Original article

Alcohol consumption for simulated driving performance: A systematic review

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ABSTRACT

Purpose: Alcohol consumption can lead to risky driving and increase the frequency of traffic accidents, injuries and mortalities. The main purpose of our study was to compare simulated driving performance between two groups of drivers, one consumed alcohol and the other not consumed, using a systematic review.
Methods: In this systematic review, electronic resources and databases including Medline via Ovid SP, EMBASE via Ovid SP, PsycINFO via Ovid SP, PubMed, Scopus, Cumulative Index to Nursing and Allied Health Literature (CINHAL) via EBSCOhost were comprehensively and systematically searched. The randomized controlled clinical trials that compared simulated driving performance between two groups of drivers, one consumed alcohol and the other not consumed, were included. Lane position standard deviation (LPSD), mean of lane position deviation (MLPD), speed, mean of speed deviation (MSD), standard deviation of speed deviation (SDSD), number of accidents (NA) and line crossing (LC) were considered as the main parameters evaluating outcomes. After title and abstract screening, the articles were enrolled for data extraction and they were evaluated for risk of biases.
Results: Thirteen papers were included in our qualitative synthesis. All included papers were classified as high risk of biases. Alcohol consumption mostly deteriorated the following performance outcomes in descending order: SDSD, LPSD, speed, MLPD, LC and NA. Our systematic review had troublesome heterogeneity.
Conclusion: Alcohol consumption may decrease simulated driving performance in alcohol consumed people compared with non-alcohol consumed people via changes in SDSD, LPSD, speed, MLPD, LC and NA. More well-designed randomized controlled clinical trials are recommended.

Introduction

The correlation between alcohol and vehicle-related death and injury was identified in an editorial of the Quarterly Journal of Inebriety for the first time in 1904.[1] Nowadays it is well accepted that alcohol consumption can lead to risky driving and increase the frequency of traffic accidents and related injuries and mortalities.[1,2] About 40% of all traffic mortalities are associated with alcohol, regarded as the most important human cause of severe automobile crashes.[2,3] Hence, there is a powerful linkage between alcohol consumption and risky driving behaviors, so driving after alcohol drinking is forbidden by law in many countries. A legal range for maximum blood alcohol concentration (BAC) was from 0.01% to 0.08% in different countries.[1] Scientific literature showed that BAC of 0.05% could impair motor vehicle driving.[4]

Driving performance has been already evaluated in many studies and it is believed that consumption of alcohol can influence some driving skills like choosing an appropriate speed, time and frequency of overtaking, braking, steering and determining the distance with other vehicles. Lane position, line crossing, number of crashes, speed deviation and time at maximum speed are other

indexes to evaluate driving performances in this area.[4–7] An important mechanism for these effects is associated with distraction caused by alcohol.[8] Also it is proposed that alcohol intake can impair neurological and cognitive functions. Furthermore it can lead to an increase in reaction time to potential hazards and a decline in short-term memory of drivers. Some factors like age, gender and driving skills could have some exacerbating effects on the alcohol-related driving. These effects seemed to be limited whereas BAC and complexity of the driving tasks were proposed as the most important factors here.[3] A significant association of other drug administration like dexamphetamine and caffeine along with alcohol on risky driving was reported.[9,10] Interestingly, simulated driving researches exceedingly helped traffic scientists in recent years.[11,12]

Our study used a systematic review to compare simulated driving performance between two groups of drivers, one consumed alcohol and the other not.

Materials and methods

Data resources

In this systematic review, electronic resources and databases including Medline via Ovid SP, EMBASE via Ovid SP, PsycINFO via Ovid SP, PubMed, Scopus, Cumulative Index to Nursing and Allied Health Literature (CINHAL) via EBSCOhost were comprehensively and systematically searched.

Search strategy

Our search strategy made by an expert librarian covering an appropriate combination of all keywords related to the concepts of driving, risk taking, dangerous behavior, aggressive behavior, riding, accident, motor vehicle, automobile, and motorcycle. We tried to have a protocol for our search strategy to be as sensitive as possible. No language and time preference were applied and it was noted that the last search was performed on January 31, 2014.

Study eligibility

Articles were included if they were randomized controlled clinical trials (RCTs) and their main intervention was related to effect of alcohol consumption on simulated driving performance. We considered no limitation on age, gender and race. The studies were also included if they evaluated following outcomes: lane position standard deviation (LPSD), mean of lane position deviation (MLPD), speed, mean of speed deviation (MSD), standard deviation of speed deviation (SDSD), number of accidents (NA) and line crossing (LC).

