: ("Drowsiness" OR "Drowsiness") AND ("Road accident" OR "Traffic Accidents" OR "Accident, Traffic" OR "Traffic Accident")
C: ("drowsy driving" OR "Sleep Stage" OR "Stage, Sleep" OR "Stages, Sleep" OR "Drowsiness" OR "Drowsiness") AND ("Road accident" OR "Traffic Accidents" OR "Accident, Traffic" OR "Traffic Accident")
D: "Drowsy Driving" AND "Road accident"
E: ("fatigue alertness" OR "sleepiness alertness") AND "Road accident"
F: ("Fatigue management" OR "sleepiness management") AND "Road accident"
G: ("Sleep" OR "forced desynchrony") AND "Road accident"
H: ("driver behavior" OR "driving simulator" OR "road engineering measures") AND "Road accident"

The search strategy was developed to maximize sensitivity of article identification. Searching process was carried out by two reviewers independently, and disagreements between them were resolved by consensus.

Since there is no single objectively defined measure of fatigue, we accepted a range of commonly used measures of drowsiness and fatigue and their likely determinants, including: sleepiness at the time of fatigue measurement, usual daytime sleepiness, acute deviation of the lines on the road, Stanford Sleepiness Scale, Swedish Occupational Fatigue Inventory (SOFI), status blinking eyes, reaction time during sleep, Electro Dermal Activity, the effective time delay physiological measure of eye closure, Karolinska Sleepiness Scale, CAS Fatigue score, reaction time, right rate and awareness about fatigue and sleepiness. For further information, definition of these measurement scales was summarized in Table 1.[11,13–22]

Table 1
Definition of scales used for measurement of drowsy driving.

Measurement scale	Definition
Epworth Sleepiness Scale (ESS)	"The Epworth Sleepiness Scale (ESS) is a scale intended to measure daytime sleepiness that is measured by use of a very short questionnaire. It was introduced in 1991 by Dr Murray Johns of Epworth Hospital in Melbourne, Australia."[13]
Eye tracking (PERCLOS) or Video Camera Methods for Detecting Eyelid Closure-PERCLOS	"Video camera methods have been developed for monitoring a subject's eyes and eyelids, detecting their eyelid closures, both as longer-than-average blinks and as more prolonged eyelid closures. Sophisticated software has been developed to detect the position of the eyelids and pupil in the video images. These methods have been proposed mainly for monitoring "sleepiness", in the sense of drowsiness, in drivers. The variable that has most commonly been measured is PERCLOS, the percentage of time (over an interval that might be a few minutes) that the subject's eyelids cover the pupil by at least 80% for periods in excess of 500 ms at a time".[14]
Stanford Sleepiness Scale (SSS)	"The Stanford Sleepiness Scale is a totally subjective rating subjects where give evaluating how they feel – from 1 to 7; 1 means totally alert (vigilant) and 7 means really struggling to stay awake and dream-like thoughts are occurring. It was first presented in 1972 by Hoddes and associates and it is one of the oldest subjective sleepiness scales still in use today".[15]
Swedish Occupational Fatigue Inventory (SOFI)	"The questionnaire which was developed for measuring work-related perceived fatigue".[16]
ALISA image-processing software	"ALISA image-processing software is being applied to video images of the driver eyes and face to detect the onset of sleep".[17]
Copilot system	"The Copilot is a video-based system for measuring slow eyelid closure. The Copilot uses a structured illumination approach to identifying a driver's eyes".[18]
Electro Dermal Activity[19]	"EDA (Electro-dermal Activity) signal is an electric response on the skin of the human body. This system, for example, can be used in detecting and preventing drowsiness driving accidents for automobile drivers".[20]
Karolinska Sleepiness Scale	"This scale measures the subjective level of sleepiness at a particular time during the day. On this scale subjects indicate which level best reflects the psycho-physical sate experienced in the last 10 min. The KSS is a measure of situational sleepiness. It is sensitive to fluctuations".[21]
CAS fatigue score	"The Circadian Alertness Simulator[22] is a practical tool for assessing the risk of diminished alertness at work. Applications of CAS include assessment of operational fatigue risk, work schedule optimization, and fatigue-related accident investigation".[11]

For quality assessment of the studies, papers which were identified in the search and fulfilled the inclusion criteria were classified by design, and critically appraised with regard to selection biases, information biases, confounding, precision and external validity. The quality of articles imported into this systematic review was also evaluated using relevant observational and randomized clinical trial study checklists including: STROBE and CONSORT checklists.

