

**The Influence of Mixers Containing Artificial Sweetener or
Different Doses of Carbohydrate on Breath Alcohol Responses in
Females**

Author

Smith, Cassie, Herzig, Peter John, Davey, Andrew, Desbrow, Ben, Irwin, Christopher

Published

2017

Journal Title

Alcoholism: Clinical and Experimental Research

Version

Accepted Manuscript (AM)

DOI

[10.1111/acer.13264](https://doi.org/10.1111/acer.13264)

Downloaded from

<http://hdl.handle.net/10072/341141>

Griffith Research Online

<https://research-repository.griffith.edu.au>

Title:

The influence of mixers containing artificial sweetener or different doses of carbohydrate on breath alcohol responses in females

Authors:

Cassie Smith^{1,2} MNutrDiet (Joint chief Investigator)

Peter John Herzig^{1,2} MNutrDiet (Joint chief Investigator)

Andrew Davey^{1,3} PhD (Investigator)

Ben Desbrow^{1,2} PhD (Investigator)

Christopher Irwin^{1,2} PhD (Investigator)

1. *Menzies Health Institute Queensland*
2. *School of Allied Health Sciences, Griffith University, Gold Coast, Queensland, Australia*
3. *School of Pharmacy, Griffith University, Gold Coast, Queensland, Australia*

Correspondence:

Chris Irwin

School of Allied Health Sciences

Griffith University

Gold Coast, QLD, 4222, AUSTRALIA

Ph +61 (07) 56787344

Fax +61 (07) 56780199

c.irwin@griffith.edu.au

Support: None noted

Abstract

Background:

Breath alcohol responses may be affected by the presence of carbohydrate (CHO) in a beverage. This study investigated the impact of consuming alcohol with mixers containing various doses of carbohydrate or an artificial sweetener on breath alcohol concentration (BrAC), ratings of intoxication and impairment, and cognitive performance in females.

Methods:

Twenty-six females (age 25.1 ± 0.7 yrs, Mean \pm SD) completed a cross-over study involving four trials. A dose of alcohol was consumed in each trial mixed with water (W), artificial-sweetener (150 \pm 1mg aspartame, AS), or carbohydrate (15g sucrose, 15CHO and 50g sucrose, 50CHO). BrAC was sampled for 210mins following beverage ingestion and analysed for peak BrAC and other parameters using WinNonlin non-compartmental pharmacokinetic modelling (c_{\max} , t_{\max} , AUC_{last}). An objective measure of cognitive performance was assessed using a four-choice reaction-time (CRT) task. Estimation of BrAC, self-reported ratings of intoxication and willingness to drive were recorded.

Results:

Mean peak BrAC was reduced in a dose-response manner when alcohol was consumed with CHO compared to both W and AS treatments (W: $0.054 \pm 0.015\%$, AS: $0.052 \pm 0.011\%$, 15CHO: $0.048 \pm 0.008\%$, 50CHO: $0.038 \pm 0.007\%$). No difference in peak BrAC was observed between W and AS treatments. WinNonlin parameters revealed

significant differences in c_{\max} and AUC_{last} (W: $4.80 \pm 1.12 \text{ g} \cdot \text{dL}^{-1} \cdot \text{h}^{-1}$, AS: $4.61 \pm 0.92 \text{ g} \cdot \text{dL}^{-1} \cdot \text{h}^{-1}$, 15CHO: $4.10 \pm 0.86 \text{ g} \cdot \text{dL}^{-1} \cdot \text{h}^{-1}$, 50CHO: $3.11 \pm 0.58 \text{ g} \cdot \text{dL}^{-1} \cdot \text{h}^{-1}$) when CHO-containing beverages were consumed compared to W and AS treatments. No difference in t_{\max} or CRT was observed between treatments. Participants were able to detect subtle differences in peak BrAC and reported greater ability to drive after consuming 50CHO compared to W. However, participant's willingness to drive and CRT did not differ between treatments.

Conclusions:

Consuming alcohol with CHO-containing mixers attenuates peak BrAC and reduces total alcohol exposure in a dose-response manner compared to drinks containing artificial-sweetener or no additives. The effect of adding CHO to alcoholic beverages may translate to reduced risk of alcohol-related harms.

