Experimental Study on the Temporal Profile of Breath Alcohol Concentration: Preliminary Findings

Y.C. LI [a], S.C. WONG [b], N.N. SZE [c], K.L. TSUI [d], F.L. SO [e]

[a,b] *Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong*
[a] *E-mail: joeyliyc@hku.hk*
[b] *E-mail: hhecwsc@hku.hk*
[c] D*epartment of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand; E-mail: tony.sze@canterbury.ac.nz*
[d,e] *Accident and Emergency Department, Tuen Mun Hospital, Tsing Chung Koon Road, Tuen Mun, Hong Kong SAR, China*
[d] *E-mail: tsuikl@ha.org.hk*
[e] *E-mail: sofl@ha.org.hk*

Abstract: Driving under the influence is believed to be correlated to high risk of convicted driving behavior. To deter against drink-driving, many jurisdictions have imposed random breath test on the road. However, the high drop-off rate of suspected driver attributed to the alcohol elimination during the period between screening breath test on road and evidential test at police station could be a concern. Therefore, it is essential to set out the temporal profile of breath alcohol concentration (BrAC) with respect to different driver's characteristics. In this study, we attempt to set out the temporal profile of BrAC with respect to characteristics include age, gender, body weight, drinking habit and alcohol dose, using an experimental study in Hong Kong. A non-linear gamma model for the BrAC profile was calibrated using the Full Bayesian approach. Results indicated that body weight and alcohol dose were found significantly modifying the BrAC profile for Chinese population.

Keywords: Breath alcohol concentration, drink-driving, breathalyzer, temporal profile

1. INTRODUCTION

Numerous studies have demonstrated that increases in blood alcohol concentration (BAC) of drivers would push up the likelihood of adopting risk-taking behaviours, and thus the risk of traffic conflicts and road crashes and injuries (Mounce and Pendleton, 1992; Robertson and Drummer, 1994, Tsui et al., 2010, Li *et al*., 2013). The World Health Organization (WHO) has reported that, on average, 20% of fatally injured drivers in high-income countries are found driving under the influence of alcohol (DUIA). Such proportion is even higher in low-income countries, ranging from 33% to 69% (WHO, 2009). In view, many countries have attempted to combat drink-driving behaviour by imposing strict legal limits on alcohol concentration while driving. In Hong Kong, the prescribed legal BAC limit of 50mg/100ml [or equivalent to breath alcohol concentration (BrAC) of 22μg /100ml] has been imposed. The police officers are authorized to conduct random breath tests (RBTs) at a roadblock or checkpoint. That means they may stop any vehicle at any time, even in the absence of evidence or reasonable cause to suspect

that the driver has consumed alcohol. Unfortunately, the current drop-off rate of drivers who have been arrested for drink-driving is considerable, because of the alcohol elimination during the period, that could be two or three hours, between the screening breathalyzer test at the road block and the evidential breath test for prosecution purposes at the police station or hospital. Therefore, it is essential to deduce a robust estimate of alcohol concentration of convicted driver back to the time of RBT or conviction of any traffic offence. In particular, the development of a temporal profile for approximation of breath or blood alcohol concentration at any point of time shall be critical.

In forensic science, Widmark's equation is widely used to deduce the BAC of a convicted driver at different points of time (Widmark, 1981). In the Widmark's equation, the temporal profile of alcohol concentration is dependent on subject's body weight, gender (average Widmark's factor is 0.68 for male and 0.55 for female respectively), and blood alcohol elimination rate. For instance, there are three main phases for the temporal profile of blood alcohol concentration: (1) the absorption phase, that is the period immediately after one starts to drink until blood alcohol concentration reach the peak; (2) the peak, with blood alcohol concentration equal to C_p; and (3) the elimination phase. Figure 1 illustrates a typical BAC profile set out by Widmark's equation (Andersson and Jones, 1995). Since then, a number of studies were conducted to verify the applicability and reliability of estimates of Widmark's equation (Tam *et al*., 2005; Gullberg, 2007; Jones and Holmgren, 2009; Yang *et al*., 2009; Jones, 2010). However, the Widmark's equation was established in Western communities, and the alcohol absorption and elimination rates could be different from Chinese. Despite of this, research studies on the temporal profile of BAC for Chinese population were rare. A case study revealed that the Widmark's factor of Chinese should be 0.68 and 0.59 for male and female respectively (Tam *et al*., 2005). Furthermore, a case study also verified the Widmark's equation for Chinese male population, whereas blood alcohol concentration is directly proportional to the alcohol dose, but inversely proportion to body weight (Yang *et al.*, 2009).