Results

In primary search we found 2226 studies accordant with our keywords. After check of the titles, 2163 were unrelated to the aim of this study and excluded. After a critical evaluation of the remaining 63 articles, there were 18 studies that fulfilled the review inclusion criteria (Fig. 1).

All these studies were reported between 1998 and 2013. Most studies had cross-sectional or interventional design except one of them that was a meta-analysis on Obstructive Sleep Apnea Syndrome (OSAS). Methodology, intervention and main results of studies which were eligible for the systematic review are summarized in Table 2.[23–37]

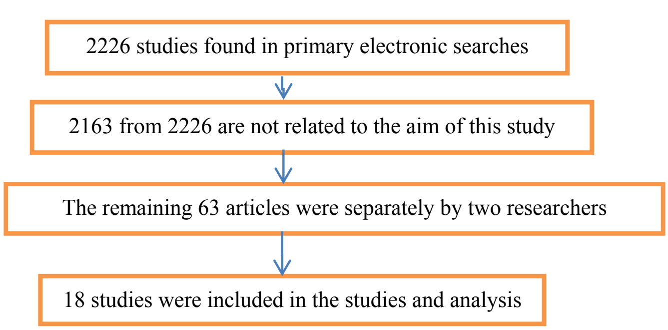

Fig. 1. Diagram of the systematic review and searches for effect of various interventions on reducing fatigue and sleepiness while driving.

In the reviewed studies, the measurement of interventions that affected fatigue or drowsiness reduction was different. These measurement scales were: reduction the amount of drowsiness based on self-reporting ($n = 2$),[1,4] deviation of the lines on the road ($n = 2$),[25,38] OSAS,[5] eye tracking (PERCLOS) and lateral driver performance measures,[6] self-rating and eye-closures,[7] Stanford Sleepiness Scale,[8] Swedish occupational fatigue inventory,[9] ALISA image-processing of video images of the driver eyes and face to detect the onset of sleep by image-processing software,[10] use of co-pilot system to measure eye-closures,[11] electro dermal activity),[11] physiological measure of eye closure, Karolinska Sleepiness Scale,[38] CAS fatigue score,[24] reaction time,[34] slow eye movement (SEM)[23] and awareness about fatigue and sleepiness.[39]

In a study of Gershon et al,[25] fatigue countermeasures that used as interventions in professional and non-professional drivers include: listening to the radio, face washing, opening the window, talking to passengers, planning rest stops ahead, stopping for a short nap and drinking coffee. Based on likert scale, talking to passengers [3.68 (SD = 0.61)], listening to the radio [3.47 (SD = 0.51)] and opening the window [3.22 (SD = 0.75)] were most frequent and effective interventions that stated by non-professional drivers. In view of professional drivers, listening to the radio [3.39 (SD = 0.90)], face washing [3.31 (SD = 0.81)] and opening the window [3.25 (SD = 0.86)] were stated as effective interventions.[25]

In a study conducted by Matthews et al[24] in the year 2012, avoiding circadian driving was introduced as an effective intervention. In another study conducted by Verster and his colleagues,[34] avoidance of using hypnotic drugs, particularly zopiclone and benzodiazepine drugs were introduced to deal with drowsy driving.

In another research conducted by Merat and his colleagues[23] in the UK, the effect of low-cost engineering methods on reduction of fatigue while driving in a simulated driving environment was evaluated. In this study, a simulated environment was used which had three features for engineering changes including rumble strips, V invert lines (chevrons) and variable message signs. Drivers participating in the study must have experience driving in such

Table 2
Studies meeting the inclusion criteria for systematic review (sequence based on the published year and type of study).