Key Words:

Ethanol, Artificially Sweetened Beverage, Carbohydrate, Fasted

Introduction

The harms associated with acute alcohol consumption are well established. Drinking alcohol reduces inhibitions (Steele and Southwick, 1985, Field et al., 2010), decision making ability (Abbey et al., 2005, MacDonald et al., 1995) and increases an individual's propensity to engage in risk-taking behaviors (Cherpitel, 1993, Lane et al., 2004). Despite increased awareness of the harms associated with alcohol consumption, drinking behaviors (i.e. frequency of drinking, amount of alcohol consumed, motivations for drinking) remain largely unchanged (Foundation of Alcohol Research and Education, 2016). Recent polling data of Australian drinkers indicates that negative behaviors (e.g. vomiting, drink-driving, violence, abuse, injuries) after drinking are common, that women are more likely to experience some of these behaviors and that individuals aged 25-34yrs are the most likely demographic group to engage in these behaviors (Foundation of Alcohol Research and Education, 2016).

The risk of alcohol-related harm increases as blood alcohol concentration rises (Taylor et al., 2010). Whilst the dose of alcohol consumed is likely to have the greatest impact on peak alcohol concentrations attained after drinking, a complex interaction between other factors such as sex, body size and composition, age, experience of drinking, genetics, nutrition, and individual metabolism can affect responses to a dose of alcohol (Eckardt et al., 1998, Pohorecky and Brick, 1988). Social factors may also influence alcohol related risk, with recent reports suggesting that regular drinkers often deviate from typical dietary behaviors to compensate for the consumption of alcohol (Foundation of Alcohol Research and Education, 2016). In females, restricting food prior to/while drinking has been reported (Bryant et al., 2012, Knight et al., 2016, Luce

et al., 2013), potentially due to excess energy intake and weight concerns (Foundation of Alcohol Research and Education, 2016). Moreover, given that artificially sweetened mixers are a commonly reported weight control strategy (Levy and Heaton, 1993), it is plausible that calorie conscious individuals may consume artificially sweetened alcoholic beverages in an otherwise fasted state. If such dietary practices influence peak alcohol concentrations, this behavior has the potential to increase the acute risks associated with alcohol consumption. In fact, results of a recent study revealed that over one-third of college students (of which 73% were female) reported consuming alcohol with artificially sweetened mixers and that these individuals experienced more alcohol-related problems, with the incidence of problems directly related to frequency of consumption (Stamates et al., 2016).

Recently, carbohydrate (CHO) co-ingested with alcohol (typically as beverage mixers) have been demonstrated to attenuate breath and blood alcohol concentrations (Irwin et al., 2014, Marczynski and Stamates, 2012, Stamates et al., 2015, Wu et al., 2006) with one potential mechanism being that artificially sweetened mixed beverages promote faster gastric emptying and more rapid absorption of alcohol into the blood circulation than regular mixed (CHO containing) beverages (Wu et al., 2006). This suggests that CHO ingestion may play an important role in reducing alcohol-related harm. Whilst evidence for the influence of CHO on alcohol responses is encouraging, there are a number of important issues that require consideration. In particular, no study to date has included an alcohol-only (control) trial to confirm if differences in alcohol response are a consequence of artificial sweeteners increasing, or CHO attenuating peak alcohol concentrations (or a combination of both effects). In addition, the amount of CHO required to illicit this response is undetermined.

Furthermore, the majority of studies to date have been performed with male participants, with only two studies combining the results for men and women (Marczinski and Stamat, 2012) (n=8 females); (Stamat et al., 2015) (n=10 females). Therefore, the purpose of this study was to examine the influence of consuming alcohol with mixers containing various doses of CHO or an artificial sweetener compared to a control beverage (a mixer providing no other nutritional ingredients) on breath alcohol concentration (BrAC), subjective ratings of intoxication and impairment, and cognitive performance in healthy young females. It was hypothesized that BrAC responses between the control and artificially-sweetened beverages would not differ, but BrAC responses would be attenuated when alcohol was consumed with a CHO containing mixer in a dose-response manner. Furthermore, it was hypothesized that subjective ratings of intoxication, impairment and cognitive performance would not be influenced with the consumption of different beverages.

Materials and Methods

Participants

Twenty-six healthy, non-smoking Caucasian females who were non-abstainers from alcohol participated in this study. Participant characteristics are displayed in Table 1. All participants provided informed consent prior to completing a self-administered health assessment questionnaire. Participants scoring ≥ 3 on the Short Michigan Alcoholism Screening Test (SMAST), indicating potential for alcohol addiction were excluded (Vogel-Sprott, 1992). Alcohol consumption was assessed using a modified personal drinking history questionnaire (PDHQ). Participants were excluded from the

study if they were breastfeeding, pregnant, diabetic, diagnosed with phenylketonuria or were taking medications that would interact with alcohol. Ethical approval for the study was granted by the University's Human Research Ethics Committee (GU Ref No: PBH/48/13/HREC).

