

MODERATE ALCOHOL INTAKE AND MOTOR VEHICLE CRASHES: THE CONFLICT BETWEEN HEALTH ADVANTAGE AND AT-RISK USE

KENNETH HENG^{1,2}, STEPHEN HARGARTEN^{1,3}, PETER LAYDE^{1,4},
ANDY CRAVEN¹ and SHANKUAN ZHU^{1,4*}

¹Injury Research Centre, Medical College of Wisconsin, Milwaukee, WI, USA, ²Emergency Department, Tan Tock Seng Hospital, Singapore, ³Department of Emergency Medicine and ⁴Department of Family and Community Medicine, Medical College of Wisconsin, Milwaukee, WI, USA

(Received 12 October 2005; first review notified 24 November 2005; in revised form 29 November 2005; accepted 30 November 2005; advance access publication 1 March 2006)

Abstract — **Aims:** To review the evidence on moderate alcohol intake and motor vehicle crash (MVC) risk, and discuss the possible public health tension in balancing risk reduction and increment with respect to moderate alcohol intake. **Method:** A Medline review was conducted on moderate alcohol intake, MVC, and cardiovascular disease (CVD) risks. **Result:** Moderate alcohol intake (24 g ethanol, two US standard drinks, or less a day) is associated with 20% reduction in risk of CVD. Public awareness of this may contribute to why rates of driving with blood alcohol content (BAC) <0.08 g/dl in the United States are static. Studies show 3- to 17-fold increased risk of a fatal MVC with BAC < 0.08 g/dl compared to sober drivers. The United States has 0.08 g/dl BAC laws, higher than that reached by a driver drinking two drinks per day or less. **Conclusion:** The public should be educated that although moderate alcohol drinking may not violate BAC laws, it still carries significant risk of MVC. Current BAC laws in some countries needs re-evaluation.

INTRODUCTION

In the United States, national surveys reveal high rates of alcohol use among adolescents, college students, and young adults (Windle, 2003). Amongst elderly American males (age ≥ 65), age trends in 2000–2001 show that, while heavier drinking significantly decreased, moderate drinking has not decreased (Breslow *et al.*, 2003). A possible reason for these trends among the middle aged and elderly is the widespread publicity and increased public awareness (Casswell, 1993; Smart and Ogborne, 2002) of the beneficial effects of moderate alcohol intake on cardiovascular disease (CVD).

The spectrum of alcohol-related problems includes moderate drinking, 'at-risk' drinking, alcohol abuse, and alcoholism (Hasin, 2003). The moderate drinker might fall into the 'at-risk' group when he partakes in an activity, such as operating a vehicle after drinking alcohol. Mixed messages from the public health perspective about the health benefits of moderate drinking with respect to cardiovascular protection creates misconceptions about drinking and its health consequences. While these recommendations are unlikely to affect the behaviour of heavy drinkers, hitherto non-drinkers and light drinkers who follow these recommendations potentially put themselves at risk for alcohol-related motor vehicle crashes (MVC) if they drink and drive.

The United States' legal blood alcohol content (BAC) limit for driving is <0.08 g/dl. This is based on studies which show that MVC risk rises exponentially with BAC > 0.08 g/dl (Borkenstein, 1964). Moderate alcohol intake gives rise to BAC of <0.08 g/dl and many moderate drinkers believe that they can safely operate their vehicles as long as they are within the legal BAC limit.

This article reviews the evidence on moderate alcohol intake and MVC risk, and highlights the public health tension

in balancing risk reduction and increment with respect to moderate alcohol intake.

METHODS

Data sources

We searched MEDLINE[®] from 1966 to 2005 using the key words alcohol consumption, MVC, motor vehicle accident, and traffic accident. There were 1123 articles found. We refined our search to articles reporting fatal or non-fatal MVC data for BAC between 0.010 and 0.079 g/dl, giving 200 articles. We also reviewed the annual reports of road traffic data published by the National Highway Traffic Safety Administration (NHTSA).

In a second search, we used the key words moderate alcohol consumption, ischaemic heart disease, and CVD, giving 143 articles.