Study selection and data extraction

We had two independent groups for article reviewing, so that each group reviewed about half of all papers in article screening in two levels (title and abstract screening) based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline for systematic reviews.[13] Each paper in each group was independently investigated by two authors and was included if both authors had agreement. At the end of screening, disagreements about any paper were resolved with group discussion. After that, remained disagreements were resolved by more discussion and consensus with other colleagues out of two groups. Finally data regarding characteristics of included papers (study design, participant, intervention, risk of biases and outcomes) were recorded in a data collection form.

Risk of bias assessment

Every included paper was assessed for any bias risk including random sequence generation (selection bias), allocation concealment (selection bias), blinding of participant and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition), selective reporting (reporting bias), co-interventions, intention to treat analysis, group similarity at baseline, compliance, timing of outcome assessments and other biases. Each item rated as high, low or unclear (in case of inadequate data) risk of bias for each paper. We scored high and unclear risks as 0 and low risk as 1. Our assessment for risk of bias was similar to Rasouli et al's method.[14]

Results

Study screening and characteristics of included papers

A total of 3618 papers were found through database searching after removing duplications. After title and abstract screening, 3570 papers were excluded because of irrelevancy to our topic and 33 full-text articles were assessed for eligibility (Fig. 1). Finally, 13 randomized clinical trials were included in qualitative synthesis. Characteristics of these included papers are shown in Table 1.

Risk of bias assessment

Based on Table 2, all included papers got a score ≤3 (out of 12) for risk of bias assessment, so all were categorized as high risk for bias. Based on this assessment, no study was excluded from our project.

Outcome evaluation

Following outcomes were investigated in the included papers: LPSD, MLPD, speed, MSD, SDSD, NA, and LC. The outcome comparison between alcoholic and non-alcoholic participants is shown in Table 3. The frequencies of the articles which showed significant relationships between alcohol consumption and related outcomes were as follows: SDSD 75%, LPSD 66.6%, speed 60%, MLPD 50%, LC 50%, NA 25% and MSD 0. Another considerable issue was related to effect of different BACs on the evaluated outcome. We tried to investigate this issue. However, in different articles, different BACs had been evaluated in our included outcomes. So unfortunately we could not pool related data. Considering Oxford Centre for Evidence-Based Medicine,[15] the level of evidence of our systematic review was 1a-, which meant that our systematic review had troublesome heterogeneity. We also found some other outcomes in these papers that were related to the purposes of our systematic review. However, these outcomes had been evaluated in just one of 13 included studies, so we did not mention them in Table 3. They were listed as follows: lane changes plus cars passed, time at maximum speed, mean values of errors occurred for speed, use of turn signals and time taken to drive fixed sections of route. Here we evaluated all of these outcomes individually.