INSERT TABLE 1 HERE

Experimental Design

This study employed a single blind, cross-over design. Participants completed four experimental trials, each separated by at least two days. Each trial involved consumption of a different treatment beverage that included a set volume of alcohol (37.5% v/v, VodkO™, Artisan Spirit Merchants, Melbourne, Australia) mixed with water and either no other ingredients (Water (W)), an artificial sweetener (AS) (Ajinomoto pure aspartame, Melbourne Food Depot, Melbourne, Australia), or different doses of sugar (15CHO and 50CHO) (Caster sugar, CSR Sugar, Yarraville, Australia). Order of trials for each participant was allocated using a repeated Latin square design. Breath alcohol concentrations, subjective ratings of alcohol intoxication and impairment, and performance on a choice reaction time (CRT) cognitive function task were measured throughout a subsequent 210min observation period (Figure 1).

INSERT FIGURE 1 HERE

Pre-experimental Procedures

Participants were required to fast from all food and beverages (except water, which was encouraged) from 21:00hrs the night before each trial. Participants were also asked to refrain from alcohol consumption for 24hrs and caffeine consumption for 12hrs prior to each trial. For the 24hr period immediately preceding the first trial, participant's recorded food intake and exercise. Participants were asked to replicate this at all subsequent trials. Compliance with the pre-experimental procedures was verbally confirmed by participants on arrival to the laboratory.

Experimental Procedures

On arrival to the laboratory, an initial BrAC sample was obtained to confirm abstinence from alcohol using a calibrated police grade portable breathalyser (Alcolizer LE4, Alcolizer Technology, Cleveland, Australia). Participants then provided a urine sample which was subsequently analysed to determine urine specific gravity (U_{sg}) as a measure of hydration status (U_{sg} refractometer UG- α [®], Atago Co., Ltd., Tokyo, Japan). Participants that recorded a U_{sg} reading >1.020 , indicating some level of pre-existing hypohydration (Sawka et al., 2007) were provided with additional water (~500mL) to consume over a 30min period, prior to having U_{sg} re-tested. Twelve participants required the additional fluid bolus. Body mass and height were then measured and a finger prick blood sample was collected for analysis of Blood Glucose Level (BGL) (Accucheck Advantage II, Roche, Castle Hill, Australia) to confirm overnight fasting and non-diabetic status (fasting BGL $< 7\text{mmol/L}$) (The Royal Australian College of General Practitioners and Diabetes Australia, 2014).

Following this, participants were provided with one of the treatment beverages. Participants received an individualised dose of alcohol, determined in the first trial and replicated across all subsequent trials. The dose of alcohol was calculated using the modified Widmark equation and designed to illicit a peak BrAC equivalent to 0.050% (Watson et al., 1981). The mean dose of alcohol provided in each of the treatment beverages was 20.51 ± 2.85 g. The total beverage volume was prepared by adding four parts water to one part vodka (total drink volume = 344 ± 50 mL). Ingredients for each of the four treatment beverages differed with regards to the type and amount of sweetener added (W: nil, AS: 150 ± 1 mg aspartame, 15CHO: 15g sucrose, 50CHO: 50g sucrose). The doses of CHO selected were done so on the basis of exposure, likely to be observed under typical drinking conditions (e.g. 15g CHO approximately 1 std. drink with a CHO-containing mixer) and with consideration for doses that have previously been investigated (18g (Irwin et al., 2014) 35g (Marczinski and Stamatatos, 2012), 65g (Wu et al., 2006)). Variation in the total energy content of the beverages occurred based on the addition of different sweeteners (W: 600.8 ± 81.9 kJ, AS: 603.4 ± 81.9 kJ, 15CHO: 851.3 ± 81.9 kJ, 50CHO: 1435.8 ± 81.9 kJ). Four equal (weighed) amounts were then partitioned into different plastic cups. The four aliquots were stored in a refrigerator at 4°C until required for consumption.

Participants were informed that they would be consuming an alcoholic beverage however were not provided with details regarding the type of alcohol or type of mixer that the beverage contained. For each of the trials, participants were provided a total of 10mins to consume the four beverage aliquots, with one drink provided every 2.5mins. Following consumption of the final beverage aliquot, participants were provided with 200mL of water in order to rinse their mouths, expelling the water

without swallowing. This was completed to assist with the reduction of residual mouth alcohol in preparation for the first BrAC measure (15mins post ingestion).

WinNonlin Parameter Analysis

Analysis of breath alcohol data was performed using Phoenix WinNonlin (Certara, St. Louis, USA) methods. All BrAC data was computed via non-compartmental analysis to determine parameters including peak breath alcohol concentration (c_{\max}), time to peak alcohol concentration (t_{\max}) and area under the breath alcohol curve at last measurement (AUC_{last}).