First author	Published year	Type of study	Nation	Participants	Drowsiness measurement	Sample size	Intervention/exposure	Main results
Merat[23]	2013	Interventional (experimental)	UK	Driver have night shifts and drivers over 45 years	Eye tracking (PERCLOS) and lateral driver performance measures	33	Three 'low cost' engineering measures to alleviating the symptoms of driver fatigue, as measured by drivers' eye closure and lateral deviation include: data. Rumble strips, V shaped lines (chevrons), variable message signs Installation	Results of the study showed a marked difference in these measures between drivers' baseline (not fatigued) and experimental (fatigued) visits. There were also some reductions in lateral deviation and eye closure (as measured by PERCLOS) when the treatments (interventions) were encountered, but no marked difference between the three treatments.
Matthews[24]	2012	Cross-sectional	Australia	Healthy individuals by average age 21.8 years	Deviation of the lines on the road	14	No alcohol use at bedtime, Limited driving action at 12:00 −6:00.	A mixed model ANOVA revealed significant main effects of circadian phase, prior wake and sleep debt on lane violations.
Gershon[25]	2011	Cross-sectional	Israel	Professional and non-professional drivers	Reduce the amount of drowsiness based on self-reporting	190	–	Listening to the radio, face wash, opening the window, planning rest stops ahead, stopping for a short nap and drinking coffee were more frequently used by drivers to reduce fatigue and drowsy while driving
Shin[26]	2011	Interventional (experimental)	Japan	Drivers with a mean age of 32 years	Slow eye movement (15)	23	Slow eye movement (15) While driving	Accidents in the SEM condition were significantly more numerous than in the non-SEM condition ($p < 0.01$). Furthermore no accident occurred in the SEM condition with a warning generated using the proposed algorithm. The SEM detection can prevent sleep-related accidents effectively in this simulated driving task
Gershon[27]	2009	Interventional (experimental)	Israel	Students 22–30 years, with 5 years driving experience	Swedish occupational fatigue inventory	10	Interactive cognitive task	When activated, the interactive cognitive task (36) increased physiological indicators of arousal, increased subjective feelings of alertness, and improved driving performance. The ICT activation had an immediate but localized influence on arousal. In the ICT condition, the participants' level of motivation increased and their feelings of sleepiness decreased.
Yang[28]	2009	Interventional (experimental)	USA	Healthy drivers	The effective time delay	12	Five different tracking tasks were given to each subject in a random order while driving: 1) a curved road; 2) a straight road with changes in steering dynamics; 3) a straight road with a lead vehicle; 4) a straight road without any disturbance; and 5) a straight road with disturbances (e.g., wind gusts), respectively.	sleep deprivation had greater effect on rule-based than on skill based cognitive functions: when drivers were sleep-deprived, their performance of responding to unexpected disturbances degraded, while they were robust enough to continue the routine driving tasks such as lane tracking, vehicle following, and lane changing. Also the study presented both qualitative and quantitative guidelines for designing drowsy-driver detection systems in a probabilistic framework based on the paradigm of Bayesian networks.

Ting[29]	2008	Interventional (experimental)	China	Driver who have driving experience in a similar environment	Stanford Sleepiness Scale (SSS) and reaction time (RT) tests	30	Removing the road from steady state	The analytical results revealed that SSS scores, reaction times (17) and unstable driving performance significantly increased over time with removing the road from steady state, Moreover, the analytical results indicated that 80 min was the safe limit for monotonous highway driving.
Kingman[30]	2007	Review	USA	Related articles	Awareness about fatigue and sleepiness	Unknown	Education	Panel members of this review suggest the educational campaign in the following three priority areas: 1. Educate young males (16–24 y old) about drowsy driving and how to reduce lifestyle- related risks. 2. Promote shoulder rumble strips as an effective countermeasure for drowsy driving; in this context, raise public and policymaker awareness about drowsy-driving risks and how to reduce them. 3. Educate shift workers about the risks of drowsy driving and how to reduce them.
Ksenia[31]	2006	Interventional (experimental)	USA	Adults with sleep deprivation	PERCLOS, Karolinska Sleepiness Scale, a sustained reaction time task based on the Psychomotor Vigilance	32	Lane departure warning (LDW) (the aim was assessing effectiveness and customer acceptance of LDW)	The Steering Wheel Vibration human machine interfaces, accompanied by Steering Wheel Torque, was found to be the most effective HMI for LDW in a group of drowsy drivers, with faster reaction times and smaller lane excursions. The Vibration HMI was also perceived by the drowsy drivers to be acceptable and helpful.
Rimini-Doering[32]	2005	Interventional (experimental)	Germany	Healthy subjects 22–27 years old	Electro dermal activity	63	Lane Departure Warning System	Because of a high number of micro-sleep episodes, the experiment design seems appropriate to measure effects of drowsiness on lane keeping behavior. The LDWs strongly reduces the number and severity of the lane departure events even in case of a micro-sleep episode. A combined analysis of the LDE with and without LDW shows significant reduction in number, time, departure length and out-of-lane area for the assisted subjects. The timing and design of the warning could furthermore prevent almost 85% of the lane departure events caused by sleepiness.
Moore-Ede[11]	2004	Interventional (experimental)	UK	Truck drivers	CAS fatigue score	868	Use of Circadian Alertness Simulator (CAS) in truck drivers	Implementing a risk-informed, performance based safety program in a 500 power-unit trucking fleet, where dispatchers and managers were held accountable for minimizing driver CAS fatigue risk scores, significantly reduced the frequency and severity of truck accidents. Further examination of CAS risk assessment validity using scenarios provided in a fatigue modeling workshop indicated that the CAS Model also performed well in estimating

