Life-threatening alcohol-related traffic crashes in adverse weather: a double-matched case-control analysis from Canada

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ABSTRACT

Importance Drunk driving is a major cause of death in North America, yet physicians rarely counsel patients on the risks of drinking and driving.

Objective To test whether the risks of a life-threatening alcohol-related traffic crash were further accentuated by adverse weather.

Design Double matched case–control analysis of hospitalised patients.

Setting Canada’s largest trauma centre between 1 January 1995 and 1 January 2015.

Participants Patients hospitalised due to a life-threatening alcohol-related traffic crash.

Exposure Relative risk of a crash associated with adverse weather estimated by evaluating the weather at the place and time of the crash (cases) compared with the weather at the same place and time a week earlier and a week later (controls).

Results A total of 2088 patients were included, of whom the majority were drivers injured at night. Adverse weather prevailed among 312 alcohol-related crashes and was significantly more frequent compared with control circumstances. The relative risk of a life-threatening alcohol-related traffic crash was 19% higher during adverse weather compared with normal weather (95% CI: 5 to 35, p=0.006). The absolute increase in risk amounted to 43 additional crashes, extended to diverse groups of patients, applied during night-time and daytime, contributed to about 793 additional patient-days in hospital and was distinct from the risks for drivers who were negative for alcohol.

Conclusions Adverse weather was associated with an increased risk of a life-threatening alcohol-related traffic crash. An awareness of this risk might inform warnings to patients about traffic safety and counselling alternatives to drinking and driving.

INTRODUCTION

Alcohol-related traffic crashes cause substantial mortality and morbidity, accounting for ten thousand deaths annually in North America and contributing to one-third of total traffic fatalities. Alcohol-related traffic fatality rates are higher in North America than many other countries that have greater alcohol consumption per-capita. In addition, life-threatening alcohol-related traffic crashes in Canada and the USA result in over 300,000 patients hospitalised for brain trauma, spinal cord injuries, orthopaedic fractures or other non-fatal complications (leading to $43 billion in societal costs annually). These patterns indicate that current public education, regulation and enforcement are insufficient for preventing drunk driving.

Motorists who drive drunk do so many times before attracting the attention of a healthcare provider. Epidemiological studies and statistical models estimate the average drunk driver needs to travel more than a million miles to cause one crash fatality. This seemingly innocuous pattern tends to build a false sense of security from prior personal experiences; specifically, a mistaken belief that the individual can drive without incident if the road situation remains the same and free of other hazards. This faulty reasoning is particularly beguiling because alcohol is a
necessary but not a sufficient factor in triggering an alcohol-related traffic crash and because drunk drivers lack insights on how even minor hazards might precipitate a crash.\textsuperscript{15}

One particularly common objective hazard is adverse weather that can create an extended disturbance for all who share the road.\textsuperscript{16} Adverse weather reduces visibility, decreases vehicle traction, creates visual glare, obscures reflective road markings and changes the patterns of vehicle cross traffic.\textsuperscript{17,18} Naturally, everyday driving entails an endless configuration of potential additional hazards that vary for each person and are easily forgotten after an uneventful trip.\textsuperscript{19} The unrecognised effect of these hazards, however, might create a fundamental mechanism explaining the complex link between drunk driving hazards, however, might create a fundamental mechanism explaining the complex link between drunk driving and traffic crashes. In this study, we test the association of alcoholism explaining the complex link between drunk driving and traffic crashes. In this study, we test the association of

METHODS

Patient selection

We identified consecutive adults admitted to Canada’s largest trauma centre, a tertiary care hospital that treats patients from crashes in the country’s largest province.\textsuperscript{20–22} For a comprehensive analysis, we included all patients hospitalised for a crash (hereafter termed a life-threatening crash) including drivers, passengers or pedestrians since multiple individuals can be injured in traffic.\textsuperscript{23,24} We focused on those who tested positive for alcohol based on history, examination, assay or police report. Unclassified or atypical road incidents were excluded (eg, skateboard misadventures). Enrolment spanned from 1 January 1995 to 1 January 2015 yielding a complete sample for the two most recent available decades.\textsuperscript{25}

Clinical characteristics

We obtained clinical characteristics for patients based on hospital records using a standardised method validated in past research.\textsuperscript{26} Information on the time, date and place of the crash was collected from paramedic reports if available and hospital records otherwise.\textsuperscript{27} Information on patient age, sex, comorbidity, vital signs (after paramedic resuscitation), Injury Severity Score and Glasgow Coma Scale was based on chart review.\textsuperscript{28,29} Of note, alcohol testing was routine in hospital trauma protocols and did not require consent. Further clinical details included surgical procedures, intensive care unit admission, total length of stay and hospital mortality.\textsuperscript{30} The available records lacked information on driver education, past infractions, addiction history, license suspensions, impact velocity, vehicle condition, distance travelled or intended destinations.