Cognitive Performance

Participants were required to complete a computer based cognitive function task on several occasions throughout each experimental trial. The computerised CRT task (Inquisit Lab 4.0, Millisecond Software, USA) involved hitting one of four keys on a keyboard corresponding to one of four boxes on a laptop screen, which changed from black to red at various delay signals (between 400ms and 2000ms). The test was ~2mins in duration involving a total of 80 recorded trials of reaction time (latency and accuracy). A practice test was given prior to the first recorded test at the beginning of each trial to reduce the influence of learning effects.

Subjective Ratings

Participants were required to estimate their BrAC level (BrAC_g) at several times throughout the observation period (Figure 1). As a guide, participants were informed that the legal driving limit in Queensland for an individual holding an open class license was 0.050%. Subjective ratings to a set of pre-defined questions were collected at specified time points throughout the trial (Figure 1) using an adaptive visual analogue scale (AVAS) (Marsh-Richard et al., 2009). Participants answered three questions presented on a laptop computer by making a mark on a 100mm line between two anchor points; 'not at all' and 'very much so'. Questions included: How much do you feel the effects of alcohol right now? How impaired do you think your ability to drive is? How willing would you be to drive a car a short distance (up to 2km)? These questions have been used in previous research investigating intoxication effects of alcohol (Irwin et al., 2014, Marczyński and Stamatēs, 2012).

Statistical Analysis

All statistical procedures were performed using SPSS for Windows, Version 21.0 (SPSS Inc., Chicago, IL). Statistical analysis of WinNonlin parameters (c_{max} , t_{max} , AUC_{last}) and differences in pre-trial BGL and U_{sg} measures between trials were analysed using one-way repeated measures analysis of variance (ANOVA). Pairwise comparisons (Bonferroni) were performed where significant main effects were present. Analysis of BrAC and scores derived from the AVAS questionnaires were subjected to a two-way repeated measures ANOVA; Trial (W, AS, 15CHO, 50CHO) x Time (min). Post hoc analysis (Bonferroni) was performed on all significant F ratios ($p < 0.05$). Statistical significance was accepted at $p < 0.05$. All data are reported as mean \pm standard deviation (SD).

Results

Pre-trial Physiological Measures

All participants reported to the laboratory and verbally confirmed compliance to pre-experimental standardisation procedures. All participants produced a 0.000% BrAC reading at the initial testing time. Pre-trial blood glucose levels were all within the non-diabetic reference range (<7mmol/L, pre-prandial) and no significant differences were identified across the four beverage trials (W: 5.4 ± 1.3 mmol/L, AS: 5.3 ± 1.2 mmol/L, 15CHO: 5.6 ± 0.5 mmol/L, 50CHO: 5.4 ± 1.3 mmol/L; $p>0.05$). Participants pre-trial urine samples indicated a mean $U_{sg} < 1.020$ with no significant differences in U_{sg} observed across the four trials (W: 1.011 ± 0.006 , AS: 1.012 ± 0.006 , 15CHO: 1.011 ± 0.006 , 50CHO: 1.012 ± 0.005 ; $p>0.05$).

BrAC Readings

Mean peak BrAC for treatments were W: $0.054\pm 0.015\%$, AS: $0.052\pm 0.011\%$, 15CHO: 0.049 ± 0.008 , 50CHO: 0.038 ± 0.007 . A significant effect of trial for mean peak BrAC was observed, $F(3, 75)=32.896$; $p<0.001$. Post hoc analysis of trial effects revealed significantly lower mean peak BrAC in the 50CHO treatment compared to all other treatments ($p<0.001$). In addition, peak BrAC in the 15CHO treatment was significantly lower than the W treatment ($p=0.036$). No other significant differences in peak BrAC comparisons between treatments were observed ($p>0.05$).

Mean BrAC responses to each treatment throughout each of the experimental trials are illustrated in Figure 2. No significant effect of trial order on mean BrAC was

observed ($p>0.05$). A significant main effect for trial, $F(2.10, 52.55)=57.14$; $p<0.001$, time, $F(1.94, 48.58)=709.58$; $p<0.001$ and a time x trial interaction, $F(5.11, 127.69)=6.92$; $p<0.001$ was observed. Post hoc analysis of trial effects revealed significantly lower BrACs in the 50CHO treatment compared to all other treatments between 15-180min time points ($p<0.05$) and in the 15CHO treatment compared to W and AS treatments between 30-150min time points ($p<0.05$). There was no significant difference in BrAC readings between W and AS treatments at any time point ($p>0.05$).