LPSD

A driver should maintain a desired position within lane. Greater within-lane deviation can be considered as an indicator for poorer driving precision. Eight studies evaluated LPSD.[3,4,6,9–11,16,17] Because of many differences among these studies including existence of co-intervention, different alcohol dosages, different methods for alcohol measurement and different speed limitations, we could not conduct a meta-analysis here. Also in the studies by
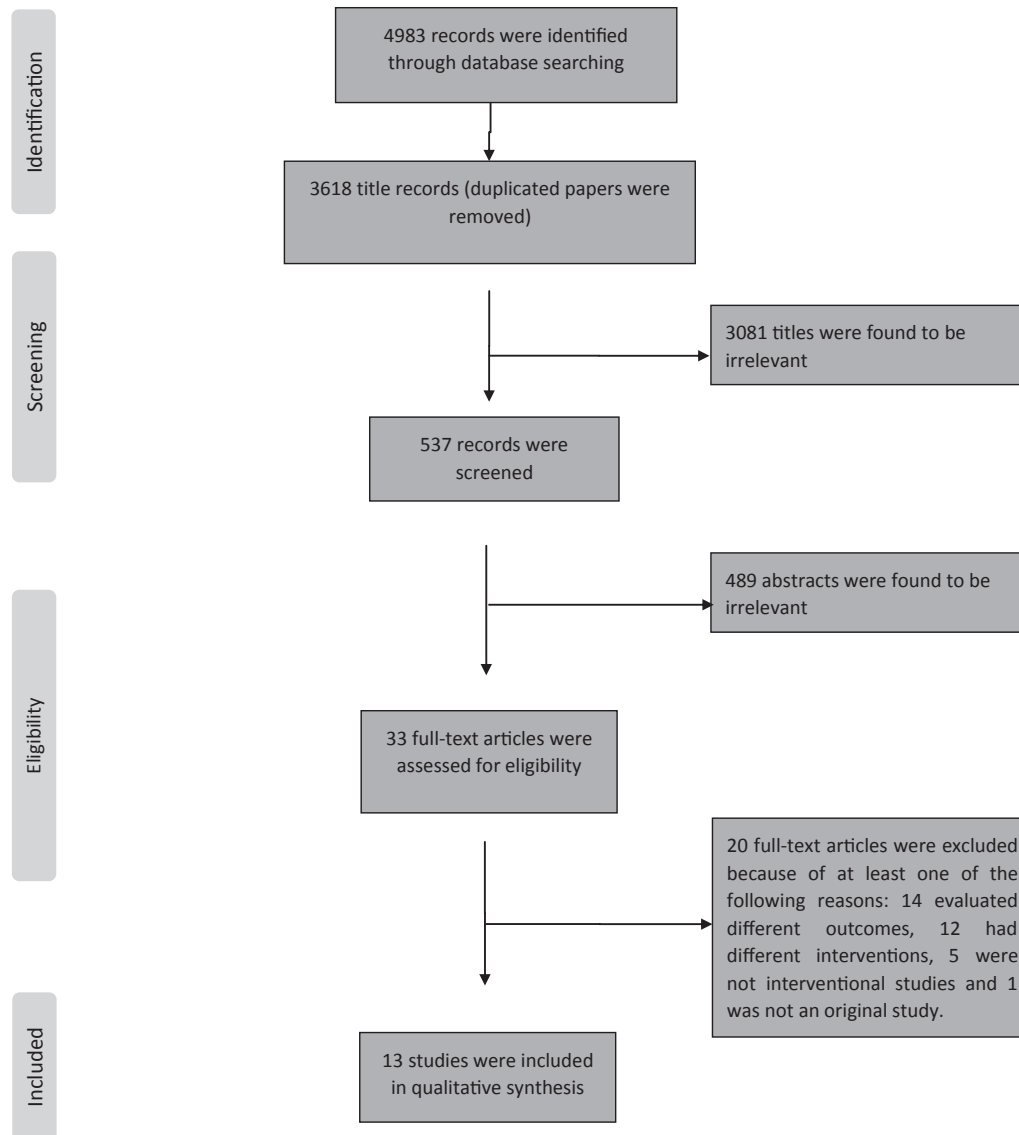
Fig. 1. Screening of studies based on PRISMA statement.

Table 1
Characteristics of included studies.

Authors	Publication year	Country	Sample size	Mean (SD) or range of participants' age (years)	Gender [n (%)]	
					Male	Female
Rim et al[8]	1982	USA	44	19–28	44 (100)	0 (0)
McMillen et al[7]	1989	USA	96	≥21	64 (66.66)	32 (33.33)
Oei et al[19]	1990	Australia	36	18–25	18 (50)	18 (50)
West et al[5]	1993	UK	15	30–55	9 (60)	6 (40)
Fillmore et al[17]	2008	USA	14	23.5 (3.2)	7 (50)	7 (50)
Rakauskas et al[9]	2008	USA	45	22.3 (not available)	45 (100)	0 (0)
Marczinski et al[3]	2009	USA	28	22.6 (2.3)	16 (57.14)	12 (42.86)
Huemer et al[18]	2010	Germany	23	25.2 (5.9)	12 (52.83)	11 (47.17)
Liu et al[2]	2010	China	8	24.12 (1.88)	6 (75)	2 (25)
Howland et al[10]	2011	USA	129	22.9 (2.23)	97 (75)	32 (25)
Spaanjaars et al[4]	2011	Netherlands	74	21.85 (1.54)	0 (0)	100 (0)
Simons et al[11]	2012	Netherlands	16	25.7 (21–37)	12 (75)	4 (25)
Veldstra et al[5] Study 1	2012	Netherlands	17	23.6 (3.8)	9 (52.94)	8 (47.06)
Veldstra et al[6] Study 2	2012	Netherlands	19	30.8 (5.68)	10 (52.63)	9 (47.37)

Table 2
Risk of bias assessment for the included papers.