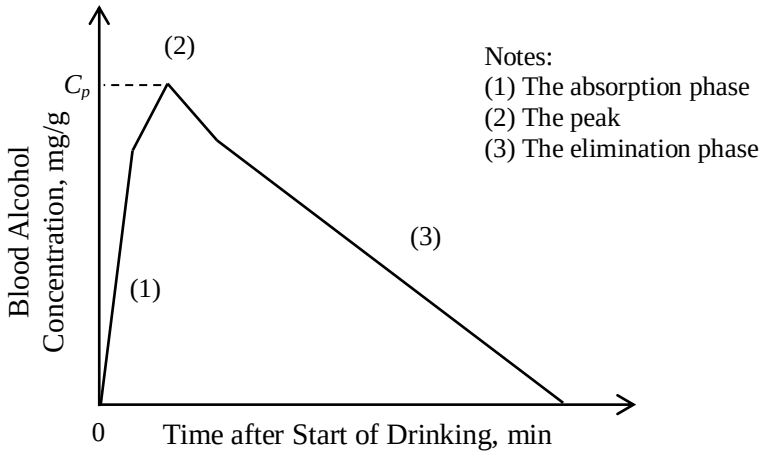

Figure 1. A typical temporal profile of BAC set out by Widmark's equation (Andersson and Jones, 1995)

Through the blood alcohol concentration is the most robust estimate for alcohol intoxication of convicted driver, breath alcohol concentration estimate deduced by breathalyzer is commonly

adopted as it is less intrusive and more convenient for the police officers (Barquin *et al*., 2008). As a supplement to Widmark's equation, numerous studies have attempted to model the temporal profile of BrAC using comparative regression analysis approach (Jachau *et al*., 2004, Pavlic *et al*., 2007; Schechtman and Shinar, 2011). Generally, ratio of BAC to BrAC ranges from 2000:1 to 2300:1 was adopted in many countries. Yet, the derivation of the above ratio could be substantial (Jones and Andersson, 1996, 2003). Attempts were made to measure the association between BrAC and factors including gender, age and drinking habit (Barquín et al., 2008, Jones and Holmgren, 2009; Yang et al., 2009). The most common practice has been to interpolate the breath alcohol concentrations of driver at different points of times, based on the assumption of linear dissipation of alcohol. However, the temporal profile of breath alcohol concentration should be nonlinear. Therefore, it is essential to develop a robust temporal profile of BrAC, taking into account the nonlinear nature of alcohol dissipation. Besides, we take this opportunity to model the temporal profile of BrAC of Chinese population, with respect to factors including gender, age, body weight, drinking habit and alcohol doses.

The remainder of this paper is structured as follows. We first describe the materials and method of analysis in Section 2. Results of the analysis and interpretations are presented in Section 3. Finally, Section 4 presents our concluding remarks and future research.

2. MATERIALS AND METHODS

2.1 Participants

In this study, a total of 20 Chinese drivers (13 males and 7 females) who had held a valid full driving license for at one year or above were recruited through the network of different driver association. Mean age of the participants was 39.7 (ranging from 21 to 56). Every participant was invited to attend two or three experiment sessions, each of which should be separated by 2 days or above. Prior to experiments, a participant should pass both the health assessment and an Alcohol Use Disorders Identification Test (AUDIT) questionnaire (Saunders *et al*., 1993), where each of which was conducted by a medical doctor. Participants who reported he or she had the experiences of alcohol or substance abuses, and psychiatric disorders would be excluded.

2.2 Apparatus and materials

To measure the breath alcohol concentration (BrAC), Alcotest 9510 evidential breathalyzer (Drager Safety AG & Co., Germany) was used. This breathalyzer is currently used in evidential alcohol test by the Hong Kong Police Force given its high specificity for ethyl alcohol. This breathalyzer quantifies the alcohol concentration based on two separated breath samples, with which one is measured by infrared red (IR) sensor and another is measured by fuel cell technology (a dual sensor technology). For instance, the maximum permissible deviation between the readings of two sensors is 5%. In this study, the mean reading of the two sensors was recorded for subsequent analysis.