Definition of alcohol intake

Moderate alcohol intake refers to drinking no more than two US standard drinks per day for men and one US standard drink per day for women (NIAAA, 1995). A standard drink refers to 12 g alcohol (approximately one glass of wine or one can of beer). Although highly variable, it is estimated that a 77 kg (170 pounds) male drinking two standard drinks on an empty stomach will yield a BAC of 0.03 g/dl within 1 h. A 62 kg (137 pounds) female consuming this amount of alcohol under identical circumstances will yield a BAC of 0.05 g/dl.

Moderate alcohol intake and neuropsychological impairments

It has been reported that impairment of driving-related skills begins with any departure from zero BAC. Divided attention, visual functions, and tracking were impaired in the 0.01–0.02 g/dl range (the level reached with one drink). Controlled behaviours (difficult tracking, divided attention tasks, information processing, etc.) are impaired at BAC 0.030–0.049 g/dl in actual traffic whereas automatic behaviours

*Author to whom correspondence should be addressed at: Injury Research Centre and Department of Family and Community Medicine, Medical College of Wisconsin, 8701 Watertown Plank Road, Milwaukee, WI 53226, USA. Tel: +1 414 456 7674; Fax: +1 414 456 6470; E-mail: szhu@mcw.edu

Table 1. Model-based risk of driver fatality in single-vehicle crashes as a function of driver BAC by age and gender, relative to sober drivers (Zador *et al.*, 2000)

Driver's BAC (g/dl)	Multiplies the chance of being killed in a single-vehicle crash increase by					
	Males			Females		
	16–20	21–34	≥35	16–20	21–34	≥35
0.010–0.019	1.55 (1.36–1.76) ^a	0.08 (0.04–0.16)	0.07 (0.04–0.16)	1.35 (1.21–1.50)	0.08 (0.04–0.16)	0.07 (0.04–0.16)
0.020–0.049	4.64 (2.97–7.26)	2.75 (2.53–2.98)	2.57 (2.34–2.84)	2.86 (1.94–4.16)	2.75 (2.53–2.98)	2.57 (2.34–2.84)
0.050–0.079	17.32 (7.56–39.70)	6.53 (5.61–7.60)	5.79 (4.84–6.93)	7.04 (3.50–14.14)	6.53 (5.61–7.60)	5.79 (4.84–6.93)

Modified from Hingson and Winter (2003).

^a95% Confidence interval for relative risk.

(over-learned tasks which require little conscious mental activity) are impaired beyond 0.05 g/dl (Krüger, 1993). Virtually all subjects tested in the studies reviewed exhibited impairment on some critical driving measure by the time they reached 0.08 g/dl (Moskowitz *et al.*, 1985).

Moderate alcohol intake and MVC injuries

In 2003 in the United States, 40% of all fatal crashes were alcohol related (NHTSA, 2003). Of these, 6% of victims of fatal crashes had BAC 0.01–0.07 g/dl and 34% had BAC ≥ 0.08 g/dl. Of all the alcohol-related fatal crashes, 13% of drivers had BAC of 0.01–0.07 g/dl. Driving skills deteriorate as BAC levels increase in such a manner that risk of a fatal crash doubles with each 0.02 increase (Zador, 1991). From US Fatality Analysis Reporting System (FARS) data, in the BAC range 0.020–0.049 g/dl, the risk of a fatal MVC increases 3–5 times compared to sober drivers. In the BAC range 0.050–0.079 g/dl, the risk of a fatal MVC increases 6- to 17-fold, with the highest risk associated with the male driver aged between 16 and 20 (Table 1). Borkenstein (1964) estimated crash risk for drivers with increasing BAC using a case-control study. The exponential rise in accident risk with increasing BAC for drivers involved in single or multiple vehicle crashes was the basis for the implementation of BAC laws.

Forty per cent of non-fatal MVCs in the United States in 2003 were alcohol-related. Pories *et al.* (1992) divided admitted MVC patients into three groups according to their BAC (i.e. = 0, <0.1 but >0, and >0.1 g/dl) and reported higher injury severity score (ISS) in the middle group compared with patients with no measurable alcohol ($P < 0.0001$). There were also significantly more head injuries in the former compared to the latter group and fewer patients were able to return home with self-care. It was found that the relationship between alcohol ingestion and serious injury was more pronounced in the group with BAC < 0.1 g/dl. Pories concluded that BAC levels below the legal limit for intoxication can significantly increase the probability of severe injury.