(*continued on next page*)

Table 2 (*continued*)

First author	Published year	Type of study	Nation	Participants	Drowsiness measurement	Sample size	Intervention/exposure	Main results
								alertness with a real-world transportation scenario of railroad locomotive engineer work/rest patterns.
Zengyong[33]	2004	Interventional (experimental)	China	Young drivers have a full driving license	Reaction time, right rate	40	Use of magnitopuncture stimulation To reduce sleepiness in drivers	This study show a significant effect of magnitopuncture stimuli on reaction time reaction time and critical flicker fusion frequency (CFF*). Subjective evaluation also exhibited significant differences ($p < 0.05$) between the two groups after the driving task. The findings showed that magnitopuncture stimuli on DU14 point and PC6 points could reduce the effects of driving fatigue.
Verster[34]	2004	Review	Netherland	Studies about effects of remove sleep medication	Deviation of the lines on the road	–	Remove of sleep medications	On-the-road studies revealed that zopiclone and benzodiazepine hypnotics significantly impaired driving ability the morning following bedtime administration. Impairment was sometimes also significant in the afternoon (16–17 h after administration)
Rimini-Doering[17]	2001	Interventional (experimental)	Germany	Students 22–28 years, male	ALISA image-processing software is being applied to video images of the driver eyes and face to detect the onset of sleep	60	Baseline: a simple 4 km segment with no fog, no curves, and no traffic. Stress: a 120 km segment in fog (50 m visibility) interrupted occasionally with gentle curves and slopes with little or no traffic. Control and test: a 10 km segment with sudden, large changes in curvature and slope in a lively street environment, partially with fog.	Performance was measured before, during, and after a 120 km stretch of stimulus-deprived, foggy highway that was intended to induce fatigue and stress. Across all trials 69% of the subjects experienced sleep events lasting several seconds, and 7 potentially fatal crashes occurred. The same driving task during the Control region caused no problems in any trials. Thus, it may be tentatively concluded that the accident resulted from the drowsiness and stress induced during the Stress region. The ALISA normality maps of the IR images of the driver's face appear to provide a reliable indicator for closed-eye states.
George[35]	2001	Interventional (before–after study)		Male drivers with untreated obstructive sleep apnea	Obstructive sleep apnea syndrome (OSAS)	210	Treatment of sleep apnea syndrome (OSAS) in patient drivers with continuous positive airway pressure (CPAP)	Motor vehicle collisions (MVCs) rates were compared for 3 years before and after CPAP therapy for patients and for the corresponding time frames for controls. Untreated patients with OSA had more MVCs than controls (mean (SD) MVCs/driver/year 0.18 (0.29) v 0.06 (0.17), ($p < 0.001$). Following CPAP treatment the number of MVCs/driver/year fell to normal (0.06 (0.17)) while, in controls, the MVC rate was unchanged over time (0.06 (0.17) v 0.07 (0.18), $p =$ NS). Thus, the change in MVCs over time between the groups was very significant (change = −0.12