2.3 Experiment procedures

All participants were required to abstain from food for 4 hours and from alcohol and sedative for

24 hours, respectively, before the experiment. In the beginning of the experiment, a clinical assessment for physiological responses of every participant was first conducted by a registered nurse. A standard breakfast was then provided in order to control the effects of food on alcohol absorption and elimination rates (Yang *et al*., 2009; Sadler and Fox, 2011). After the breakfast, the initial BrAC (the *"baseline"* measurement) was measured to ensure that every participant was abstinence from alcohol. About 30 minutes after the breakfast, participant would be asked to consume 500ml of alcoholic drink[1] (40% alcohol by volume vodka mixed with orange juice) within 20 minutes. After that, BrACs would be measured at an average interval of 15 minutes. indeed the BrAC would be measured an interval of 10 minutes in absorption phase and 30 minutes in elimination phase respectively. The experiment would end when BrAC falls into a level of 10μg/100ml or below, or 5 hours after the alcohol intake. The protocol of this study was approved by the Institutional Review Board of the University of Hong Kong / Hospital Authority Hong Kong West Cluster, and all participants provided informed consent prior to the participation.

2.4 Statistical analysis

2.4.1 Alcohol concentration versus time curve

Despite that most of the previous studies has set out the alcohol concentration profile using linear regression approach, the temporal profile of breath alcohol concentration (BrAC) should be non-linear. In this study, a gamma function was adopted to model the BrAC and the association between BrAC and possible contributory factor as follows,

$$C(t) = s \cdot t^{a-1} \frac{exp(-\frac{t}{b})}{b^a \Gamma(a)} \quad (1)$$

where *C* is the breath alcohol concentration (in μg/100ml), *t* is the time after start of drinking, *s* is the parameter that denotes the range of breath alcohol concentration; while *a* and *b* refers to the shape and scale parameter that determine the model shape, respectively. For instances, *s* and *b* is defined as a linear function of possible factors, **X** and **Y** respectively, as follows,

$$b = g(\beta X) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_i X_i \quad (2)$$

$$s = h(\gamma Y) = \gamma_0 + \gamma_1 Y_1 + \gamma_2 Y_2 + \cdots + \gamma_i Y_i \quad (3)$$

where β and γ is the coefficient of corresponding factors. In this study, possible factors are gender, age, body weight, drinking habit (the AUDIT score) and alcohol doses. The reciprocal of the scale parameter, $r = 1/b$ is known as the rate parameter, which actually reflects the mean BrAC and the time at which the BrAC reaches the peak.

[1] The dose of alcohol is either 0, 2, 4 or 6 standard drinks. One standard drink should contain 10g of pure alcohol and is equivalent to 100ml of wine of 12% alcohol by volume)

2.4.2 Bayesian approach

In this study, the Bayesian method was applied, using the Markov Chain Monte Carlo (MCMC) simulation approach, to estimate the parameters of the above gamma functions. The simulation was performed on the *WinBUGS* platform (Ntzoufras, 2009). For instance, the MCMC approach could generate sequences of random points, whereas their distributions should converge to the target posterior distributions (Gelman and Rubin, 1992). Based on Bayes' theorem, the posterior distribution of parameters can be derived by integrating the prior distribution and likelihood functions as follows,

$$f(\theta|y) = \frac{f(y,\theta)}{f(y)} = \frac{f(y|\theta)f(\theta)}{f(y)} \quad (4)$$

where y is the observed outcome and θ is the parameter estimate. The marginal distribution of y can be specified as follows,

$$f(y) = \int f(y|\theta)f(\theta)d\theta \quad (5)$$

which is a constant with fixed value of y. The posterior distribution can be further expressed as an unnormalized posterior distribution by omitting the factor $f(y)$ as follows:

$$f(\theta|y) \propto f(y|\theta)f(\theta) \quad (6)$$

2.3.1 Goodness-of-fit

Spiegelhalter *et al*. (2002) proposed the deviance information criteria (DIC) as a measure of model complexity and fit. As with the Akaike or Bayesian information criterion indicators, a lower DIC value indicates a better model fit.