Authors	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participant and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition)	Selective reporting (reporting bias)	Co-interventions	Intention to treat analysis	Group similarity at baseline	Compliance	Timing of outcome assessments	Other biases	Score	Conclusion
Rim et al[8]	?	?	−	?	?	?	?	?	?	?	−	−	3	High
McMillen et al[7]	?	?	−	−	?	?	?	?	?	?	−	−	3	High
Oei et al[19]	?	?	?	?	?	?	?	?	?	?	?	−	1	High
West et al[5]	?	?	−	−	?	?	+	?	+	?	−	−	3	High
Fillmore et al[17]	?	?	+	−	?	+	+	?	+	?	+	−	3	High
Rakauskas et al[9]	?	?	+	?	?	+	?	?	+	?	−	−	2	High
Marczinski et al[3]	?	?	+	+	+	+	?	+	+	?	?	−	2	High
Huemer et al[18]	?	?	+	−	+	?	?	?	+	?	?	−	2	High
Liu et al[2]	?	?	+	?	?	?	?	+	+	?	+	−	1	High
Howland et al[10]	?	?	+	+	?	+	+	?	+	?	+	−	1	High
Spaanjaars et al[4]	?	?	+	?	−	?	+	?	?	?	−	−	3	High
Simons et al[11]	?	?	+	?	−	+	+	+	+	?	−	−	3	High
Veldstra et al[5] Study 1	?	?	+	?	−	+	+	?	+	?	−	−	3	High
Veldstra et al[6] Study 2	?	?	+	?	−	?	+	?	?	?	−	−	3	High

Note: The sign "?" means unclear risk of bias, the sign of "−" means low risk of bias and the sign of "+" means high risk of bias.

Rakauskas et al[8] and Marczinski et al,[12] we found no mean and standard deviation (SD) values for LPSD. However, based on these studies in Table 3, SD values of lane position was significantly higher in alcoholic groups in comparison with non-alcoholic groups, except in the studies by Rakauskas et al,[8] Fillmore et al[18] and Spaanjaars et al.[16]

MLPD

MLPD was defined as center of right lane minus car's current road position in feet. It was evaluated in two studies by Rakauskas et al[8] and Howland et al.[9] SD values related to this outcome had not been presented in the study of Rakauskas et al.[8] Mean values of MLPD in both studies were significantly higher in alcoholic groups in comparison with control groups.[8]

Speed

The average overall speed was evaluated in four studies.[5,10,18,16] In Simons et al' s study, methods for alcohol measurement were different and data were incomplete.[10] A significantly higher mean speed was reported in alcoholic groups in comparison with control groups.[5,10] But no significant difference was reported in the studies by Spaanjaars et al[16] and Fillmore et al.[18]

MSD

MSD defined as current speed minus posted speed, was evaluated in two studies.[2,9] However, the definition was different and also we could not get the complete data in Marczinski et al's study.[2] In both studies, alcohol consumption had no significant effect on the speed.

SDSD

SDSD was evaluated in three studies.[1,5,9] Two studies showed a significant effect of alcohol on SDSD.[1,9]

NA

Three studies investigated the effect of alcohol on NA.[2,5,10] Among these studies, only Simons et al[10] reported a significant effect of alcohol on NA. Marczinski et al[2] reported an infrequent accident, therefore they could not run any meaningful analysis.

LC

LC is defined as crossing the center line into oncoming traffic or road shoulder. Three studies evaluated LC.[2,10,19] Marczinski et al[2] reported incomplete data regarding mean and SD values of LC but he reported a significant higher LC in alcohol group in comparison with control group. However, higher mean of LC in alcohol groups was not significant in comparison with control group.[18] Oei et al[19] also compared mean number of times subjects drove off the road totally among two groups (for and against drunk-driving) and under three conditions (pre, 0.04% and 0.08% BAC).

Other outcomes

Lane changes and cars passed were two variables that were summed for measurement of risk taking encompassing both weaving and speed.[6] Time at maximum speed was another outcome that has been evaluated.[6] A significant effect of alcohol on these two outcomes was not seen.

Effect of alcohol consumption on the mean values of errors occurred for speed, braking, steering and use of turn signals has been measured by Rimm et al.[7] An analysis of covariance on the combined brake and steering errors showed a significant beverage effect.[7]

There was no significant difference for low and moderate alcohol consumptions compared with placebo regarding "time taken to drive fixed sections of route" in the study by West et al.[4]

Table 3
p values of the studied outcomes between alcoholic and non-alcoholic groups.