Moderate alcohol intake and risk factors for MVC

It has been reported that alcohol-related fatal MVCs are more likely to be associated with speeding. Thirty-nine per cent of motorists in the United States with alcohol-related fatal MVCs with positive BAC were speeding compared with 14% of sober motorists (NHTSA, 2005). Drivers in alcohol-related MVCs are less likely to wear a seatbelt, and the higher the driver's BAC, the lower the seatbelt use (NHTSA, 2005).

Sixty-two per cent of motorists in the US with BAC >0.00 g/dl were unrestrained compared with 26% of sober motorists. Andersen *et al.* (1990) found that alcohol-impaired drivers admitted to hospital after an MVC were less likely to be wearing a seatbelt. The ISS increased from 24.5–28.3 ($P < 0.01$) when seatbelts were not worn, significantly increasing the length of stay in hospital (Reynaud *et al.*, 2002).

Alcohol-related MVCs were more likely to occur at night. Seventy-seven per cent of alcohol-related fatal MVCs in the United States occur between 6:00 p.m. and 5:59 a.m. compared with 18% between 6:00 a.m. and 5:59 p.m. Alcohol-related MVCs are approximately twice as likely to be involved in single-vehicle accidents compared to non-alcohol-related MVCs. Alcohol intake was found to interact adversely with driver fatigue. An experimental study comparing alcohol and prolonged wakefulness using a simulated driving test showed that 18.5 and 21 h of wakefulness produces changes in driving test of the same magnitude as BACs of 0.05 and 0.08 g/dl, respectively (Arnedt *et al.*, 2001). Another experimental study (Horne *et al.*, 2003) showed that moderate ('legally passable') intake of alcohol is dangerous for drivers if they are sleepy. It also showed that sleepy drivers who had consumed alcohol did not realize that alcohol had increased their sleepiness to an extent that impaired their driving.

It is clear that many inter-related factors such as risk-taking behaviour like speeding (Nabi *et al.*, 2005), poor compliance with seatbelt use (Eensoo *et al.*, 2005), and sleepiness operate to increase the risk of fatal and non-fatal injuries for the alcohol-impaired driver, despite legally passable BACs.

The alcohol risk-benefit dilemma

Moderate alcohol intake has been found to be associated with protection against ischaemic stroke (Sacco *et al.*, 1999; Truelsen *et al.*, 1998; Reynolds *et al.*, 2003) and CVD (Klatsky *et al.*, 1990; Maclure, 1993; Doll, 1997; Corrao *et al.*, 2004; Zhu *et al.*, 2004) with meta-analysis showing a 20% risk reduction for CVD with moderate alcohol intake (Corrao *et al.*, 2004). This risk reduction is in the form of a J-shaped curve in which abstainers and drinkers exceeding 89 g alcohol/day do not have the cardioprotection experienced by moderate drinkers. In its Dietary Guidelines for Healthy American Adults 1996, the Nutrition Committee, American Heart Association stated, 'Incidence of heart disease in those who consume moderate amounts of alcohol is lower than that in nondrinkers', stressing moderation amongst alcohol drinkers (Krauss *et al.*, 1996). There is an increased public

awareness of the benefits of moderate alcohol drinking (Casswell, 1993; Smart and Ogborne, 2002). In the United States, from the middle of the 1990s to 2002, rates of traffic fatalities in the BAC range 0.010–0.079 has not shown any signs of decreasing. In 2000 in the United States, there were 513 000 alcohol-related non-fatal MVCs (i.e. BAC > 0.00 g/dl), costing an estimated at \$51 billion (Goldberg, 2002). Recently, Fillmore (2000) challenged the validity of previous studies reporting risk reduction in cardiovascular mortality from moderate drinking, citing systematic error and incomplete controlling for critical confounding factors. In contrast, several studies reported no protective effect for light-to-moderate alcohol drinking (Camacho, 1987; Fillmore *et al.*, 1998a, b; Leino *et al.*, 1998).