$$DIC = D(\overline{\theta}) + 2p_D = \overline{D(\theta)} + p_D, \quad (7)$$

where $D(\overline{\theta})$ is the usual deviance evaluated at the posterior means of parameter θ, and $\overline{D(\theta)}$ is the posterior mean of deviance, and p_D is the effective number of parameters. Usual deviance can be defined as follows:

$$D(\theta) = -2logf(y|\theta). \quad (8)$$

The validity of the model can be evaluated by comparing the observed and replicated data. The replicated data can be predicted in the simulation process set out by the posterior predictive distribution. For instance, a chi-square test statistic can be calculated by

$$x^2(y,\theta) = \sum_{i=1}^{n} \frac{[y_i - E(y_i|\theta)]^2}{Var(y_i|\theta)} \quad (8)$$

where y_i is either the observed or the replicated response. In each iteration t of the MCMC

simulation, the difference between $x^2\left(y^{rep}, \theta^{(t)}\right)$ and $x^2\left(y, \theta^{(t)}\right)$ is monitored, as should the corresponding posterior predictive p-value. Results indicate that the proposed model does not fit well if p-value is close to 0 or 1 (Gelman *et al*., 2004).

3. RESULTS

3.1 Breath alcohol concentration (BrAC) profile

As mentioned previously, every participant was asked to attend two to three experiment sessions, and the BrAC was recorded frequently during the experiment. In this study, a total of 524 BrAC measurements were obtained. A BrAC profile with respect to gender, age, body weight, AUDIT score, and alcohol doses was then be set out. Table 1 summarizes the characteristics of the 524 observations.

Table 1. Summary statistics of all observations

Factor	Range/attribute	Mean	SD
Number of observations = 524			
Gender	1: Female; 0:Male	0.31	0.46
Age	Min: 21; Max: 56	39.71	11.98
Weight (lbs)	Min: 108; Max: 223	148.24	23.84
Height (mm)	Min: 150; Max: 180	169.83	7.04
AUDIT	Min: 1; Max: 7	2.21	1.60
Alcohol dose (g)	Min: 0; Max: 60	34.38	15.50

SD: standard deviation.

With the use of Full Bayesian approach, the relationship between breath alcohol concentration (BrAC), time, and possible factors was modeled. Table 2 illustrates the results of parameter estimates of proposed gamma function for temporal profile of BrAC. The proposed model generally fit well with the observations, with the DIC of 3486.08 (*p-value* equals to 0.5). Besides, the model fit could also be demonstrated in the plots of observed and predicted values of BrAC, that is likely to follow the 45^o trend line, as shown in Figure 2.

Table2. Gamma regression models for alcohol concentration-time

	Coefficient	(*t*-statistic)
Number of observations = 524		
Parameter, *a*	1.163	(81.158)**
Parameter, *b*		
- Constant	205.100	(4.754)**
- Gender		
▪ Female	-19.590	(-1.568)
▪ Male	(Control)	
- Age	-0.142	(-0.249)
- Weight	1.164	(3.590)**
- AUDIT	-1.975	(-0.566)
- Alcohol Dose	-3.083	(-3.926)**
Parameter, s		
- Constant	10.780	(0.108)
- Gender		
▪ Female	43.550	(0.448)
▪ Male	(Control)	
- Age	7.681	(0.450)
- Weight	-7.359	(-1.219)
- AUDIT	61.800	(0.797)
- Alcohol Dose	241.600	(18.700)**
DIC	3486.08	
p-value	0.50	