Authors	LPSD	MLPD	Speed	MSD	SDSD	NA	LC
Fillmore et al[17]	NS	–	NS	–	–	–	NS
Rakauskas et al[9]	NS	$p < 0.01$[a]	–	–	–	–	$p = 0.002$
Marczinski et al[3]	$p = 0.004$[a]	–	–	NS	–	Not mentioned	–
Huemer et al[18]	$p < 0.05$[a]	–	–	–	–	–	–
Liu et al[2]	–	–	–	–	$p = 0.05$[a]	–	–
Howland et al[10]	$p < 0.001$[a]	NS	–	NS	$p < 0.001$[a]	–	–
Spaanjaars et al[4]	NS	–	NS	–	–	–	–
Simons et al[11]	$p < 0.05$[a]	–	$p < 0.05$[a]	–	–	$p < 0.03$[a]	–
Veldstra et al[5] Study 1	$p < 0.05$[a]	–	$p < 0.05$[a]	–	NS	NS	–
Veldstra et al[6] Study 2	$p < 0.05$[a]	–	$p < 0.05$[a]	–	$p < 0.02$[a]	NS	–

Note: LPSD = lane position standard deviation; MLPD = mean of lane position deviation; MSD = mean of speed deviation; SDSD = standard deviation of speed deviation; NA = number of accidents; LC = line crossing; NS means no significant difference.
[a] Shows a statistically significant value.

Mean highest speed had been compared among two groups (for and against drunk-driving) and in three conditions (pre, 0.04% and 0.08% BAC).[19] Mean highest speed for drunk-driving increased in higher BAC. However, mean highest speed first decreased from pre to 0.4% BAC. The exact values related to this outcome including mean, SD and p values were not available.

Discussion

In this systematic review, we found that among our included outcomes, SDSD, LPSD and speed were mostly deteriorated by alcohol consumption. However, the level of evidence of our systematic review was 1a-. It meant that our systematic review had troublesome heterogeneity. Such evidence is inconclusive and can only generate the lowest grade of recommendations.

Speed has been evaluated in many studies and proposed as a factor that could be influenced by alcohol consumption. It was evaluated in different forms including average overall speed, speed deviation (mean and SD) time at maximum speed, and mean highest speed. Most studies in our project reported that alcohol could lead to risky driving by its effect on speed in all mentioned forms.[1,2,5,9,16,17,19] Lane position like speed was evaluated in different definitions including mean and SD of lane position deviation affected by alcohol.[2,5,8–10,16,17]

Alcohol has a significant effect on crossing the line in a road which can be considered as a related outcome to lane position.[8,18] The "number of crashes" had not been considered in many studies and even if considered, it was not analyzed due to infrequent crashes.

Speed and lane position had been investigated in all included studies after publication year of 2000 at least in one of the mentioned definitions.

About 1.2 million people die every year because of road accidents. Injuries related to road traffic are categorized as the 2nd to 6th causes for death all around the world in the age groups of fifteen to sixty. So, controlling such injuries should be considered as an important public health concern.[20] Driving is an important task and alcohol drinking is one of the important causes of automobile crashes.[16,21] In a retrospective study in Sweden, the authors evaluated concentrations of alcohol and other illicit and psychoactive drugs in blood of drivers killed in road traffic crashes.[22] They showed a high median of BAC among these drivers and reported that impairment due to alcohol drinking should be considered as an important factor for traffic crashes.[22] Alcohol and cannabis can affect driving skills and lead to a poorer vehicle control. Roadside studies showed that drivers frequently has a positive test for one or both of these two drugs.[23] The considerable point is that a significant number of drug users do not know that their driving can be impaired because of drugs.[23,24] Alcohol was considered as the most prevalent substance among drivers in some countries.[25] Also some medications like psychotropic agents and those with side effects in central nerve system can lead to different levels of impaired driving. In a case-control study in Norway, the most prevalent illicit drug among drivers that involved in crashes was amphetamine/methamphetamine. However, the combination of this drug with benzodiazepines has the highest risk of being arrested for driving under the influence.[26] On the other hand, alcohol consumption has different effects on some of these mentioned medications. It can increase the risk of overdose with benzodiazepines and subsequently cause some problems in alertness, respiration and psychomotor function. It can trigger side effects of some medications like hypoglycemia induced by bisquanides and sulfonylureas and drowsiness by muscle relaxants. On the other hand, the mediation like ranitidine blocks liver enzyme that metabolize alcohol and leads to more BAC.[21]

