Effect of dissolved oxygen in alcoholic beverages and drinking water on alcohol elimination in humans

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A B S T R A C T

Oxygen plays an important role in the metabolism of alcohol. An increased dissolved oxygen level in alcoholic beverages reportedly accelerates the elimination of alcohol. Therefore, we evaluated the effect of dissolved oxygen in alcohol and the supportive effect of oxygenated water on alcohol pharmacokinetics after the excessive consumption of alcohol, i.e., 540 ml of 19.5% alcohol (v/v). Fifteen healthy males were included in this randomized, 3 × 3 crossover study. Three combinations were tested: X, normal alcoholic beverage and normal water; Y, oxygenated alcoholic beverage and normal water; Z, oxygenated alcoholic beverage and oxygenated water. Blood alcohol concentrations (BACs) were determined by conversion of breath alcohol concentrations. Four pharmacokinetic parameters (Cmax, Tmax, Kel, and AUCall) were obtained using non-compartmental analysis and the times to reach 0.05% and 0.03% BAC (T0.05 and T0.03) were compared using one-way analysis of variance (ANOVA) and Duncan's post hoc test. With combination Z, the BAC decreased to 0.05% significantly faster (p < 0.05) than with combination X. Analyzing the pharmacokinetic parameters, the mean Kel was significantly higher for combination Z than for combinations X and Y (p < 0.05), whereas the mean values of Cmax, Tmax, and AUCall did not differ significantly among the combinations. Dissolved oxygen in drinks accelerates the decrease in BAC after consuming a large amount of alcohol. However, the oxygen dissolved in the alcoholic beverage alone did not have a sufficient effect in this case. We postulate that highly oxygenated water augments the effect of oxygen in the alcoholic beverage in alcohol elimination. Therefore, it is necessary to investigate the supportive effect of ingesting additional oxygenated water after heavy drinking of normal alcoholic beverages.

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I n t r o d u c t i o n

For several years, water which has been artificially oxygenated at concentrations from 30 to 120 mg/L has been available commercially. This is at least five times higher than in normal drinking water, which contains 6–10 mg/L dissolved oxygen. The oxygenated water increases the oxygen content in the portal vein when given intragastrically (Forth & Adam, 2001). Therefore, we postulated that the oxygenated water would facilitate alcohol oxidation in the liver because the liver receives most of its blood flow from the portal vein.

Several studies have investigated the effects of oxygenated drinks on the ethanol elimination rate and concluded inefficacy in humans (Hyvärinen et al., 1978; Laakso et al., 1979; Maring & von Wartburg, 1980). Recently, Baek, Lee, and Kwon (2010) reported that dissolved oxygen in alcoholic beverages facilitated alcohol elimination. They focused on the report that oxygen absorbed through the stomach increased the oxygen content in the liver more than did breathing (Forth & Adam, 2001), and suggested that elevated dissolved oxygen in alcoholic beverages accelerated the metabolism and elimination of alcohol. They used an oxygenated alcoholic beverage rather than oxygenated water as the source of the dissolved oxygen and showed that the time to reach 0.000% blood alcohol concentration (BAC) with the highly oxygenated alcoholic beverage was significantly faster than normal. Nevertheless, this approach might be of limited use because the oxygenation of spirits can lead to unwanted flavors and harmful effects (Lachenmeier & Rehm, 2010).

In this study, we hypothesized that the oxygen in drinks would accelerate the elimination of alcohol sufficiently during bouts of heavy drinking (total 83.08 g of ethanol). Therefore, this study was intended to confirm the effect of dissolved oxygen in drinks on alcohol pharmacokinetics and investigate the usefulness of oxygenated water in alcohol elimination after heavy alcohol consumption.
Materials and methods

Subjects

Twenty healthy male volunteers gave written informed consent to participate. After physical examinations, 15 subjects were selected (mean age 26.6 (20–30) years, mean height 176.0 (165.0–183.0) cm, mean weight mass 70.3 (65–78) kg). Given the concern regarding the adverse effects of consumption of a large quantity of alcohol, female volunteers were excluded. All participants restricted the consumption of alcoholic beverages and other substances for one week before and during the study period (Baek et al., 2010).

Materials

Two types of alcoholic beverages and two types of drinking water were studied (Sunyang Co., Ltd., Daejeon, Korea). The alcoholic beverages were a Korean distilled spirit containing 19.43 ± 0.01% (v/v) ethanol and various dissolved oxygen concentrations (8.28 ± 0.03 vs. 26.07 ± 0.06 ppm). The drinking water contained 8.21 ± 0.06 or 51.96 ± 0.12 ppm oxygen. The alcoholic beverage and drinking water were administered in different combinations (Table 1). All materials were supplied on the day of the experiment and were stored at room temperature (21.2 °C) until administered.