Crash setting

Data on crash locations spanned a wide diverse geographic area (1 million km\textsuperscript{2}), were extracted in differing formats (street intersection, geographic coordinates, postal code) and were subsequently transformed to exact geocodes for the crash site.\textsuperscript{31,32} Patients with missing or inexact crash locations were retained for analysis, denoted explicitly and subjected to sensitivity analysis. Geographic proximity to the trauma unit was estimated by Euclidean (straight-line) distance for those with known crash locations and by the median distance for those with missing or inexact crash locations. Crash time was recorded to the nearest hour to match the precision of standardised archived weather information.\textsuperscript{33}

Adverse weather

The official Canada Climate Data and Information Archive provided weather data indexed to date and hour, as validated in past research.\textsuperscript{34} We focused on adverse conditions defined in the archive as rain, fog, drizzle, showers, snow, storms, freezing rain or freezing drizzle.\textsuperscript{35,36} All other conditions were defined as normal and included clear, mainly clear, mostly cloudy and cloudy. Daytime was crudely distinguished from night-time using simple thresholds of 07:00 and 19:00 hours.\textsuperscript{37} We selected the weather station closest to the crash for patients with exact crash locations and the most central airport weather station for patients with inexact crash locations so no case was excluded (cases with inexact locations also subjected to sensitivity analysis).

Control comparisons

We identified two control days for each crash defined by the circumstances a week earlier and a week later (when presumably no other traffic crash was present).\textsuperscript{38} A crash at midnight on 14 July 2011, for example, was compared with the same place at midnight on 7 July 2011 and 21 July 2011. This case-only design controlled for seasonal, daily and hourly trends; required no matching on individual patient characteristics; avoided ecological bias; and minimised multiple potential confounders including age, sex, genetics, personality, habits, education and road configuration.\textsuperscript{39} The prevailing weather at the same time and place for crashes and control days was extracted in a blinded manner (no knowledge of outcome), with rare cases of missing weather data substituted by the immediately preceding hour so all comparisons were complete.

Statistical analysis

Our prespecified primary analysis involved a matched evaluation of individual cases comparing the prevalence of adverse weather on the crash day to the prevalence of adverse weather on the control days at the same time and place.\textsuperscript{40} The relative risk of a crash associated with adverse weather was calculated using conditional logistic regression (accounting for 1:2 matching).\textsuperscript{41,42} Stratified analyses were conducted to further account for individual characteristics. Secondary analyses repeated the calculations for drivers who were negative for alcohol to check if the risks associated with adverse weather were distinct to drinking and driving. All estimates were calculated using exact 95% CIs and considered each patient a separate case.
A total of 10,199 patients were injured because of a life-threatening traffic crash during the study, of whom 2,088 (20%) tested positive for alcohol (exact concentrations unavailable for analysis). The majority of the alcohol-related crashes involved patients as drivers, most occurred at night and less than half used a seatbelt (table 1). Alcohol-related crashes were distributed throughout the year, although counts were marginally higher in the spring and summer months. As expected, alcohol-related crashes were more common on weekends than weekdays and slightly more numerous during the first decade than the second decade of the study. An exact crash location was identified for the majority of patients regardless of whether the crash was alcohol-related.

The average patient in an alcohol-related crash was a middle-aged adult with no medical comorbidity. Men were disproportionately involved, as were those younger than age 65 years and those who had not been wearing a seatbelt. Patients in an alcohol-related crash were no less seriously injured as measured by the distribution of abnormal vital signs, decreased Glasgow Coma Scale scores or Injury Severity Scale scores compared with patients who were negative for alcohol. Almost all patients were transported to hospital by ambulance (table 2). One-third of the patients required blood transfusions, over half required surgery and over half required a critical care admission. Ultimately, 174 patients died following an alcohol-related crash.