								(95% *CI*: 0.17−0.06), $p < 0.001$)). The MVC rate in untreated patients ($n = 27$) remained high over time.
Grace[36]	2001	Interventional (experimental)	Germany	Drivers with Commercial Driving License (CDL)	Eye tracking (PERCLOS)	16	Use of copilot as drowsiness detection and warning devices	Effect of this device as drowsiness feedback include: (1) driver alertness −drowsiness; (2) driving performance and (3) driver initiated behaviors. In conclusion the Copilot is a low-cost drowsiness monitor intended for use in commercial operations involving nighttime driving. The unit is designed for robust operation in a heavy truck environment. Work is continuing to validate the Copilot, to refine the driver interface and to determine the best practices for using the monitor.
Verwey[14]	1999	Interventional (experimental)	Netherland	Driver aged between 22 and 55	self-rating and eye-closures	26	Use of electronic devices of drowsiness detection such as game box	When driving with the Game box, drivers reported a lower degree of drowsiness and fewer instances of sleep episodes as compared to a control condition. Driving with the device resulted in fewer incidents and accidents, and these occurred later in the session.
Nguyen[37]	1998	Review and survey	USA	Experts Driving and Traffic Safety	Reduce the amount of drowsiness based on self-reporting	1221	–	Although interventions such as stopping and getting out of the car, napping, changing drivers, listening to the radio, conversing, consuming beverages or snacks, including those with caffeine, slapping the face and opening the window were among the respondents' recommended preventative strategies for drowsy drivers, but there exists little if any scientific proof of what behaviors are effective (or ineffective) countermeasures to drowsiness while driving. Most people agree that there is no substitute for sleep.

Table 3
Interventions designed to reduce fatigue and sleepiness while driving.

Published year	Study type	Nation	Population	Most independent variables	Dependent variables	Intervention	Effect*
Panel A: Interventions include change in the behaviors							
2012	Cross-sectional[24]	Australia	Healthy individuals averaged 21.8 years old	Time (hours per day), time awake	Deviation from the line side of the road	- No alcohol use at bedtime - Limiting driving behavior from 0:00–6:00	Fair
2011	Cross-sectional[25]	Israel	Professional and non-professional drivers	Age, sex, BMI, education, socioeconomic status, vehicle type, driving license type, driving history, location	Reduce fatigue and sleepiness while driving	- Talking to passengers - Listening to the radio - Open the window - Face washing	Good
2007	Systematic review of cost-effectiveness[30]	USA	Articles related to OSAS and traffic accidents from 1980 to 2003	Events related with OSAS	Economic costs, quality of life	Treatment of drivers with sleep apnea syndrome (OSAS)	Fair
2004	Cross-sectional[34]	Netherland	–	–	–	Do not use sleep medications	Fair
1998	Cross-sectional[37]	USA	Experts of driving and traffic safety	Different environmental conditions such as wind and driving variables	Drowsiness	- Driving the other person rather than a driver who is tired for 1–2 h - Stop the car and sleep for 30–45 min - Drink a caffeinated beverage	Fair
Panel B: Interventions include Changes in the environment							
2013	Interventional[23]	UK	Group 1: persons with night shifts Group 2: drivers over 45 years	Night shift work, age, driving after eating lunch	Fatigue and drowsiness	Rumble strips, V-shaped lines (chevrons), variable message signs installation	Good
2011	Interventional[26]	Japan	Drivers with a mean age of 32 years	Open-eyes SEM and closed-eyes SEM	Number of traffic accidents	Detection of slow eye movement while driving	Good
2009	Interventional[27]	Palestine	Students aged 22–30 years with 5 years of driving experience	Interactive cognitive task	SOFI	Interactive cognitive task	Good
2009	Interventional[28]	USA	Drivers	The lack of sleep	The root-mean-square error, the effective time delay	- Dynamic guide signs - Smart car - Dummy changes in uniform roads	Fair
2008	Interventional[29]	China	Driver who have driving experience	Environmental changes in the road	Drowsiness based on SSS	Removing the road from steady state	Good
2006	Interventional[31]	USA Ford company	Adults with sleep deprivation	Methods of LDW like Steering Wheel Torque	physiological measure of eye closure, Karolinska Sleepiness Scale	Different methods alarming deviations from the line side of the road (Lane departure warning)	Fair
2005	Interventional[32]	Germany	Healthy persons aged 22–27 years	Having the Lane Departure Warning System	Reaction time during sleepiness, electro dermal activity	Lane Departure Warning System	Good
2004	Case–control[33]	China	Young drivers have a full driving license	Physically tired, lazy, want to lie down, irritable, no energy	Reaction time, right rate	Magnitopuncture stimulation method to reduce sleepiness in drivers	Good
2004	Interventional[11]	England	Truck drivers	Driving schedule	CAS Fatigue Score	Use of Circadian Alertness Simulator (30) for truck drivers	Fair
2001	Interventional[17]	Germany	Students aged 22–28 years, male	Stress, fog, horizontal and vertical curves	Fatigue and drowsiness	- Create a gentle horizontal curve in the uniform roads - Establish uniform gentle slope on the road - Produce fog in road - Produce light traffic on the road	Good
2001	Interventional[36]	Germany	Persons with Commercial Driving License	Existence of drowsiness detection and warning devices	Fatigue and sleepiness based on the eyes situation	Drowsiness detection and warning devices like Copilot-DDI	Good
1999	Interventional[14]	Netherland	Driver aged 22–55 years	Driving duration in 24 h, listen to the radio, drinking coffee	Fatigue and drowsiness	Electronic devices of drowsiness detection such as game box	Good
Panel C: Interventions include educational programs							
2007	Systematic review[30]	USA	Primary articles	Various environmental and demographic variables	Awareness about fatigue and sleepiness	- Education of 16–24 y boys about driving and reduce sleepiness and fatigue while driving, - Learning how to deal with fatigue and sleepiness while driving - Training the workers in job rotation about fatigue and sleepiness while driving	Fair