It is said that the professionals like truck drivers use stimulant agents for maintaining their work schedule. Alcohol consumption and use of illicit drug have been proposed as an important concern among these drivers in Brazil.[21] A systematic review in Brazil showed that alcohol, amphetamine, marijuana and cocaine were the most frequent substances. A varied range for using these substances was reported, especially about alcohol (0.1%–91.0%). A varied range might be due to different methods of collecting data, so that obtaining information via self-reporting method leaded to more prevalence of substance abuse in comparison with biological tests. This study also showed that unlike other substances, alcohol drinking was associated with individual characteristics of drivers and their health conditions.[27]

Driving performance in term of SDLP, SDSD and braking reaction time can be correlated with the level of alcohol consumption. If breath alcohol concentration increases in one unit, it can lead to degrade in braking reaction time and SDLP by 0.3% and 0.2% respectively.[28] The association between BAC and motor or non-motor vehicle injuries has been also evaluated.[27] A significant odds ratio (OR) was reported for fatal motor vehicle injury in all levels of BAC. The OR of 1.74 (95% CI: 1.43–2.14) was detected for every 0.02% increase in BAC. It was interesting that at BAC of 0.08% (the legal limit in most countries), the related OR was 13 (95% CI: 11.1–15.2).[29] Also in another meta-analysis, it was proposed that

for non-motor vehicle accidents, the *OR* increased from 1.30 (95% *CI*: 1.26–1.34) to 24.2 (95% *CI*: 16.2–36.2) at 140 g pure alcohol. Based on these studies, no levels of BAC seemed to be safe for driving.[30] Here, we collected data regarding each performance outcomes in a systematic review to have a better view on each dimensions of this problem and make a better decision to reduce the traffic related accidents. As we pointed it before based on the result of our study, speed, SDSD and LPSD were mostly deteriorated by alcohol drinking. However, there are a lot factors that should be addressed in this issue. One of them is the mechanism that alcohol influences driving performance, such as its effect on drivers' visual scanning capacity.[31] Another point is the interaction between alcohol and other factors like gender and age of drivers. It is showed that older adult drivers can be more influenced by alcohol consumption but the mechanism is not clear and more studies regarding this topic are still needed.[32] On the other hand, it is proved that drivers cannot have a good judgment about their levels of intoxication and their fitness to drive after drinking.[33] Furthermore, some drivers do not know that their situation for driving can be influenced by alcohol consumption. So we believed that all of these conditions should be considered in public educational programs.

Based on the association between alcohol drinking and risky driving, some recommendations for reducing alcohol related accidents have been proposed. One of the suggested technologies that can effectively reduce the number of alcohol related accidents is filled breath test. It can be done in sobriety checkpoint or for all drivers involved in serious injury accidents. It was showed that using this technology, more progress in detection and reducing the impaired drivers could be possible.[34] Training for BAC estimation could also be very important and it should be considered as a useful component at least for moderate drinkers in prevention programs for drunk driving.[35] However, tendency to estimate lower BAC can lead to more risky driving regardless of actual BAC.[36] Some other alcohol-related interventions like consideration of minimal legal age for drinking and increasing the excise taxes for alcohol were proposed for reducing accident related mortality.[37]

It should be noted that because of specific conditions related to alcohol and moral issues, we could not find studies related to real situation and all of our included studies had been done by a simulator. Moreover, after systematically reviewing data, because of remarkable heterogeneity between them, we could not do a meta-analysis. Differences in alcohol dosages, methods for alcohol measurement, definitions of same outcomes and speed limitation in different virtual roads were the important factors causing the heterogeneity. Furthermore, it has been proved that there is a strong dose-response association between alcohol consumption and vehicle accident injury.[30] However, as we pointed it out before, because of evaluation of different BAC on different outcomes in included studies, we could not investigate effect of different BAC on outcomes related to risky driving.

Among the driving performance outcomes, SDSD, LPSD and speed are mostly deteriorated by alcohol consumption. So, considering them in educational programs and raising public awareness seem to be necessary. On the other hand, based on our literature review, no BAC is safe for driving. However, conducting well-designed randomized controlled clinical trials in the way that the researchers can run meta-analyses regarding effect of different BAC on risky driving is recommended.

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