INSERT FIGURE 2 HERE

WinNonlin Parameters

Summary data from WinNonlin analysis are presented in Table 2. No significant effect of trial order on WinNonlin computed parameters was observed ($p>0.05$). A significant main effect of trial, $F(3, 75)=33.74$; $p<0.001$, was observed for c_{max} , with post hoc analysis indicating a significantly lower c_{max} value for the 50CHO treatment compared to all other treatments ($p<0.05$). In addition, c_{max} for the 15CHO treatment was significantly lower than the W treatment ($p<0.002$). No other significant effects for c_{max} were observed ($p>0.05$). A significant main effect of trial for AUC_{last} was observed, $F(2.20, 55.01)=48.11$; $p<0.001$. Post hoc analysis revealed a significantly lower AUC_{last} for the 50CHO treatment compared to all other treatments ($p<0.001$). In addition, AUC_{last} for the 15CHO treatment was significantly lower than the W and AS treatments ($p<0.02$). No differences in AUC_{last} were observed between W and AS trials ($p>0.05$).

No significant difference was observed for measures of t_{\max} between the four treatments ($p>0.05$).

INSERT TABLE 2 HERE

Choice Reaction Time (CRT) Performance

No significant differences between trials, across time or interactive effects were observed for latency or accuracy in CRT response ($p>0.05$). Participants had a high degree of success (>97%) in response selection to stimuli across all treatments.

Estimations of BrAC Level ($BrAC_g$)

Participant's mean $BrAC_g$ throughout each of the experimental trials are illustrated in Figure 3. A significant main effect of time, $F(1.97, 45.26)=272.85$; $p<0.001$, trial, $F(3, 69)=4.87$; $p<0.005$ and a time x trial interaction $F(5.62, 129.20)=2.35$; $p<0.05$ was observed. Post hoc analysis indicated that $BrAC_g$ were significantly higher at the first time point following alcohol ingestion (15mins) compared to all other time points ($p<0.001$). A significant difference in mean $BrAC_g$ was observed between W and 50CHO treatments from 15-90min ($p<0.05$).

When asked to guess their BrAC, participant's overestimated peak BrAC in all treatments except for the W treatment (mean actual peak; mean peak estimation, W: $0.054\pm 0.015\%$; $0.053\pm 0.016\%$, AS: $0.052\pm 0.011\%$; $0.055\pm 0.015\%$, 15CHO: 0.049 ± 0.008 ;

0.054±0.015%, 50CHO: 0.038±0.007; 0.044±0.012%). A significant difference between peak BrAC and peak BrAC_g was only identified for the 50CHO treatment (p=0.038).

INSERT FIGURE 3 HERE

Subjective Ratings

A significant effect of time for 'feeling the effects of alcohol', $F(1.785, 39.276)=143.581$; $p<0.001$, 'ability to drive a car', $F(1.833, 40.325)=122.194$; $p<0.001$ and 'willingness to drive', $F(1.785, 39.268)=90.177$; $p<0.001$, was observed. Post hoc analysis revealed that participants felt the effects of alcohol more, believed their ability to drive was more impaired and were less willing to drive a car after consuming alcohol. These effects gradually dissipated over time. Mean ratings of 'ability to drive' throughout each of the experimental trials are illustrated in Figure 4. A significant main effect of trial was observed for perceived 'ability to drive a car', $F(2.23,49.15)=3.30$; $p=0.04$. Post hoc analysis revealed that ratings of 'ability to drive a car' were significantly lower in the W treatment compared to the 50CHO treatment between 20-60mins ($p<0.05$). No significant effects of trial were observed for participants 'willingness to drive' ($p>0.05$).

INSERT FIGURE 4 HERE

Discussion

This study examined the impact of consuming a moderate dose of alcohol with mixers containing various doses of carbohydrate or artificial sweetener on BrAC responses, subjective ratings of intoxication and impairment, and performance on a choice reaction time task in healthy females. Results of this study support our hypothesis that consuming alcohol with CHO-containing mixers attenuates peak BrAC in a dose-response manner and that BrAC responses observed between the alcohol control (water) and artificially sweetened treatments are not different. Findings from this study also support the hypothesis that cognitive performance would not be influenced by the different beverages consumed, but are in contrast with the hypothesis that subjective ratings of intoxication and impairment would not be influenced when alcoholic beverages containing different mixers and CHO levels are consumed.