Apparatus

The BAC was determined from the breath alcohol concentration measured using a Lion Alcolmeter SD-400 (Lion Laboratories, Wales, UK). The instruments were validated using 0.100% alcohol standard gas according to the International Organization for Standardization protocol (ISO9002:BS5750).

Study design

The study was performed using a randomized, 3 × 3 crossover design. The 15 subjects were divided into three groups that received different beverage combinations during each study period. Between each experimental period, there was a washout period of at least 14 days. The procedures were in accordance with the standards of the ethics committee of the Institute of Drug Research and Development at Chungnam National University (Daejeon, South Korea), and the Helsinki Declaration of 1975, as revised in 1983.

Procedures

Each experiment started at 17:00 after the subjects had fasted for 4 h to minimize diurnal variability. The subjects drank a 40-ml alcoholic beverage every 4 min, nine times. The BAC was first measured 4 min after the ninth drink. Then, the subjects were given four additional 40-ml drinks in the same way and a final 20-ml drink, for a total of 540 ml. While drinking the alcohol, the subjects were offered 150 ml of drinking water and 755 kcal of standardized food, and they completed the ingestion of the offered water and food until the last alcohol consumption. Eight minutes after the last alcohol drink, all of the subjects consumed an additional 150 ml of water four times at 56-min intervals.

After a second BAC measurement 8 min after the last alcohol drink, breath samples for BAC were collected every 28 min. When the BAC was <0.03%, the measurement was repeated after a further 5 min. When the BAC was confirmed, and the experiment was terminated.

Data analysis

To evaluate the effect of dissolved oxygen on ethanol elimination, the pharmacokinetic parameters and times to reach 0.05 and 0.03% BAC were calculated and compared.

The pharmacokinetic analysis was performed using non-compartmental methods with WinNonlin Standard version 2.1 (Pharsight, Palo Alto, CA). The pharmacokinetic parameters compared were the maximum plasma concentration (Cmax), time to Cmax (Tmax), elimination rate constant (Kel), and area under the plasma concentration versus time curve (AUC). Since a BAC of 0.03% was the endpoint of this experiment, Tmax values were compared. In addition, T0.05% values were compared, as this is the legal limit for drinking and driving in Korea. The times to achieve BACs of 0.03 and 0.05% were obtained by linear interpolation from the data.

Statistical analysis

All data are presented as means ± standard deviations. For the statistical comparisons of the pharmacokinetic parameters and times to reach 0.03 and 0.05% BAC, SPSS ver. 19 (SPSS, Chicago, IL) was used to perform one-way analysis of variance (ANOVA). Subsequent pairwise comparisons were made with Duncan’s test and statistical significance was accepted at p < 0.05.

Results

The alcohol pharmacokinetic profiles after administration of the alcoholic beverage and water containing various oxygen concentrations were identified by plotting the mean BAC (Fig. 1). Non-compartmental analysis was used to evaluate the differences in the pharmacokinetic parameters. In addition, the times taken for the BAC to fall to 0.05 and 0.03% were calculated. The comparisons of these parameters using ANOVA are shown in Table 2.

The mean Tmax was similar for the three combinations of materials, i.e., 129.6 ± 35.4, 122.1 ± 41.8, and 129.6 ± 39.9 min in ascending order of dissolved oxygen concentration. Likewise, the mean Cmax was similar regardless of the dissolved oxygen concentration. For combination X (alcoholic beverage containing 8 ppm oxygen and normal water with 8 ppm oxygen), Cmax was only slightly higher than for combination Y (oxygenated alcoholic beverage with 26 ppm oxygen and normal water) or Z (oxygenated alcoholic beverage with 26 ppm oxygen and highly oxygenated water with 51 ppm), but the differences were not significant.

For Kel, there were significant differences according to the dissolved oxygen concentrations of the beverage and water. The mean Kel for combinations X, Y, and Z was 0.253 ± 0.046, 0.291 ± 0.029, and 0.346 ± 0.079 h⁻¹, respectively, and the value for Z was significantly different from the other two (p < 0.05, post hoc.

Table 1
The beverage combinations used in this study.