** Significant at 1% level; * Significant at 5% level.
DIC: Deviance information criterion

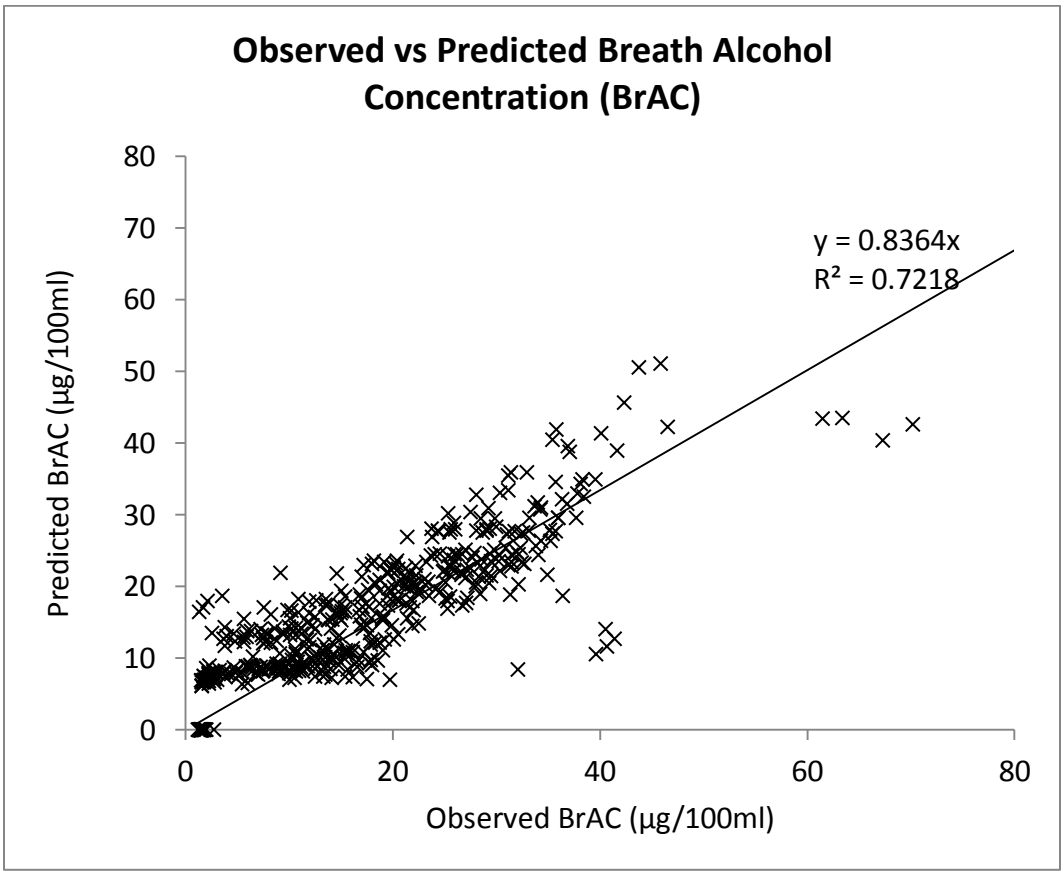

Figure 2. A plot of the observed and predicted BrAC

3.1 Scale parameter

In the proposed model, parameters *a* and *b* govern the shape and scale of BrAC profile. As shown in Table 2, increase in the value of *b* significantly correlated to the increase in body weight (Estimate = 1.164; 95% CI = [0.524, 1.847]), at the 1%level. On the other hand, decrease in the value of *b* significantly correlated to the increase in alcohol dose (Estimate = -3.083; 95% CI = [-4.668, -1.651]), at the 1% level. In other word, the time to reach the peak BrAC decreases with the body weight, but increase with the amount of alcohol dose.

3.2 Range parameter

The range of BrAC is governed by range parameter, *s*. As also shown in Table 2, it is reasonable to observe that the range of BrAC increases with the amount of alcohol dose (Estimate = 241.6; 95% CI = [216.5, 267.2]), at the 1% significant level. Nevertheless, no evidence could be established for the relationship between the range of BrAC and other factors under consideration. Consequently, based on the above estimates of shape, scale and range parameters, we have set out two illustrate sets of BrAC profiles: (a) Alcohol dose of 4 units with varying body weight; and (b) body weight of 148lb with varying alcohol dose in Figures 3a and 3b respectively, for 40 years old male.