This illustrates how fragmented evidence and dichotomous messages from public health experts can lead to confusion and untoward consequences. The challenge is to educate the public that though the cardiovascular benefits of alcohol are compelling, it is a double-edged sword and beneficial moderate drinking can easily spill over to at-risk drinking, if mixed with driving. The goal is to strike a balance between the long-term benefits and the substantial short-term risks. Goldberg (2003) succinctly wrote that 'If alcohol were a newly discovered drug . . . we can be sure that no pharmaceutical company would develop it to prevent CVD. Nor would many physicians use therapy that might reduce the rate of myocardial infarction by 25–50%, but that would result in thousands of additional deaths per year due to cancer, motor vehicle accidents, and liver disease.' Studies are needed to compare projected number of lives saved through decreased CVD risk and lives lost through alcohol-related MVC.

Countermeasures

Social norms pertaining to alcohol consumption may be difficult to change and the public may continue to drink moderately for their health and operate their vehicle under the influence. In order to attenuate at-risk drinking, other countermeasures need to be considered. Concomitant food intake decreases alcohol absorption by delaying gastric emptying, slowing intestinal absorption, and increasing first-pass metabolism of alcohol, leading to lower-peak BAC (Mumenthaler *et al.*, 1999). This lends credence to the old adage of 'not drinking on an empty stomach'. While most alcohol drinking behaviour is ritualized around meals, the effect of food on alcohol absorption is, at best, variable and public health authorities should be cautious in advocating food as a means of attenuating alcohol risk.

Passive countermeasures to curb at-risk drinking like having stricter BAC laws should be considered. International experience with the lowering of BAC laws has shown that injuries and fatalities have decreased in most jurisdictions in which legal limits were reduced (Mann *et al.*, 2001). Henstridge (1997) evaluated the lowering of BAC law from 0.08 to 0.05 g/dl in two states in Australia using time series analysis, statistically correcting for the impact of legislative initiatives such as the implementation of random breath testing, and found a reduction in fatal collisions by 8 and 18%, and all serious collisions by 7 and 14%, in New South Wales and Queensland, respectively. Norström (1997) evaluated that the effect of reducing the BAC limit from 0.05 to

0.02 g/dl in Sweden observed significant reductions in fatal collisions, single-vehicle collisions, and all collisions of 9.7, 11.0, and 7.5%, respectively. In some cases, beneficial effects decline over time, (McLean *et al.*, 1995) while in others, lasting reductions in alcohol-related collisions and fatalities have been reported (Henstridge, 1997; Norström, 1997). Factors which ensure continued success include continued high publicity/public education efforts and high levels of visible enforcement by the authorities (Homel, 1990).

CONCLUSION

Health authorities reporting the benefits of alcohol in reducing CVD risk should always state that caution should be exercised, and that the public should not drink and drive. The public should be educated that even though moderate alcohol drinking may not cause them to exceed the BAC laws, it still carries a significant risk of a fatal MVC. Following the success of countries that have lowered their BAC laws to 0.05 and 0.02 g/dl, current statutory levels in the United States, the United Kingdom, and some other countries with driving limits of 0.08 g/dl, should be reviewed.

Acknowledgements — This study was supported by a grant (PHS CDC R49 CCR519614) from the Centres for Disease Control and Prevention, Atlanta, GA. We would like to thank Ann Christiansen and the staff of the Injury Research Centre at the Medical College of Wisconsin for their assistance.