<table>
<thead>
<tr>
<th>Combination of materials</th>
<th>Dissolved oxygen concentration (mean ± S.D.)</th>
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<tbody>
<tr>
<td></td>
<td>Alcoholic beverage (ppm)</td>
</tr>
<tr>
<td>X (normal alcoholic beverage + normal water)</td>
<td>8.28 ± 0.03</td>
</tr>
<tr>
<td>Y (oxygenated alcoholic beverage + normal water)</td>
<td>26.07 ± 0.06</td>
</tr>
<tr>
<td>Z (oxygenated alcoholic beverage + oxygenated water)</td>
<td>26.07 ± 0.06</td>
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Duncan’s test). Finally, the mean AUCall calculated using the observed BACs did not differ significantly.

The mean values of $T_{0.033}$ and $T_{0.055}$ decreased as the dissolved oxygen concentration increased. The time required to fall to 0.03% BAC was $423.4 \pm 36.8$, $397.1 \pm 55.8$, and $373.4 \pm 71.7$ min with combinations X, Y, and Z, respectively, although the differences were not significant by ANOVA. The time to reach 0.05% BAC was $346.5 \pm 35.4$, $310.2 \pm 51.5$, and $290.6 \pm 75.8$ min, respectively, and the difference was significant ($p < 0.05$, ANOVA). In the post hoc test, $T_{0.055}$ obtained by administration of combination Z was 55.9 min faster than for combination X ($p < 0.05$, Duncan’s test). In addition, $T_{0.055}$ with combination Z was 19.6 min faster than with Y, but this difference was not significant.

**Discussion**

Many studies have investigated the factors that influence alcohol pharmacokinetics. These include gender, food and food composition, body composition and lean body mass, liver volume, genetic polymorphisms, and alcohol-metabolizing enzymes (Agarwal & Goedde, 1992; Kalant, 2000; Mumenthaler, Taylor, O’Hara, & Yesavage, 1999; Neumark et al., 2004; O’Neill, Williams, & Dubowski, 1983; Ramchandani, Bosron, & Li, 2001; Ramchandani, Kwo, & Li, 2001). Recently, Baek et al. (2010) investigated the influence of dissolved oxygen in alcoholic beverages on alcohol pharmacokinetics. In this context, we re-examined the effect of dissolved oxygen on alcohol elimination and applied this hypothesis to a greater total amount of alcohol. Furthermore, we included additional dissolved oxygen in oxygenated water because the effect of the dissolved oxygen in only the alcoholic beverage might be insufficient.

As previously stated, parameters $C_{\text{max}}$ and $T_{\text{max}}$ were similar among all three combinations of beverage and water, concurring with the results of Baek et al. (2010). Thus dissolved oxygen does not influence the absorption of alcohol. Conversely, the oxygen dissolved in the alcoholic beverage and water significantly increased the elimination rate constant ($K_{\text{el}}$) and significantly decreased the time to reach 0.05% BAC ($T_{0.055}$). Therefore, the dissolved oxygen facilitated alcohol metabolism, eliminating the alcohol more rapidly, even at high blood alcohol concentrations.

For AUCall and $T_{0.033}$, the p-values obtained by ANOVA were 0.060 and 0.065, respectively. Although the differences were not significant statistically, the time to descend to 0.03% BAC was 50 min faster with the oxygenated alcoholic beverage and oxygenated water ($373.4 \pm 71.7$ min) than with the normal alcoholic beverage and normal water ($423.4 \pm 36.8$ min), which may be relevant clinically. Also, the decrease of the AUCall as dissolved oxygen was increased may have clinical significance, supporting the result that $K_{\text{el}}$ was increased significantly for combination Z than for X or Y.

No variable was significant when the normal and oxygenated alcoholic beverages were compared, implying that the dissolved oxygen in the alcoholic beverage had no effect on alcohol
elimination. This seems to counter the result of the effect of dissolved oxygen in the alcoholic beverage on the alcohol pharmacokinetics. However, the total quantity of alcohol consumed was very high compared with the previous study, suggesting that there is a limit as to what the oxygen dissolved in only an alcoholic beverage can do.

As mentioned in “Letter to the editor in regard to Baek, Lee, and Kwon (2010),” these results would have very limited application in industry (Lachenmeier & Rehm, 2010). However, our study shows the usefulness of ingesting oxygenated water to lower the blood alcohol concentration after consumption of an oxygenated alcoholic beverage. Although there were no significant differences between combinations Y and Z for most variables, the mean $K_{el}$ differed significantly between combinations Z and Y. We postulated that this was a result of the oxygen in the water, while we cannot completely exclude the possible influence of the oxygen in the alcoholic beverage. Therefore, additional studies would be needed to further confirm the effect of oxygenated water on alcohol pharmacokinetics when consumed with normal alcoholic beverages. Furthermore, we should be cautious about generalizing this result, as females were excluded in this study.

References