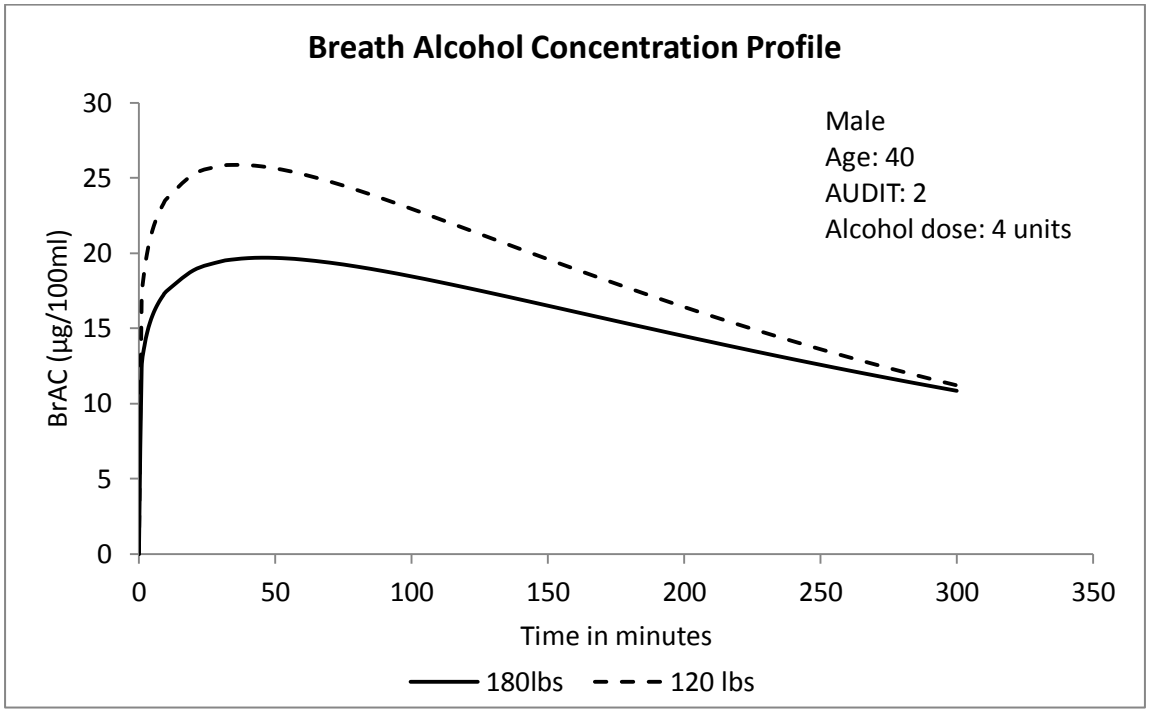

Figure 3a. Typical BrAC profiles (Variation on the body's weight)

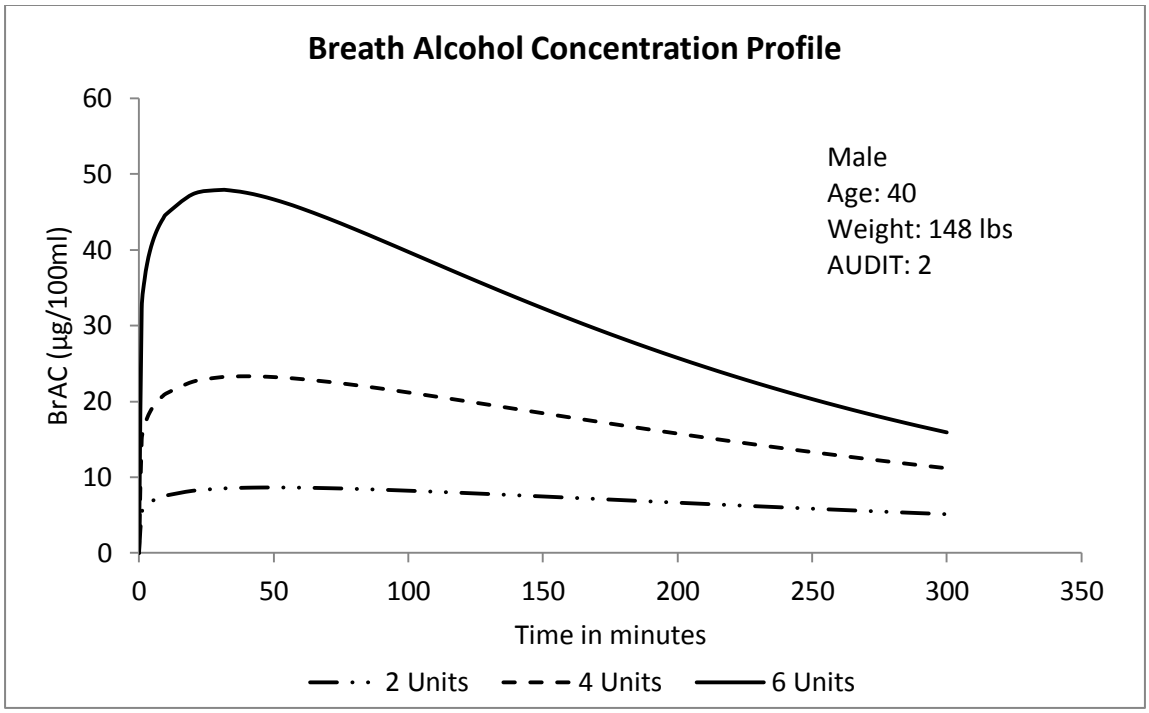

Figure 3b. Typical BrAC profiles (Variation on the alcohol consumption)

4. DISCUSSION AND CONCLUDING REMARKS

4.1 Major contributing factors to temporal profile of BrAC

It is reasonable that the amount of alcohol dose significantly contribute to the scale and shape of the proposed gamma model for temporal profile of BrAC, as the initial dose is deterministic to the human metabolic and alcohol absorption and elimination. Besides, body weight was found significantly correlated to the estimate of BrAC of Chinese population. This is consistent to that of many other experimental studies on the (linear) relationship between alcohol dose, body weight and BrAC in Western countries (Widmark, 1981; Barquín *et al*., 2008, Jones and Holmgren, 2009; Yang *et al.*, 2009).