Overall, 312 of the 2,088 (15%) alcohol-related crashes were characterised by adverse weather conditions. In contrast, 537 of the 4,176 (13%) control days were characterised by adverse weather conditions at the same time and place (figure 1). The difference in prevailing weather equalled a 19% increased risk of a life-threatening alcohol-related traffic crash associated with adverse weather compared with normal weather (95% CI: 5 to 35, p=0.006). The absolute difference amounted to 43 additional life-threatening alcohol-related traffic crashes associated with adverse weather (one-in-seven of those observed). In contrast, drivers who were negative for alcohol showed no increased risk of a life-threatening traffic crash associated with adverse weather (estimate = −1%, 95% CI: −11% to +8%, p=0.704).

The increased risk of a life-threatening alcohol-related traffic crash extended to diverse patient groups (figure 2). Drivers tended to predominate, yet the relative increase in risk associated with adverse weather also applied to
pedestrians and passengers (low counts). Similarly, nighttime crashes were more numerous than daytime crashes, yet the increased relative risk associated with adverse weather applied regardless of the time of day. Analyses stratified by season, weekday, decade, crash location, age, sex, Injury Severity Scale scores and mortality all showed increased relative risks of an alcohol-related traffic crash associated with adverse weather and wide 95% CIs. No analysis showed the opposite pattern, no pairwise interaction term was statistically significant and all point-estimates overlapped the primary analysis.

The increased risk of a life-threatening alcohol-related traffic crash associated with adverse weather resulted in substantial inpatient hospital care. The mean length of hospital stay was similar for patients injured in adverse weather conditions compared with patients injured in normal weather conditions (figure 3). In total, the absolute increase in risk associated with adverse weather accounted for about 793 additional patient-days in hospital (online supplementary appendix). Similarly, the absolute increase in risk associated with adverse weather accounted for 52 additional surgical operations and 255 additional patient-days in critical care (online supplementary appendix). The net economic consequences were equivalent to approximately $1 million in additional economic costs (online supplementary appendix).

**DISCUSSION**

We studied about 2000 patients injured in a life-threatening alcohol-related traffic crash over twenty years in Canada. We found that adverse weather was prevalent in many cases, accounted for a further 19% increased relative risk and might explain one-in-seven life-threatening alcohol-related crashes. The increased risk associated with adverse weather extended to diverse patient groups, applied during night-time and daytime, and accounted for hundreds of additional patient-days in hospital. An increased relative risk of this magnitude is twice as large as driving without an air bag and an absolute risk of this magnitude is particularly important due to the high baseline risk of a traffic crash for all drunk drivers.43–46
Several limitations of our findings merit emphasis. The study is not a randomised trial because the weather is impossible to control and drunk driving cannot be assigned in an ethical manner. Trauma centre medical assessments often underestimate the presence of alcohol, yet this imprecision tends to slant primary and stratified analyses towards the null. Alcohol studies cannot be blinded easily so unconscious biases in clinicians might distort the assessment of outcome data. Our analysis also lacks data on traffic volumes, distances, speeds, spacing and finer weather details at exact crash sites. Superimposed crossing lines denote crashes occurring in adverse weather and crashes occurring in normal weather conditions. Main findings show similar mean, median and distribution of length of hospital stay for both groups.

Additional limitations relate to our study setting and justify replication in future research on other patients with life-threatening alcohol-related traffic crashes. The data reflect one large region that may not match drinking and driving patterns elsewhere. Canada is also notorious for long cold dark nights that are conducive to alcohol consumption and an impediment to roadside traffic police. Different regions have different traffic patterns and also vary in the age for legal drinking (19 years in most of Canada, 21 years in the USA). Finally, we examined only one hazard that was objective and widespread yet daily traffic provides a large array of additional hazards that could precipitate a life-threatening alcohol-related crash. Alcohol causes traffic crashes because of impaired judgement, decreased attention, reduced alertness and many other factors that limit the ability to compensate for hazards. A further subtle mechanism is how alcohol lowers visual acuity when moving. Laboratory experiments indicate, for example, that three drinks of alcohol cause a one-line loss on a Snellen eye chart test due to faulty visual tracking and reduced dynamic visual acuity. Acute alcohol ingestion also causes decreased contrast sensitivity, sluggish glare adaption and impaired risk perception that is unnoticed when stationary. The net effect is that eyesight deficits may be irrelevant when seated indoors (static vision), critical when driving in adverse weather (high-speed optical flow) and part of the false sense of security associated with drinking and driving.