REFERENCES

- Andersen, J. A., McLellan, B. A., Pagliarello, G. *et al.* (1990) The relative influence of alcohol and seatbelt usage on severity of injury from motor vehicle crashes. *Journal of Trauma* **30**, 415–417.
- Arnedt, J. T., Wilde, G. J., Munt, P. W. *et al.* (2001) How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis and Prevention* **33**, 337–344.
- Borkenstein, R. F., Crowther, R. F., Shumate, R. F. *et al.* (1964) *The role of the drinking driver in traffic accidents 'The Grand Rapid Study'*. Department of Police Administration, Indiana University, Indiana.
- Breslow, R. A., Faden, V. B. and Smothers, B. (2003) Alcohol consumption by elderly Americans. *Journal of Studies on Alcohol* **64**, 884–892.
- Camacho, T.C. (1987) Alcohol and consumption in Alameda County. *Journal of Chronic Diseases* **40**, 229–236.
- Casswell, S. (1993) Public discourse on the benefits of moderation: implications for alcohol policy development. [see comment]. *Addiction* **88**, 459–465.
- Corrao, G., Bagnardi, V., Zambon, A. *et al.* (2004) A meta-analysis of alcohol consumption and the risk of 15 diseases. *Preventive Medicine* **38**, 613–619.
- Doll, R. (1997) One for the heart. *British Medical Journal* **315**, 1664–1668.
- Eensoo, D., Paaver, M., Harro, M. *et al.* (2005) Predicting drunk driving: contribution of alcohol use and related problems, traffic behaviour, personality and platelet monoamine oxidase (MAO) activity. *Alcohol and Alcoholism* **40**, 140–146.
- Fillmore, K. M. (2000) Is alcohol really good for the heart? *Addiction* **95**, 173–4.
- Fillmore, K. M., Golding, J. M., Graves, K. L. *et al.* (1998a) Alcohol consumption and mortality: I Characteristics of drinking groups. *Addiction* **93**, 183–203.
- Fillmore, K. M., Golding, J. M., Graves, K. L. *et al.* (1998b) Alcohol consumption and mortality: III Studies of female populations. *Addiction* **93**, 219–229.