In previous studies, driver demographics including gender and age were found correlated to the BrAC (Lucey *et al*., 1999; Tam *et al*., 2005; Barquín *et al*., 2008). However, some argued that the effects of age and gender on BrAC were neligible (Cowan *et al*., 1996; Tam *et al*., 2005; Jones, 2010). Yet, based on the results of current study, no evidence could be set out to quantify the relationship between gender, age, and BrAC profile. This could be because the deterministic factor to temporal profile of BrAC should be body water content, which was in turn highly correlated to age (Watson *et al*., 1980, 1981). However, some even argued that such association between BrAC and body water content might not be applicable to Chinese population, whose the body water content might not be varied with age and gender (Tam *et al*., 2005). Nevertheless, this should worth investigation in future research.

4.2 Variations in temporal profile of BrAC

4.2.1 Variation by body weight

In this study, gamma models were established to model the nonlinear temporal profile of BrAC with respect to factors including age, weight, and alcohol dose. As shown in Figure 3(a), the increase in peak BrAC was found less than proportionate with the decrease in body weight. This implies that the impairment by alcohol on subject with lower body weight could be deterministic. Yet, the ultimate BrACs among subjects of different weight were comparable five hours after the initial dose. This calls for the urgency to establish a framework for robust estimate of BrAC back to the time when a convicted driver was stopped on the road.

4.2.2 Variation by amount of alcohol dose

Besides, as shown in Figure 3(b), the increase in peak BrAC was found more than proportionate with the increase in the amount of alcohol dose. The differences in the BrAC level across drivers with different level of initial alcohol dose remains remarkable, at the time five hours after the initial dose. This strengthens the argument that the impairments on driving performance and thus the risk of road accident should increase dramatically with the increase in alcohol dose. This implies a stricter punishment should be imposed to deter against seriously convicted drink driver. For instance, three-tier enforcement scheme has been imposed in Hong Kong to deter against severe drink driving behavior and repeated conviction. The proposed BrAC profile is considered as a useful tool to back calculate alcohol concentration in breath at the time of traffic offence.

4.3 Limitations and further studies

In this experimental study, the alcohol data of 20 participants (13 males and 7 females) only was deployed to establish the temporal profile of BrAC. The heterogeneity effects on the association between the time trends of BrAC and possible factors by the individual might not be negligible. It would be worth exploring the effects of possible factors including driving habit and metabolic on the time-trend of BrAC, given that comprehensive BrAC data is available when sample size increase in extended study.

ACKNOWLEDGEMENTS

The research described here was supported by a Research Postgraduate Studentship, and a grant from the Research Grant Council of the Hong Kong Special Administrative Region, China (Project No. HKU 7188/11E).

REFERENCES

Andersson R. and Jones A.W. (1995). "Erik M.P. Widmark (1889–1945): Swedish pioneer in forensic alcohol toxicology." *Forensic Science International,* 72(1),1-14.

Barquín J., Luna Jde D., Hernández A.F. (2008). "A controlled study of the time-course of breath alcohol concentration after moderate ingestion of ethanol following a social drinking session." *Forensic Science International,* 177(2-3),140-145.

Cowan J.M., Weathermon A., McCutcheon J.R., Oliver R.D. (1996). "Determination of volume of distribution for ethanol in male and female subjects." *Journal of Analytical Toxicology,* 20, 287-290.

Drummer O.H., Gerostamoulos J., Batziris H. et al. (2004). "The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes." *Accident Analysis and Prevention,* 36, 239-248.

Gelman A. and Rubin D.B. (1992). "Inference from Iterative Simulation Using Multiple Sequences." *Statistical Science,* 7(4), 457-472.

Gelman A., Garlin J.B., Stern H.S. and Rubin D.B. (2004). *Bayesian data analysis,* 2nd ed., Chapman & Hall/CRC, Boca Raton, FL.