Observations from this study are consistent with recent reports indicating higher breath and blood alcohol concentrations when alcohol is consumed with an artificially sweetened mixer compared to a regular mixer (Irwin et al., 2014, Marczinski and Stamates, 2012, Rossheim and Thombs, 2011, Wu et al., 2006, Zacchia et al., 1991). Previous studies provided regular alcoholic beverages containing 18g CHO (Irwin et al., 2014), 35g CHO (Marczinski and Stamates, 2012) and 65g CHO (Wu et al., 2006) to compare against artificially sweetened alcoholic beverages. In these studies, the magnitude of change in the breath alcohol response was 60%, 18% and 56% respectively, between the CHO-containing beverage and the artificially sweetened beverage. The present study provided beverages containing either 15g or 50g CHO, resulting in an 8% and 37% decrease in maximal alcohol response as measured by BrAC

or WinNonlin C_{max} parameters. In addition, total alcohol exposure (measured via WinNonlin AUC values) was reduced when alcohol was combined with a CHO-containing mixer. With the exception of two studies (Irwin et al., 2014, Zacchia et al., 1991), the collective evidence indicates a clear dose response effect of CHO on attenuating alcohol responses. The discrepancy observed with Irwin et al. (2014) and Zacchia et al. (1991) studies may be a result of employing a between subjects study design, which introduces substantial variability to alcohol responses (Jones and Jonsson, 1994). The potential of CHO doses in excess of 65g to further attenuate alcohol responses in a within subjects design is yet to be elucidated.

A further aim of this study was to clarify if the attenuation in alcohol response was a consequence of artificial sweeteners increasing, or CHO reducing peak alcohol concentrations (or a combination of both effects). The comparison between W and AS treatments demonstrated no difference in peak BrAC. This indicates that differences in alcohol response observed between artificially sweetened and regular alcoholic beverages are not a consequence of artificial sweeteners increasing peak alcohol concentrations, but that the differences are mediated by the presence of CHO in the beverage.

The mechanism proposed for the attenuation of peak BrAC when CHO beverages are consumed with alcohol is related to the rate of gastric emptying (Wu et al., 2006). It has been established that speed of gastric emptying has a major influence on the first pass metabolism of alcohol (Oneta et al., 1998). Furthermore, when beverages contain higher levels of CHO, gastric emptying rate is reduced significantly (Vist and Maughan, 1995). Although gastric emptying was not measured in the present study, the CHO

dose response effect observed on peak BrAC is consistent with the expected delay in gastric emptying associated with higher CHO intakes. However, determining if differences in gastric emptying times exist between alcohol alone or alcohol mixed with artificially sweetened beverages may provide further insight into mechanisms responsible for attenuation in peak BrAC.

Participants were able to detect subtle differences in peak BrAC between the W and 50CHO treatments, indicating an awareness of lower BrAC when the drinks contained a larger amount of CHO. In addition, participant's reported greater ability to drive after consuming the 50CHO compared to the W treatment. However, participant's willingness to drive and an objective measures of cognitive function as determined by choice reaction time did not differ between treatments. These results support the findings of Irwin et al. (2014) and Marczynski and Stamatēs (2012) who also found no difference in willingness to drive between artificially sweetened and regular beverage treatments. Results of these studies may reflect the caution individuals demonstrate when provided doses of alcohol that elicit peak BrAC's close to the legal driving limit in their jurisdictions. Whilst participants made more conservative decisions concerning willingness to drive under the present laboratory conditions, whether these results translate into actual behaviour in natural environments is unknown.

Evidence highlighting the growing concerns regarding altered dietary behaviours and alcohol misuse (Stamatēs et al., 2016, Knight et al., 2016) indicate the importance of understanding the interaction between alcohol and artificially sweetened and CHO-containing beverage mixers. These findings have implications for alcohol consumers, particularly females, many of whom drink alcohol whilst concurrently considering the

caloric repercussions of this behaviour (Knight et al., 2016, Stamatou et al., 2016). The present study suggests that decisions to consume alcohol devoid of calories may acutely increase an individual's risk of harm. These results require translation through educational messages to allow alcohol consumers to make informed decisions about the beverages they select.

Whilst the present study indicates the effects of consuming alcohol with artificially sweetened or CHO-containing mixers on BrAC responses, the dose of alcohol and volume of mixer beverage provided may not represent consumption patterns observed in real-world settings. The volume of alcohol consumed in the present study elicited BrACs close to that of the legal driving limit in a group of young female participants. Effects at higher alcohol concentrations, with types and volumes of mixer beverage more representative of typical consumption patterns and in females of different age demographics should be considered. In addition, a single objective measure of cognitive performance was employed in the present study. Future research should consider the effects on complex tasks of psychomotor performance or applied tasks such as simulated driving to provide greater insight into the effects of alcohol consumed with different mixer types on alcohol-related harm.

In summary, results of this investigation indicate that consuming alcohol with CHO-containing mixers reduces BrAC compared to an artificially sweetened mixer in a dose-response manner. Individual's decisions to consume alcohol devoid of calories may affect their acute risk of alcohol-related harm.

Acknowledgments

No external financial support was received to conduct this research and no authors hold positions in which the results on this study provide a financial gain.