* The effect is assessed based on likert scale.

conditions. The results showed that the impact of the three methods tested on driver's performance were not very different, however, use of any of the three methods caused further improvement in the performance and alertness of the drivers in vehicle control.

Other studies found in this systematic review assessed various interventions for reduction of drowsy driving and their results are summarized in Table 3.[14,17,26–33,35–37]

Based on these results, interventions designed to reduce fatigue and sleepiness while driving in the world can be classified in three categories: (1) interventions include change in the behaviors, (2) interventions include changes in the environment and (3) interventions include educational programs. These classifications are shown in Table 3.[11,14,17,23–32,34,36,37]

Discussion

Based on the results obtained in this systematic review, various interventions have been done in different parts of the world for reducing drowsiness while driving. These interventions can be classified into three categories:

1. Educational activities
2. Change in the behaviors
3. Changes in the environment

The results of this systematic review showed that different methods with various interventions were assessed to reduce drowsiness while driving. Moreover, due to different effect indicators used to determine the effect, doing meta-analysis in the end of systematic review was not possible.

As mentioned in introduction section, the main objective of this study was to find a variety of interventions to reduce sleepiness while driving and secondary objective was to find the true effect size for each of the interventions. In current study the main objective was achieved, but as mentioned previously, because of heterogeneity in study methods and interventions which were used in the studies, insufficient number of studies for evaluation of the effect of each intervention, determination of actual effect for each intervention (using meta-analysis) as the second objective of the study was not possible.

Our results showed, among interventions that introduced based on driver behavioral changes, talking to the passengers, listening to the radio, opening the window and face washing were more effective than others. In addition, among interventions based on environment change, some of them revealed superior effect, including use of rumble strips, V-shaped lines (chevrons), variable message signs installation, drowsiness detection and warning devices (such as game box), changing the road from steady state, create a gentle horizontal curve in the steady roads, establishing uniform gentle slope on the road, produce fog in road, creating light traffic on the road and Lane Departure Warning System. As for the intervention of fog production, the effect is controversial since it will affect driver's vision and hence its practice for reducing sleepiness is a challenging.[39,40]

In contrast to two categories of interventions mentioned above (driver behavioral changes and environmental changes), interventions that are based on educational programs did not show any effect. In the other words, with administration of educational programs alone, we could not achieve remarkable success in decreasing drowsy driving unless these training programs lead to changes in driver's behaviors.

Although this study carried out in the end of 2014, we researched all above mentioned databases again in May 2015 for extracting new related papers but we did not find further researches in the latest. Generally, in the studies that have been done so far in the world, many interventions have been introduced to reduce sleepiness while driving and according to the results obtained from our review, each of these interventions can be used to decrease the sleepiness while driving but the precise effect of each intervention is unknown. Interventional studies are required in this field to illustrate the actual and precise effect for these interventions. Further studies are required for comparison of the efficiency of each intervention and localization of each intervention according to the traffic patterns of each country.

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