Our study suggests adverse weather is directly relevant for alcohol-related crashes yet does not identify all the other hazards accentuating the traffic risks. Worsened surface glare, wheel traction and light backscatter may compromise how nearby traffic compensates for an impaired driver. External sensors or other assistive vehicle technologies can malfunction when wet. Traffic police may also dislike adverse weather and reduce enforcement in the rain. Together, these factors can help explain why adverse weather could be distinctly dangerous to drunk drivers; specifically, a crude OR of 25 associated with drunk driving might increase to a theoretical OR of 30 when driving in the rain (25×1.19). The net result could contribute to hundreds of patients requiring acute hospitalisation in North America each year (online supplementary appendix).

An increased risk of a life-threatening alcohol-related crash associated with adverse weather also means that police enforcement alone is not an easy solution against drunk driving. Traditional enforcement commonly includes sobriety checkpoints, mass media campaigns, encouraging seatbelts and random roadside alcohol breath testing. These interventions, of course, are effective and merit continuation. In daily practice, however, the inconvenience of police enforcement (especially in adverse weather) helps explain the high ongoing rates of drunk driving in many countries. Clinicians wishing to save their patients from becoming more traffic injury statistics, therefore, might consider additional interventions beyond police enforcement.

Drunk driving is a life-threatening behaviour, yet little data are available to guide clinicians for prevention. Current clinical efforts mostly include treating alcohol misuse or reporting unfit drivers to licensing authorities. Drunk driving, however, also stems from a patient’s dismissal of health hazards that seem innocuous due to misleading past experiences. Clinicians intending to save patients from traffic injuries, therefore, might also counsel how crash risks vary substantially from one trip to the next due to adverse weather or other external hazards. Such counselling could mention a pre-planned taxi or ride-sharing option since both inebriation and uneventful past experiences can impair judgement.

Although not prescribed by a physician, this study suggests that alcohol is a drug that endangers patients and justifies tactful medical attention.
Adverse weather is associated with an increased risk of an alcohol-related traffic crash.