References

- ABBEY, A., SAENZ, C. & BUCK, P. O. 2005. The cumulative effects of acute alcohol consumption, individual differences and situational perceptions on sexual decision making. *Journal of studies on alcohol*, 66, 82.
- BRYANT, J. B., DARKES, J. & RAHAL, C. 2012. College students' compensatory eating and behaviors in response to alcohol consumption. *Journal of American college health*, 60, 350-356.
- CHERPITEL, C. J. 1993. Alcohol, Injury, and Risk-Taking Behavior: Data from a National Sample. *Alcoholism: Clinical and Experimental Research*, 17, 762-766.
- ECKARDT, M. J., FILE, S. E., GESSA, G. L., GRANT, K. A., GUERRI, C., HOFFMAN, P. L., KALANT, H., KOOB, G. F., LI, T.-K. & TABAKOFF, B. 1998. Effects of moderate alcohol consumption on the central nervous system. *Alcoholism: Clinical and Experimental Research*, 22, 998-1040.
- FIELD, M., WIERS, R. W., CHRISTIANSEN, P., FILLMORE, M. T. & VERSTER, J. C. 2010. Acute alcohol effects on inhibitory control and implicit cognition: implications for loss of control over drinking. *Alcoholism: Clinical and Experimental Research*, 34, 1346-1352.
- FOUNDATION OF ALCOHOL RESEARCH AND EDUCATION. 2016. *Annual alcohol poll 2016: Attitudes and behaviours* [Online]. [Accessed 01/07/2016].
- IRWIN, C., SCHUM, D., DESBROW, B. & LEVERITT, M. 2014. Comparing the effects of alcohol mixed with artificially-sweetened and carbohydrate containing beverages on breath alcohol concentration. *Journal of Alcohol and Drug Education*, 58, 27.
- JONES, A. & JONSSON, K. 1994. Between-subject and within-subject variations in the pharmacokinetics of ethanol. *British Journal of Clinical Pharmacology*, 37, 427-431.
- KNIGHT, A., CASTELNUOVO, G., PIETRABISSA, G., MANZONI, G. M. & SIMPSON, S. 2016. Drunkorexia: An Empirical Investigation among Australian Female University Students. *Australian Psychologist*.

- LANE, S. D., CHEREK, D. R., PIETRAS, C. J. & TCHEREMISSINE, O. V. 2004. Alcohol effects on human risk taking. *Psychopharmacology*, 172, 68-77.
- LEVY, A. S. & HEATON, A. W. 1993. Weight control practices of US adults trying to lose weight. *Annals of Internal Medicine*, 119, 661-666.
- LUCE, K. H., CROWTHER, J. H., LEAHEY, T. & BUCHHOLZ, L. J. 2013. Do restrained eaters restrict their caloric intake prior to drinking alcohol? *Eating behaviors*, 14, 361-365.
- MACDONALD, T. K., ZANNA, M. P. & FONG, G. T. 1995. Decision making in altered states: effects of alcohol on attitudes toward drinking and driving. *Journal of personality and social psychology*, 68, 973.
- MARCZINSKI, C. & STAMATES, A. 2012. Artificial sweeteners versus regular mixers increase breath alcohol concentrations in male and female social drinkers. *Alcoholism: Clinical and Experimental Research*, 1-7.
- MARSH-RICHARD, D. M., HATZIS, E. S., MATHIAS, C. W., VENDITTI, N. & DOUGHERTY, D. M. 2009. Adaptive Visual Analog Scales (AVAS): a modifiable software program for the creation, administration, and scoring of visual analog scales. *Behavior research methods*, 41, 99-106.
- ONETA, C., SIMANOWSKI, U., MARTINEZ, M., ALLALI-HASSANI, A., PARES, X., HOMANN, N., CONRADT, C., WALDHERR, R., FIEHN, W. & COUTELLE, C. 1998. First pass metabolism of ethanol is strikingly influenced by the speed of gastric emptying. *Gut*, 43, 612-619.
- POHORECKY, L. & BRICK, J. 1988. Pharmacology of ethanol. *Pharmacology and Therapeutics*, 36, 335-427.
- ROSSHEIM, M. & THOMBS, D. 2011. Artificial sweeteners, caffeine, and alcohol intoxication in bar patrons. *Alcoholism: Clinical and Experimental Research*, 35, 1891-1896.
- SAWKA, M., BURKE, L., EICHNER, E., MAUGHAN, R., MONTAIN, S. & STACHENFIELD, N. 2007. American college of sports medicine position stand: Exercise and fluid replacement. *Medicine and Science in Sports and Exercise*, 39, 377-390.