Gullberg R.G. (2007). "Estimating the uncertainty associated with Widmark's equation as commonly applied in forensic toxicology." *Forensic Science International,* 172(1), 33-39.

Jachau K., Sauer S., Krause D., Wittig K. (2004). "Comparative regression analysis of concurrent elimination-phase blood and breath alcohol concentration measurements to determine hourly degradation rate." *Forensic Science International,* 143(2-3), 115-120.

Jones, A.W. and Andersson, L. (1996). "Variability of the blood/breath alcohol ratio in drinking drivers." *Journal of Forensic Science,* 41(6), 916-921.

Jones, A.W. and Andersson, L. (2003) "Comparison of ethanol concentrations in venous blood and end-expired breath during a controlled drinking study." *Forensic Science International,* 132(1), 18–25.

Jones A.W. and Holmgren A. (2009). "Age and gender differences in blood-alcohol concentration in apprehended drivers in relation to the amounts of alcohol consumed." *Forensic Science International,* 188(1-3), 40-45.

Jones A.W. (2010). "Evidence-based survey of the elimination rates of ethanol from blood with applications in forensic casework." *Forensic Science International,* 143(1-3), 115-120.

Li Y.C., Sze N.N., Wong S.C., Tsui K.L. and So F.L. (2013) "Effects of drink driving on crash risk based on random breath test data." *Hong Kong Journal of Emergency Medicine,* 20, 146-154.

Lucey M.R., Hill E.M., Young J.P., Demo-Dananberg L., Beresford T.P. (1999). "The influence of age and gender on blood ethanol concentrations in healthy humans." *Journal of Studies on Alcohol*, 60(1), 103–110.

Mann R.E., Macdonald S., Stoduto G., Bondy S., Jonah B., Shaikh A. (2001). "The effects of introducing or lowering legal per se blood alcohol limits for driving: An international review." *Accident Analysis and Prevention*, 33(5), 569-583.

Mounce N.H. and Pendleton O.J. (1992). "The relationship between blood-alcohol concentration and crash responsibility for fatally injured drivers." *Accident Analysis and Prevention*, 24(2), 201-210.

Ntzoufras, I. (2009). *Bayesian modeling using WinBUGS*, Wiley.

Pavlic M., Grubwieser P., Libiseller K., Rabl W. (2007) "Elimination rates of breath alcohol." *Forensic Science International*, 171(1), 16-21.

Robertson M.D. and Drummer O.H.. (1994). "Responsibility analysis – a methodology to study the effects of drugs in driving." *Accident Analysis and Prevention*, 26(2), 243-247.

Sadler D.W. and Fox J. (2011). "Intra-individual and inter-individual variation in breath alcohol pharmacokinetics: The effect of food on absorption." *Science and Justice*, 51(1), 3-9.

Schechtman E. and Shinar D. (2011). "An analysis of alcohol breath tests results with portable and desktop breath testers as surrogates of blood alcohol level." *Accident Analysis and Prevention*, 43(6), 2188-2194.

Tam T.W.M., Yang C.T., Fung W.K. and Mok V.K.K. (2005). "Widmark factors for local Chinese in Hong Kong: A statistical determination on the effects of various physiological factors." *Forensic Science international*, 151(1), 23-29.

Tsui K.L., Sze N.N., So F.L., Wong S.C. (2010). "Association between drink driving and severity of crash injuries to road users." *Hong Kong Journal of Emergency Medicine*, 17, 34-39."

Watson P.E., Watson I.D., Batt R.D. (1980). "Total body water volumes for adult males and females estimated from simple anthropometric measurements." *The American Journal of Clinical Nutrition*, 33(1), 27–39.

Watson P.E., Watson I.D., Batt R.D. (1981). "Prediction of blood alcohol concentrations in human subjects." *Journal of Studies on Alcohol*, 42(7), 547–556.

WHO (2009). *Global Status Report on Road Safety: Time for Action.* World Health Organization, Albany, NY.

Widmark EMP. *Principles and applications of medicolegal alcohol determination.* [translated into English by R. C. Baselt]. 1st ed. Mosby; 1981. p. 163.

Yang C.T., Fung W.K. and Tam T.W.M. (2009) "Alcohol study on blood concentration estimation: Reliability and applicability of Widmark formula on Chinese male population." *Legal Medicine*, 11, 163-167.