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Contributors
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REFERENCES
1. U.S. Department of Transportation, National Highway Traffic Safety Administration. National Highway Traffic Safety Administration. Traffic Safety Facts: Alcohol impaired driving. 2014 http://www-nrd.nhtsa.dot.gov/Pubs/812231.pdf (Cited 26 Jul 2016).
2. Sauber-Schatz EK, Ederer DJ, Dellinger AM, et al. Vital signs: motor vehicle injury prevention - United States and 19 comparison countries. MMWR Morb Mortal Wkly Rep 2016;65:672–7.
3. World Health Organization. Recorded alcohol per capita (15+ years) consumption in litres of pure alcohol, from 1990. Geneva: World Health Organization, 2016.
4. Fenelon A, Chen LH, Baker SP. Major causes of injury death and the life expectancy gap between the United States and other high-income Countries. JAMA 2016;315:609–11.
5. Majdani M, Planckova D, Maas A, et al. Years of life lost due to traumatic brain injury in Europe: a cross-sectional analysis of 16 countries. PLoS Med 2017;14:e1002331.
6. Blincove L, Miller TR, Zaloshnja E, et al. The economic and societal impact of motor vehicle crashes, 2010 (Revised); U.S. Department of Transportation, National Highway Traffic Safety Administration, 2015.
7. Mello MJ, Nirenberg TD, Lindquist D, et al. Physicians’ attitudes regarding reporting alcohol-impaired drivers. Subst Abus 2003;24:233–42.
8. Spithoff S, Turner S. A systemic failure to address at-risk drinking and alcohol use disorders: the Canadian story. CMAJ 2015;187:479–80.
9. Zador PL, Krawchuk SA, Moore B. U.S. Department of Transportation, National Highway Traffic Safety Administration. Drinking and driving trips, stops by the police, and arrests: analyses of the 1995 National Survey of Driving and Drinking Attitudes and Behavior [Internet]. 2000 https://www.bts.gov/lib/26000/26600/26662/080_184.pdf (Cited 19 Jul 2017).
10. Redelmeier DA, Vinkatesh V, Stanbrook MB. Mandatory reporting by physicians of patients potentially unfit to drive. Open Med 2008;2:e8–e17.
11. Cavaliola AA, Strohmeier DB, Abreo SD. Characteristics of DUI recidivists: a 12-year follow-up study of first time DUI offenders. Accident Analysis & Prevention 2007;39:855–61.
12. Solomon R, Chamberlain E, Abdoullaeva M, et al. Random breath testing: a Canadian perspective. Traffic Inj Prev 2011;12:111–9.
13. U.S. Department of Transportation: National Highway Traffic Safety Administration. National Highway Traffic Safety Administration. Traffic Safety Facts: 2014 data [Internet]. 2015 https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812231 (Cited 18 Mar 2017).
14. Paxion J, Galy E, Berthelon C. Mental workload and driving. Front Psychol 2014;5:1344.
15. PLoS Medicine Editors. Preventing road deaths—time for data. PLoS Med 2010;7:e1000257.
16. Elvik R. Does the influence of risk factors on accident occurrence change over time? Accid Anal Prev 2016;91:91–102.
17. Hranac R, Sterzin E, Krechmer D, et al. Empirical studies on traffic flow in inclement weather. Washington (DC): U.S. Department of Transportation, National Highway Traffic Safety Administration, 2006.
18. Higgins L, Miles JD, Carlson P, et al. Nighttime visibility of prototype work zone markings under dry, wet, recovery, and rain conditions. Transp Res Rec 2009;2107:89–75.
19. Klauser SG, Guo F, Simons-Morton BG, et al. Distracted driving and risk of road crashes among novice and experienced drivers. N Engl J Med 2014;370:54–9.
20. McMurry RT, Nelson WR, de la Roche MR. Current concepts in trauma: 2. The Sunnybrook Medical Centre trauma program: the first 11 years. CMAJ 1990;141:555–9.
21. Brenneman FD, Boulanger BR, McLellan BA, et al. Acute and long-term outcomes of extremely injured blunt trauma victims. J Trauma 1995;39:320–4.
22. Sunnybrook Health Sciences Centre. Facts & Figures. 2016 http://sunnybrook.ca/content/?page-statistics(Cited 19 July 2017).
23. Sunnybrook Health Sciences Centre. Sunnybrook Health Sciences Centre. Strategic Plan for Sunnybrook’s Trauma Strategic Priority; 2015–2019 (Executive Overview). 2014 https://sunnybrook.ca/uploads/1/programs/trauma-emergency-care/strategic-plan/trauma-strategic-plan-executive-overview.pdf (Cited 13 Nov 2018).
24. Canadian Institute for Health Information. Ontario Trauma Registry comprehensive data set dictionary - May 2014; Canadian Institute for Health Information, 2014. https://www.cihi.ca/en/services_otr_cds_dict_en.pdf. (Cited 13 Nov 2018).
25. Lustig AJ, Kurdyak PA, Thiruchelvam D, et al. Physician warnings in psychiatry and the risk of road trauma: an exposure crossover study. J Clin Psychiatry 2017;77:e1256–e1261.
26. Boulanger BR, McLellan BA, Sharkey PW, et al. A comparison between a Canadian regional trauma unit and an American level I trauma center. J Trauma 1993;35:261–6.
27. Redelmeier DA, Raza S. Life-threatening motor vehicle crashes in bright sunlight. Medicine 2017;96:e5710.