- STAMATES, A. L., LINDEN-CARMICHAEL, A. N. & LAU-BARRACO, C. 2016. Mixing alcohol with artificially sweetened beverages: Prevalence and correlates among college students. *Addictive Behaviors*, 62, 79-82.
- STAMATES, A. L., MALONEY, S. F. & MARCZINSKI, C. A. 2015. Effects of artificial sweeteners on breath alcohol concentrations in male and female social drinkers. *Drug and alcohol dependence*, 157, 197-199.
- STEELE, C. M. & SOUTHWICK, L. 1985. Alcohol and social behavior: I. The psychology of drunken excess. *Journal of personality and social psychology*, 48, 18.
- TAYLOR, B., IRVING, H., KANTERES, F., ROOM, R., BORGES, G., CHERPITEL, C., GREENFIELD, T. & REHM, J. 2010. The more you drink, the harder you fall: a systematic review and meta-analysis of how acute alcohol consumption and injury or collision risk increase together. *Drug and alcohol dependence*, 110, 108-116.
- THE ROYAL AUSTRALIAN COLLEGE OF GENERAL PRACTITIONERS AND DIABETES AUSTRALIA 2014. General practice management of type 2 diabetes – 2014–15. Melbourne.
- VIST, G. E. & MAUGHAN, R. J. 1995. The effect of osmolality and carbohydrate content on the rate of gastric emptying of liquids in man. *The Journal of physiology*, 486, 523.
- VOGEL-SPROTT, M. 1992. *Alcohol tolerance and social drinking: Learning the consequences*, Guilford Press.
- WATSON, P. E., WATSON, I. D. & BATT, R. D. 1981. Prediction of blood alcohol concentrations in human subjects. Updating the Widmark Equation. *Journal of studies on alcohol*, 42, 547-556.
- WU, K., CHAIKOMIN, R., DORAN, S., JONES, K., HOROWITZ, M. & RAYNER, C. 2006. Artificially sweetened versus regular mixers increase gastric emptying and alcohol absorption. *The American Journal of Medicine*, 119, 802-804.
- ZACCHIA, C., PIHL, R., YOUNG, S. & ERVIN, F. 1991. Effect of sucrose consumption on alcohol-induced impairment in male social drinkers. *Psychopharmacology*, 105, 49-56.

Figure Legends

Figure 1. Experimental trial procedure for alcohol trial. BrAC, Breath alcohol concentration measure; U_{sg} , Urine specific gravity measure; VAS, Adaptive visual analogue scale measure; CRT, Choice reaction time measure, BrAC Guess, Participant self-intoxication estimation measure.

Figure 2: BrAC responses (mean \pm SD) for each of the experimental conditions. 15CHO, 15g sucrose trial; 50CHO, 50g sucrose trial. Some error bars have been omitted from trials to provide clarity. *Significant difference between 50CHO and all other beverage trials ($p<0.05$). **Significant difference between 15CHO and all other beverage trials ($p<0.05$).

Figure 3: BrAC estimations (mean \pm SD) across the four beverage trials. 15CHO, 15g sucrose trial; 50CHO, 50g sucrose trial. Error bars for some trials have been omitted to improve clarity. *Significant difference between Water and 50CHO trials.

Figure 4. Participant ratings of ability to drive (mean \pm SD) across the four beverage trials. 15CHO, 15g sucrose trial; 50CHO, 50g sucrose trial. Error bars for some trials have been omitted to improve clarity. *Significant difference between Water and 50CHO trials ($p<0.05$).

Tables

Table 1. Participant characteristics and drinking related habits

Parameter	Sample (n=26)
	M±SD
Age (yrs)	25.1±0.7
Body weight (kg)	67.3±15.4
BMI (kg/m ²)	22.6±5.5
Drinking history (yrs)	6.9±3.3
PDHQ drinking frequency/year	19.53±17.53
Standard drinks/drinking occasion	4.4±2.7

Table 2: WinNonlin parameters

Variable	W	AS	15CHO	50CHO
t _{max} (min)	20.76±9.97	20.76±10.17	17.88±4.93	23.08±10.68
c _{max} (g/dL)	0.057±0.012	0.054±0.010	0.050±0.008#	0.040±0.007*
AUC _{last} (min*g/dL)	4.80±1.12	4.61±0.92	4.10±0.86*	3.11±0.58*

Table Legends

Table 1 Abbreviations: M; mean, SD; standard deviation, BMI; body mass index, PDHQ; past drinking history questionnaire.

Table 2 Abbreviations: Values are mean \pm SD; t_{\max} , mean time to peak concentration; c_{\max} , mean peak concentration; AUC_{last} , area under the curve to the last measured time point. *Significant difference compared to all other trials ($p<0.02$). #Significant difference compared to W and 50CHO trials ($p<0.02$).