- Goldberg, J. (2002) Economic impact of motor vehicle crashes. *Annals of Emergency Medicine* **40**, 429–430.
- Goldberg, I. J. (2003) To drink or not to drink? *New England Journal of Medicine* **348**, 163–164.
- Hasin, D. Classification of Alcohol Use Disorders. *National Institute on Alcohol Abuse and Alcoholism Publications*, Dec 2003. Available at <http://www.niaaa.nih.gov/publications/arh27-1/5-17.htm> (accessed July 20, 2005).
- Henstridge, J., Homel, R. and MacKay, P. (1997) *The Long Term Effects of Random Breath Testing in Four Australian States: A Time Series Analysis*. Federal Office of Road Safety, Canberra.
- Hingson, R. and Winter, M. (2003) Epidemiology and consequences of drinking and driving. *Alcohol Research and Health* **27**, 63–78.
- Homel, R. (1990) Random breath testing and random stopping programs in Australia. In *Drinking and Driving: Advances in Research and Prevention*, Wilson, R. J., Mann, R. E. eds, pp. 159–202. Guilford Press, New York.
- Horne, J. A., Reyner, L. A. and Barrett, P. R. (2003) Driving impairment due to sleepiness is exacerbated by low alcohol intake. *Occupational and Environmental Medicine* **60**, 689–692.
- Klatsky, A. L., Armstrong, M. A. and Friedman, G. D. (1990) Risk of cardiovascular mortality in alcohol drinkers, ex-drinkers and non-drinkers. *American Journal of Cardiology* **66**, 1237–1242.
- Krauss, R. M., Deckelbaum, R. J., Ernst, N. *et al.* (1996) Dietary guidelines for healthy American adults. A statement for health professionals from the Nutrition Committee, American Heart Association. *Circulation* **94**, 1795–1800.
- Krüger, H. (1993) Effects of low alcohol dosages: A review of the literature. In *Alcohol, Drugs and Traffic Safety—T'92: Proceedings of the 12th International Conference on Alcohol, Drugs and Traffic Safety, Cologne, September 28–October 2, 1992*, Utselmann, H.-D., Berghaus, G. and Kroj, G. eds, pp. 763–778.
- Leino, E. V., Romelsjo, A., Shoemaker, C. *et al.* (1998) Alcohol consumption and mortality: II. Studies of male populations. *Addiction* **93**, 205–218.
- Maclure, M. (1993) Demonstration of deductive meta-analysis: ethanol intake and risk of myocardial infarction. *Epidemiologic Reviews* **15**, 328–351.
- Mann, R. E., Macdonald, S., Stoduto, L. G. *et al.* (2001) The effects of introducing or lowering legal per se blood alcohol limits for driving: an international review. *Accident Analysis and Prevention* **33**, 569–583.
- McLean, A. J., Kloeden, C. N., McColl, R. A. *et al.* (1995) Reduction in the legal blood alcohol limit from 0.08 to 0.05: effects on drink driving and alcohol-related crashes in Adelaide. In *Alcohol, Drugs and Traffic Safety—T'95. NHMRC Road Accident Research Unit, University of Adelaide, Adelaide, Australia*, Kloeden, C. N., McLean, A. J. eds, pp. 373–377.
- Moskowitz, H., Burns, M. M. and Williams, A. F. (1985) Skills performance at low blood alcohol levels. *Journal of Studies on Alcohol* **46**, 482–485.
- Mumenthaler, M. S., Taylor, J. L., O'Hara, R. *et al.* (1999) Gender differences in moderate drinking effects. *Alcohol Research and Health* **23**, 55–64.
- Nabi, H., Consoli, S. M., Chastang, J. F. *et al.* (2005) Type A behaviour pattern, risky driving behaviours, and serious road traffic accidents: a prospective study of the GAZEL cohort. *American Journal of Epidemiology* **161**, 864–870.
- NHTSA (2003) Traffic Safety facts 2003. National Centre for Statistics and Analysis of the National Highway Traffic Safety Administration. (Available at <http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2003F.pdf>; accessed June 20, 2005).
- NHTSA (2005) *Alcohol Involvement in Fatal Motor Vehicle Crashes, 2003*. DOT HS 809 822. Available at http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2005/809_822/images/809822.pdf, accessed June 20, 2005.
- NIAAA (1995) National Institute on Alcohol Abuse and Alcoholism: The Physician's Guide to Helping Patients with Alcohol Problems.
- Norström, T. and Laurell, H. (1997) Effects of the lowering of the legal BAC limit in Sweden. In: *Alcohol, Drugs and Traffic Safety—T'97. Centre d' Etudes et de Recherche en Medicin du Traffic*, Mercier-Guyun, C. ed., pp. 87–94. Annecy, France.
- Pories, S. E., Gamelli, R. L., Vacek, P. *et al.* (1992) Intoxication and injury. *The Journal of Trauma* **32**, 60–64.
- Reynaud, M., Le Breton, P., Gilot, B. *et al.* (2002) Alcohol is the main factor in excess traffic accident fatalities in France. *Alcoholism: Clinical and Experimental Research* **26**, 1833–1839.
- Reynolds, K., Lewis, B., Nolen, J. D. *et al.* (2003) Alcohol consumption and risk of stroke: a meta-analysis. [erratum appears in *JAMA* **289**, 2798. Note: Lewis, Brian L [corrected to Lewis, Brian]]. *Journal of the American Medical Association* **289**, 579–588.
- Sacco, R. L., Elkind, M., Boden-Albala, B. *et al.* (1999) The protective effect of moderate alcohol consumption on ischaemic stroke. *Journal of the American Medical Association* **281**, 53–60.
- Smart, R. G. and Ogborne, A. C. (2002) Beliefs about the cardiovascular benefits of drinking wine in the adult population of Ontario. *The American Journal of Drug and Alcohol Abuse* **28**, 371–378.
- Truelsen, T., Gronbaek, M., Schnohr, P. *et al.* (1998) Intake of beer, wine, and spirits and risk of stroke: the Copenhagen city heart study. *Stroke* **29**, 2467–72.
- Windle, M. (2003) Alcohol Use Among Adolescents and Young Adults. *Alcohol Research & Health* **27**, 79–85.
- Zador, P. L. (1991) Alcohol-related relative risk of fatal driver injuries in relation to driver age and sex. *Journal of Studies on Alcohol* **52**, 302–310.
- Zhu, S., St-Onge, M. P., Heshka, S. and Heymsfield, S. B. (2004) Lifestyle behaviours associated with lower risk of having the metabolic syndrome. *Metabolism: Clinical and Experimental* **53**, 1503–1511.