28. Kondziolka D, Schwartz ML, Walters BC, et al. The Sunnybrook neurotrauma assessment record: improving trauma data collection. J Trauma 1989;27:730–5.
29. Walters BC, McNeill I. Improving the record of patient assessment in the trauma room. J Trauma 1990;30:398–409.
30. Tien HC, Spencer F, Tremblay LN, et al. Preventable deaths from hemorrhage at a level I Canadian trauma center. J Trauma 2007;62:142–6.
31. Kelusky R. 2001. Geocode Street Guide. Toronto: Toronto Works and Emergency Services, 2001.
32. Statistics Canada. Land and freshwater area, by province and territory: Statistics Canada, 2005.
33. Ahmed MM, Abdel-Aty M, Lee J, et al. Real-time assessment of fog-related crashes using airport weather data: a feasibility analysis. Accid Anal Prev 2014;72:308–17.
34. Fralick M, Denny CJ, Redelmeier DA. Drowning and the influence of hot weather. PLoS One 2013;8:e71689.
35. Meteorological Service of Canada. Glossary. Environment Canada: 1994–2014. http://climate.weather.gc.ca/glossary_e.html (Cited 26 Nov 2016).
36. Environment Canada. Manual of Surface Weather Observation. 2015 (Cited 26 Nov 2016).
37. Meteorological Service of Canada. Environment Canada; 1994–2014. http://climate.weather.gc.ca/historical_data/search_historical_data_e.html (Cited 26 Nov 2016).
38. Redelmeier DA, Stewart CL. Driving fatalities on Super Bowl Sunday. N Engl J Med 2003;349:386–9.
39. Redelmeier DA, Tibshirani RJ. A simple method for analyzing matched designs with double controls: McNemar’s test can be extended. J Clin Epidemiol 2017;81:51–5.
40. Redelmeier DA, Yarnell CJ. Can tax deadlines cause fatal mistakes? J Clin Epidemiol 2016;76:114–7.
41. Hosmer D, Lemeshow S. Applied logistic regression. 2nd edn. New York (NY): Wiley and Sons, 2000:243–59.
42. Redelmeier DA, Tibshirani RJ. Methods for analyzing matched designs with double controls: excess risk is easily estimated and misinterpreted when evaluating traffic deaths. J Clin Epidemiol 2018;98:117–22.
43. Evans L. Traffic Safety. Bloomfield (MI): science serving society. 2004.
44. Zador PL, Krawchuk SA, Voas RB. Alcohol-related relative risk of driver fatalities: a review of involvement in fatal crashes in relation to driver age and gender: an update using 1996 data. J Stud Alcohol 2000;61:387–95.
45. Cummings P, McKnight B, Rivara FP, et al. Association of driver air bags with driver fatality: a matched cohort study. BMJ 2002;324:1119–22.
46. Compton RR, Berning A. Drug and alcohol crash risk. Journal of Drug Addiction, Education, and Eradication 2011;5:29–46.
47. Gentilioli LM, Villaveces A, Ries RR, et al. Detection of acute alcohol intoxication and chronic alcohol dependence by trauma center staff. J Trauma 1999;47:1131–5.
48. Colby SM, Barnett NP, Eaton CA, et al. Potential biases in case detection of alcohol involvement among adolescents in an emergency department. Pediatr Emerg Care 2002;18:350–4.
49. National Highway Traffic Safety Administration. National motor vehicle crash causation survey: report to congress: U.S. Department of Transportation: National Highway Traffic Safety Administration, 2008.
50. Fleming J. Learning to work together: police and academics. Policing 2010;4:139–45.
51. Ludwig A, Marshall M. Using crime data in academic research: issues of comparability and integrity. Records Management Journal 2015;25:228–47.
52. Sauber-Schatz EK, Ederer DJ, Dellinger AM, et al. Vital signs: motor vehicle injuries: prevention - united states and 19 comparison countries. MMWR Mort Mortal Wkly Rep 2016;65:672–7.
53. Li R, El-Basyouny K, Kim A. A city-wide safety analysis of mobile speed enforcement: proceedings of the 25th CARSProc: speeding and aggressive driving, Ottawa (ON): Canadian Association of Road Safety Professionals, 2015.
54. Perreault S. Impaired driving in Canada, 2015. Ottawa (ON): Statistics Canada, 2016.
55. World Health Organization. Global status report: alcohol policy: World Health Organization, 2004.
56. Moskowitz H, Fiorentino D. A review of the scientific literature regarding the effects of alcohol on driving-related behavior at blood alcohol concentrations of 0.08 grams per deciliter and lower: U.S. Department of Transportation, National Highway Traffic Safety Administration, 2000.
57. Voas RB, Lacey JC. Alcohol and highway safety 2006: a review of the state of knowledge: U.S. Department of Transportation, National Highway Traffic Safety Administration, 2011.
58. Irwin C, Judahina E, Desbrow B, et al. Effects of acute alcohol consumption on measures of simulated driving: a systematic review and meta-analysis. Accid Prev Anal 2017;102:248–66.
59. Martin TL, Solbeck PA, Mayers DJ, et al. A review of alcohol-impaired driving: the role of blood alcohol concentration and complexity of the driving task. J Forensic Sci 2013;58:1238–50.
60. Schmälzle E, Kunz R, Ortmann C, et al. Effect of ethanol on dynamic visual acuity during vertical body oscillation in healthy volunteers. Eur Arch Otorhinolaryngol 2000;257:485–9.